ON ASSOCIATION OF RADIO EMISSION WITH SOLAR SURGES

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Abstract. About 45% non-flare surges are found to be associated with radio bursts inferred from spectral data. Associated surges are mostly accompanied by type I (24%) and type III (29%) bursts.

1. Introduction

Surges appear (in Hα) as straight or curvilinear spikes and grow upward from the chromosphere with velocities between 50–200 km s^{-1}. After attaining a maximum height (2 × 10^5 km), the material is usually seen to descend apparently along the original trajectory (cf. Švestka, 1976). Sometimes the material ejected during the surge occurrence returns to neighbouring active centres (Macris, 1971; Verma and Pande, 1982). Surges last typically for 10–20 min and often tend to recur at the same position at a rate of one per hour (Tandberg-Hanssen, 1977). Surges do not show any significant association with sudden ionospheric disturbances (Verma, 1984), soft X-ray (Rust *et al.*, 1977) and hard X-ray emissions (Verma, 1985).

The association of the solar surges with radio emissions is scantily studied and only a few references are available in the literature (Wild and Zirin, 1956; Swarup *et al.*, 1960; Westin, 1969; Garczynska *et al.*, 1982). Swarup *et al.* (1960) reported that a small portion of ejective solar prominences (surge) are accompanied by radio bursts. Westin (1969) finds that 11% of the solar surges are associated with radio bursts on spectral data. Wild and Zirin (1956) found that some limb surges are associated with group of type-I bursts. Recently, Graczynska *et al.* (1982) found that 40% non-flare surges show association with type I bursts.

The present communication is an effort towards a general study of solar surge association with different types of radio bursts observed on spectral data, excluding such surges which are associated with flares.

2. Observational Data

The solar surges are regarded as chromospheric mass ejections from the Sun and since 1980 the *Solar Geophysical Data* (SGD) start publishing the required data in the chapter 'Mass ejection from the Sun'. SGD report the durations of occurrence and the location for each surge. For radio bursts recorded on decimetric, metric, and decametric wavelengths corresponding to each solar surge, we obtained data from Weissenau Observatory (F.R.G.) and Sagamore Hill Radio Observatory (U.S.A.). We also used

radio data published in SGD. The present study covers the period 1 January, 1980 to 30 June, 1983.

3. Data Analysis

At the outset it is necessary to say that we are interested in studying the association of non-flare surges with radio bursts observed on decimetric, metric, and decametric wavelengths. We designate here such surges and non-flare surges (NFS), during the evolution of which no flare has been observed.

In order to study the association of solar surges with radio bursts of types I to V inferred from spectral data we followed the time correlation procedure used earlier by Swarup *et al.* (1960) and Zirin (1978). We used this method because the spatial location of each surge in Hα is known while the spatial location of radio bursts corresponding to each surge is unknown. Following time-correlation procedure, Swarup *et al.* (1960) studied the correlation of flares and surges with radio bursts. In the present study, in cases when no flare-like activity is present on the Sun and the radio bursts occur up to 10 min before the onset of corresponding Hα solar surges, we assumed the observed radio burst may be due to the solar surge.

For elucidating the association of non-flare solar surges with radio bursts observed on spectral data, we noted surges from SGD along with their durations of occurrence as observed in Hα. We also noted the radio bursts (types I to V) observed up to 10 min before the onset of corresponding Hα surges.

After excluding surges corresponding to NFO (no flare observations), FP (flare present on the Sun), NRO (no radio observations), and SSE (start and end times of surges are unknown), we are left with the non-flare surges (NFS) as shown in Tables I and II. In Table I, TSR and RES stands for total number of surges recorded and the number of surges with radio bursts observed on spectral data. Between 1 January, 1980 to 30 June, 1983, a total of 779 surges are known to have been recorded throughout the world. From Table I, it is clear that out of these, only 295 NFS surges are left for our study after excluding NFO = 122, FP = 278, SSE = 84, and NRO = 10. Further we find that corresponding to 295 surges only 134 surges show an association with radio

TABLE I

Association of radio bursts (type I to V) with solar surges

Year	TSR	NFO	FP	SSE	NRO	NFS	RES
1980	74	4	36	–	–	34	24
1981	357	56	89	1	5	206	89
1982	266	48	104	60	5	49	19
1983 [a]	82	14	49	23	–	6	2
Total	779	122	278	84	10	295	134

[a] Period of observation 1 January–30 June, 1983.

TABLE II

Association of different types of radio bursts (inferred from spectral data) with non-flare surges

NFS	RES	No. of surges with type I bursts only	No. of surges with type III bursts only	No. of surges with type V bursts only	No. of surges with type I and III bursts only	No. of surges with type II and III bursts only	No. of surges with type III and V bursts only	No. of surges with type I, II, III, and IV bursts only	No. of surges with type I, II, III, and V bursts only
295	134	48	57	1	20	3	3	1	1

bursts observed on spectral data. Out of the 134 surges associated with different types of radio bursts (I to V) 48 (16%) surges are accompanied by type-I bursts, 57 (19%) surges are accompanied by type III bursts and 20 (7%) surges are accompanied by types I and III bursts both. The association of different types of radio bursts inferred from spectral data with NFS is shown in Table II. From Table II, it is clear that out of 134 surges associated with radio bursts observed on decimetric, metric, and decametric wavelength, overall 85 (29%) surges are accompanied by type III bursts and 70 (24%) surges are accompanied by type I bursts or storm bursts.

To know the association among all types of bursts (I to V) observed on spectral data, we calculated upper mean level with 95% confidence, we found that only type I and type III bursts show significant association with solar surges while the association of type II, IV, and V radio bursts is inappreciable.

The time-delay observed between the onset of Hα surges and type III bursts was also studied as shown in Figure 1. Figure 1 is a plot of onset time differences in minutes between the Hα surges and type III radio bursts versus the number of solar surges with type III radio bursts. In Figure 1, small dashed vertical line shows start of surge in Hα. The broad-dashed horizontal line is upper mean line with 95% confidence and the peaks above this line are considered significant. The interpretation of 95% confidence interval is that, having constructed a random interval which has probability 0.95 of enclosing the true mean (Jenkins and Watts, 1968). It is obvious from Figure 1 that most of the surges are accompanied by types III radio bursts up to 5 min before the onset of Hα solar surge. Moreover, some surges are accompanied by type III radio bursts up to 5 min after the onset of Hα solar surge and only inappreciable number of surges show simultaneous times of onset for Hα solar surges and corresponding radio bursts.

We have also investigated the longitudinal distribution of the surges associated with the radio bursts observed on decimetric, metric, and decametric wavelength. Figure 2 is a plot of number of surges with radio bursts (types I to V) versus heliographic longitude. In Figure 2, the horizontal dashed line is the upper mean level with 95% confidence and only the peaks above this line are considered significant. From Figure 2, it is clear that radio bursts associated surges are most prolific at 80°, 110°, 260°, and
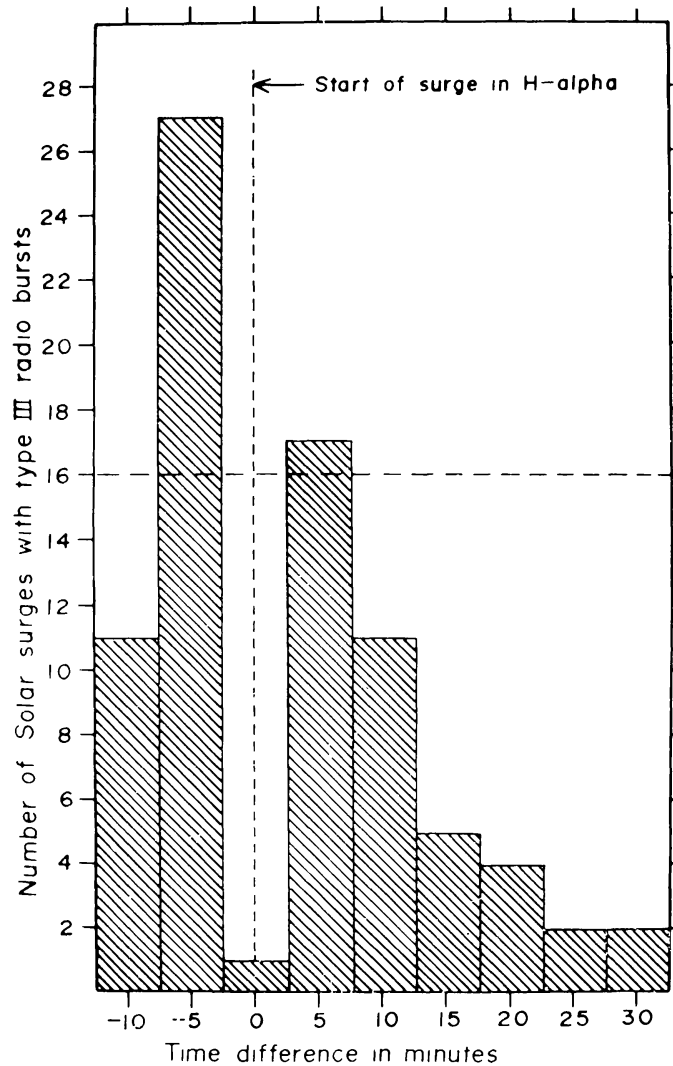
Fig. 1.   Plot of number of surges with type III radio bursts versus onset time difference in minutes between Hα surges and type III bursts.

290° longitudes (Verma, 1984). The separation between first and third longitude is 180° and second and fourth is also 180°. The separation between the 1 and 2 pair, and the 3 and 4 pair of longitudes is 30° only. It is also clear from Figure 2, that the radio-emitting surges are concentrated in two zones, having widths of about 50°.

4. Results and Discussion

In the preceding sections, we have studied the association of radio bursts (types I to V) inferred from the spectral data with solar surges. The salient results are as under:

(1) About 45% non-flare surges are accompanied by radio bursts (types I to V) as inferred from spectral data. Out of these 24% and 29% of solar surges are found to be associated, respectively, with type I and type III radio bursts. No significant number of solar surges show association with type II, IV, and V radio bursts.
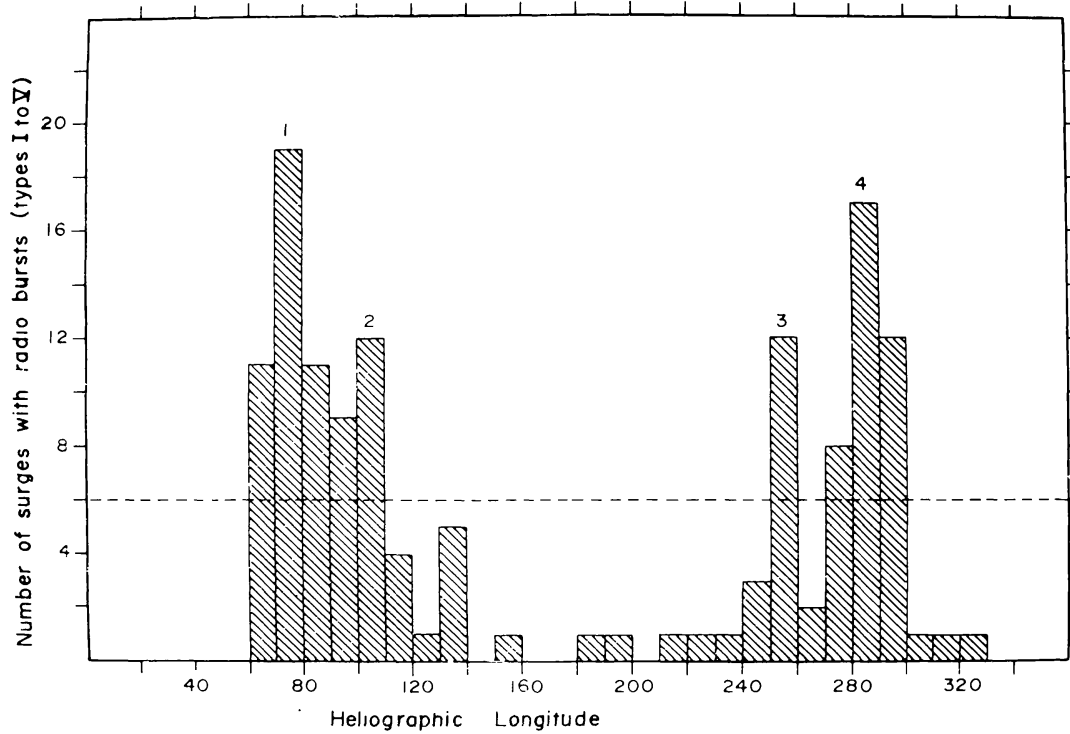
Fig. 2. Plot of number of surges with radio bursts inferred from spectral data versus heliographic longitude on the Sun.

(2) It was also noted that type III radio bursts associated with the solar surges mostly start up to 5 min earlier to the onset of Hα solar surges. Also, during some surges, the type III bursts start up to 5 min after the onset of Hα solar surges.

(3) Surges with radio bursts are found to be most prolific at 80°, 110°, 260°, and 290° longitudes, concentrated in two zones having width of about 50° each (Figure 2).

Earlier, Swarup *et al.* (1960) found that out of 99 non-flare surges 21 produce type III bursts. The results of the various investigators who have adopted the same procedure for studying the association between the solar surges and radio bursts are shown in

TABLE III

The association of solar surges with radio bursts (type I and III) as found by various investigators

Name and year (authors)	No. of surges	No. of surges with type I bursts	Percentage	No. of surges with type III bursts	Percentage
Swarup *et al.* (1960)	99	–	–	21	21
Westin (1969)	173	7	4	12	7
Garczynska *et al.* (1982)	74	30	40	10	14
Verma (Present work)	295	70	24	85	29

Table III. However, the data of various investigators is inhomogeneous in the sense that the durations prior to the Hα surges for which the observed bursts are taken as associated with the Hα surge are different with different investigators. Along with the bursts observed during Hα surge Swarup *et al.* (1960) counted all the bursts observed up to 30 min before the start of corresponding Hα surges, Westin (1969) counted bursts observed up to 5 min before the onset of corresponding Hα surges and Garczynska *et al.* (1982) also counted bursts observed up to 10 min before the occurrence of corresponding surges. In the present study along with bursts observed during surge occurrence, we counted only those corresponding radio bursts which are observed up to 10 min before the start of surge in Hα. As per our results the association of type I and type II radio bursts seems to be valid.

The type I and type III radio bursts originate $0.2\ R_\odot$ above the photosphere (Krüger, 1979) and the plasma ejected during surge occurrence attains heights up to 2×10^5 km ($\sim 0.3\ R_\odot$). The observed energy associated with solar surge is greater than 10^{29} ergs (Verma and Pande, 1982; Verma, 1983) while the energies associated with type I and type III bursts are less than 10^{27} ergs (Krüger, 1979; Garczynska *et al.*, 1982). Keeping the above facts in mind, we may say that the association of type I and type III bursts with solar surges seems energetically quite plausible.

The time-delay study between type III bursts and surges shows that the type III bursts start up to 5 min before or up to 5 min after the onset of solar surges in Hα (Figure 1). This may be interpreted in terms of two types of surges which originate at different heights and have different mechanisms of origin (Verma, 1985). Since the above findings are based on crude (time correlation) data, therefore, the above interpretation must be verified by data for positional matching.

Acknowledgements

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