Type I radio bursts and the minimum between sunspot cycles 22 & 23

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Abstract. Spectral observations of Type I radio bursts published in the *Solar Geophysical Data* are used to show that the minimum between solar cycles 22 & 23 occurred during October 1996.

Key words: Sun: general – Sun: radio radiation – Sun: sunspots

1. Introduction

It is well known that the most frequently observed solar phenomenon at meter and decimeter wavelengths are disturbed periods usually of hours' or days' duration; these periods consist of a long series of bursts called storm bursts, and the radiation at such times is called the noise storm or *enhanced radiation* (see Kundu 1965; Elgarøy 1977; Krüger 1979; Kai et al. 1985, for a review on the topic). On single frequency records obtained with high time resolution ($\sim$100 msec), it appears as a steady or slowly varying backgound level with frequent short-lived bursts. The background level (without the bursts) is commonly referred to as the background continuum, and the bursts superimposed upon it are known as the storm bursts or type I bursts (Wild et al. 1963). It is generally accepted that the noise storm radiation originates in the solar atmosphere above a group of sunspots, and reaches a sharp maximum near the central meridian passage of the associated spot group (Hey 1946; McCready et al. 1947). The chances that a sunspot is associated with a noise storm increases with the area of the spot. Payne-Scott & Little (1951) found that sunspots whose area is > 400-millionths of the Sun's disc are more likely associated with noise storms. A similar result was arrived at independently by Le Squeren (1963). However, later observations indicate that even spots of size ~ 100 millionths of the solar disc are associated with type I storms (Dodson & Hedeman 1957; Dulk & Nelson 1973). Strong magnetic fields are also necessary for the generation of type I storms since the latter are 100% circularly polarised at most times (Ryle & Vonberg 1946; Martyn 1946; Appleton & Hey 1946). Based on a statistical study of solar activity observed during the sunspot minimum period in 1954, Dodson & Hedeman (1957) concluded that the spots associated with noise

storms have a field strength ≥ 1300 Gauss. This is expected because there is a close relationship between the size of a sunspot and its associated magnetic field (Payne-Scott & Little 1951). Elgarøy (1982) pointed out that the observed characteristics of the noise storms varies with sunspot cycle, i.e. they are more frequent and intense during the maximum of the cycle, and are rare and weak during the minimum. Brueckner (1983) showed that all type I noise storms observed during the Skylab period were caused by changes in the coronal magnetic field structure, and all coronal magnetic field changes observed on the disc were correlated with newly emerging flux. According to Kai et al. (1985), it is possible that the source of a type I storm lies in a closed loop of strong magnetic field just above the associated active region. Therefore, it is clear that the existence of a sunspot or a group of sunspots is a necessary condition for the generation of noise storms. In view of this close association between the two, we use the observations of type I radio bursts to independently verify the time of the minimum between the solar cycles 22 & 23.

2. Data set

The type I radio burst data reported were obtained from the spectral observations of solar radio emission published in the *Solar Geophysical Data* (March 1993 - February 2000). The reporting stations were Bleien (47N 9E), Potsdam (52N 13E), Ondřejov (49N 14E), San Vito (41N 18E), Izmiran (55N 37E), Learmonth (22S 114E), Hiraiso (36N 140E), Culgoora (30S 150E), Palehua (21N 204E) and Sagamore Hill (42N 289E). On occasions, data obtained with the Gauribidanur radioheliograph (13N 77E, Ramesh et al. 1998) was also used for the present study. One can notice that the longitudinal distribution of the different observing locations is such that there is almost a continuous observation of the Sun over a period of 24 hrs. Fig. 1 shows the total number of type I radio bursts observed each year during the period 1993–99. The lowest number of bursts observed was during 1996, the official minimum between the solar cycles 22 & 23 (Harvey & White 1999, and the references therein). In order to ascertain the exact time of minimum during 1996, we plotted a histogram of the total number of bursts observed each month during 1996 (Fig. 2). One can notice that no bursts were observed during the month of October 1996. The non-uniformity in
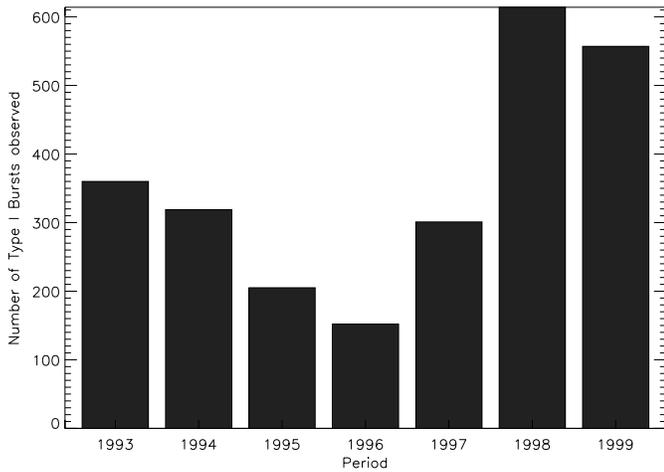
Fig. 1. Histogram showing the total number of type I radio bursts observed each year during the period 1993–99.
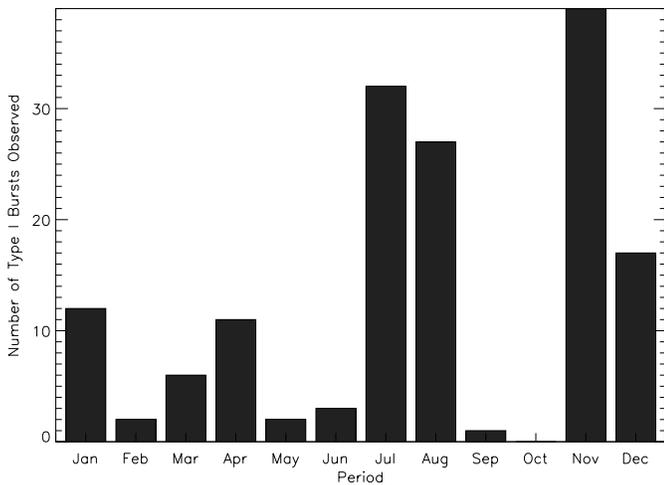
Fig. 2. Histogram showing the number of type I radio bursts observed each month during the year 1996.

the distribution of bursts in each of the above two figures (Figs. 1 & 2) might be due to the differences in the probability of their association with different classes of sunspots (Fokker 1960; Le Squeren 1963), according to the Zürich classification scheme. Figs. 3 & 4 shows the number of type I radio bursts observed each month during 1996 plotted against the monthly average of the 10.7-cm radio flux, and sunspots respectively (The data corresponding to the F10.7 monthly average and sunspot monthly average in Figs. 3 & 4 were taken from De Toma et al. [2000]). The variations in the number of observed bursts correlates well with that in the 10.7-cm flux and in sunspot number.

3. Discussions and conclusions

Historically the minimum of a sunspot cycle is generally the period when quantities like the smoothed sunspot number, monthly sunspot number, monthly number of spot groups, maximum number of spotless days, and 10.7-cm radio flux show a minimum. Equal numbers of old and new cycle regions is another
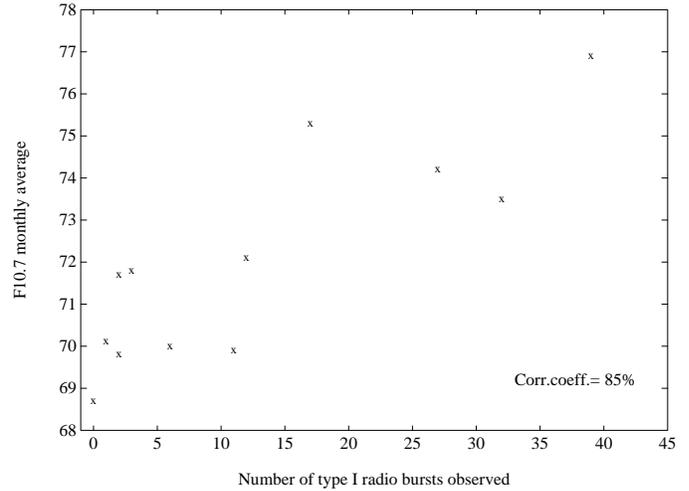
Fig. 3. Variation of the number of type I radio bursts observed each month during 1996 with the monthly average of 10.7-cm radio flux during the same year.
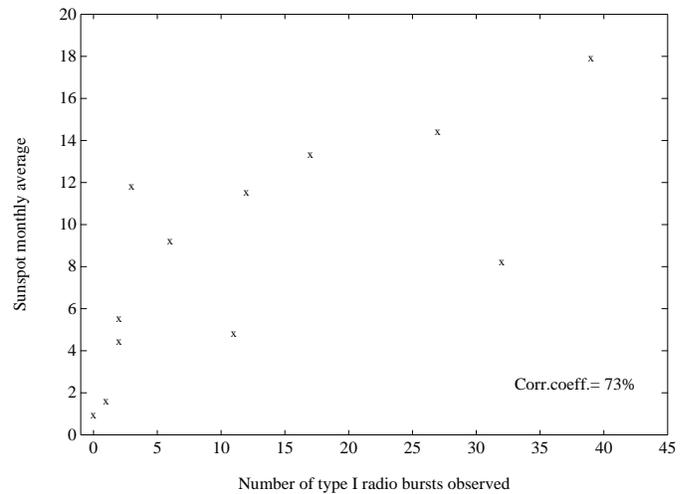
Fig. 4. Variation of the number of type I radio bursts observed each month during 1996 with the monthly average of sunspots during the same year.

indicator. Parameters like Mg II chromospheric index, Ca II K index, He I 1083-nm equivalent width, and total irradiance are also used to monitor the sunspot cycle. It is obvious that the inclusion of other measures of transition between cycles can lead to differences between the official minima and the minimum in the respective quantities. According to published reports, two periods of low activity were identified in 1996, one in the month of May and the other in October, for the solar cycle 22 (Joselyn et al. 1997; Harvey & White 1999). We performed a statistical study of the type I radio bursts observed during the period 1993–99 to verify the time of the minimum between the solar cycles 22 & 23. Our main conclusion is that October 1996 is the most probable time of sunspot minimum, since it was the period when no type I radio bursts were observed (As mentioned in the earlier section, the occurrence of radio noise storms requires the presence of sunspots or sunspot groups of size ~ 100

millionths of the solar disc, and magnetic field strength ~ 1000 Gauss). This agrees well with the earlier result that no sunspots were observed for more than one solar rotation (Carrington rotation 1914), during September-October of 1996. Also, October 1996 was the period when there was a minimum in the monthly sunspot number, monthly number of sunspot groups and 10.7-cm radio flux (Harvey & White 1999; De Toma et al. 2000).

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