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HIGH ENERGETIC SOLAR PROTON FLARES ON THE DECLINING PHASE OF SOLAR CYCLE 22

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ABSTRACT

During the declining phase of the solar cycle 22, in June 1991, energetic flares were produced by active regions NOAA/USAF 6659. The associated solar proton events affected the earth environment. An evaluation of the solar activity during the first half of June 1991 was made, leading to a possible method for high energetic solar flares prediction. The method depend on cumulative summation curves of the H-alpha flares, and x-ray bursts, in the active region 6659 during the rotation when the energetic solar flares of June 1991 have occurred. It is shown that a steep trend of increased activity begins several tens of hours prior to the occurrence of the energetic flare.

INTRODUCTION

Large solar events and geomagnetic disturbances can affect satellites and people in space as well as Earth-based systems. The activity of solar Region 6659 of June 1991 during the declining of solar cycle 22 is an example of how events on the sun can interfere with systems we all depend on.

Active region 6659 was recognized at an area worth watching even before it appeared at the eastern limb of the sun on 2 June 1991. Behind the limb flare activity forewarned of at least a moderately active sunspot group approaching the visible disk. However, the extraordinary nature of the region was realized before the sunspots themselves began to rotate into view. At that time, the sunspot were observed to be arranged in very large and compact configuration that is historically seen in only the most significant sunspot groups. This region had produced X-ray event X12/1B at $14^h\ 56^m$ UT on 1 June, 1991 with coordinates N25 E90 and duration 150 minutes at the eastern limb before the sunspots themselves began to rotate into view on 2 June, 1991.

By 2 June 1991 a DKC spot group of area about 270 millionths (msh) with a large penumbral mass centered at N30 E85 was visible, and a Beta/Delta magnetic configuration was discernible. Although still beyond east limb, the area was assigned as region 6659 by NOAA, Boulder, Colorado, USA. The region produced X12 / 1F Tenflare measured on 10 cm wavelength with strong type II and IV radio sweeps at $15^h\ 20^m$ UT of 2 June 1991. The flare occurred beyond the east limb, a spectacular spray with material was visible to 0.5 solar radii, bright surges and loops have been also reported. This flare was the largest since the X15 flare of October 1989. This region continued its major flare production. An X12 / 3B flare was released at $3^h\ 34^m$ on 4 June, 1991.

The two-ribbon Hα flare occured at $3^h\ 34^m$ on 4 June, 1991, associated with a white-Light flare and followed by an emission spray and post-flare loops. The energy released by the white-light flare at leff = 4100 Å is estimated to be about 1.5×10^{28} erg s^{-1} /1/. The flare is associated with 10cm radio emissim flux of 11000 sfu started at $3^h\ 37^m$ with duration 76 minutes.

An associated proton event began at $8^h\ 20^m$ on 4 June, 1991 with proton flux 3000 pfu for energy > 10 Mev as measured by GOES spacecraft at the maximum phase of the event at $14^h\ 20^m$ on 11 June, 1991. Another X12/4B produced at $1^h\ 8^m$ UT of 6 June, associated with 10 cm radio emission of flux 55000 sfu and duration 137 minutes. Also, X10 / 3B flare was released at $1^h\ 43^m$ UT on 9 June, associated with 10cm radio emission flux of 8600 sfu and duration 159 minutes.

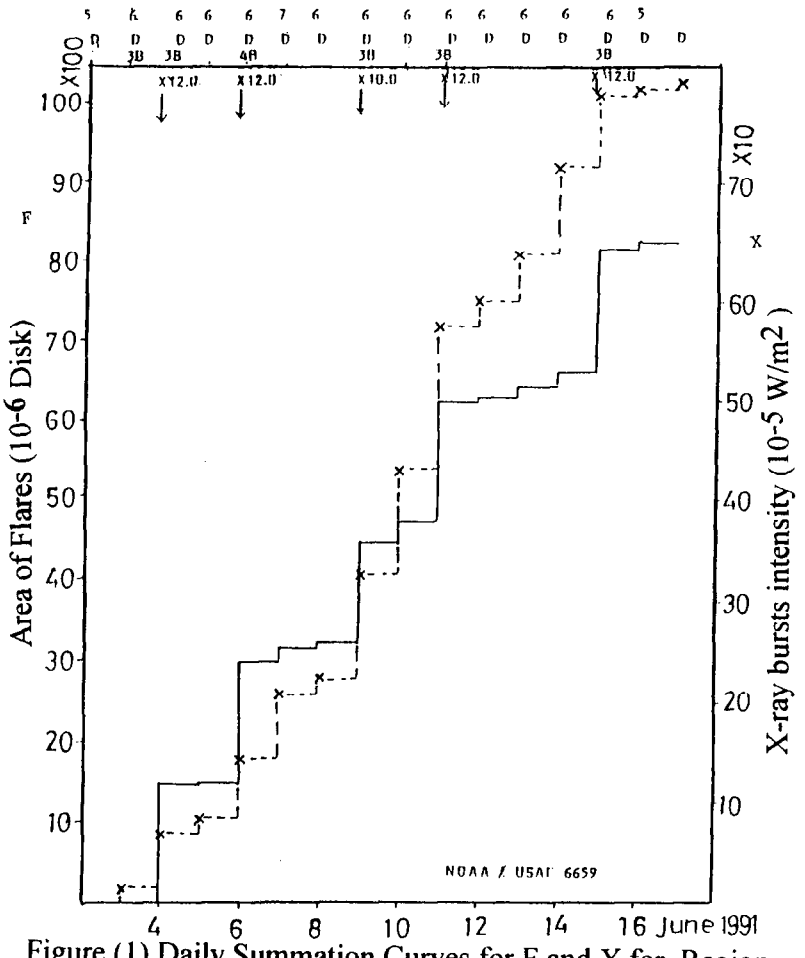

Figure (1) Daily Summation Curves for F and X for Region 6659 during June 1991.

Region 6659 continued its domination of activity levels, producing X12/3B flare at $2^h\ 9^m$ UT on 11 June, associated with 10 cm radio emission flux of 10000 sfu and duration 120 minutes. Another, a X 12/3B flare was released at $8^h\ 21^m$ on 15 June, 1991, associated with 10 cm flux of 14000 sfu and duration 123 minutes.

All these outstanding flares on 4, 6, 9, 11, and 15 June 1991 from region 6659 were associated with strong type II and IV radio sweeps and presumably mass ejection from the sun as indicator by the CME proxy indicators, the development of the activity in the region where the proton flares, have occurred during June 1991, is analysed with the help of the method of summation curves like with some of the proton regions in the past /2, 3, 4/.

This method which shows the trend in the release of energy of active regions for flare and X-ray bursts, can be used to characterize typical intervals in the active region development, which often display the same trend of development over a number of days. The method can also be used as a possible way of forecasting the occurrence of flares with emissions of energetic particles. If a steep trend, e.g. of the flare parameter F (H-alpha index) or X (X-ray index) is in evidence, one may expect a proton flare to occur one or a few days later. The effects of Region 6659 on the earth's ionosphere and geomagnetism are summarized in tables (1) and (2).

DATA TREATMENT

The used data have been obtained from "Solar-Geophysical Data", Prompt Reports No. 563 and 564, and Comprehensive Report No. 568, published by NOAA, Boulder, Colorado, USA.

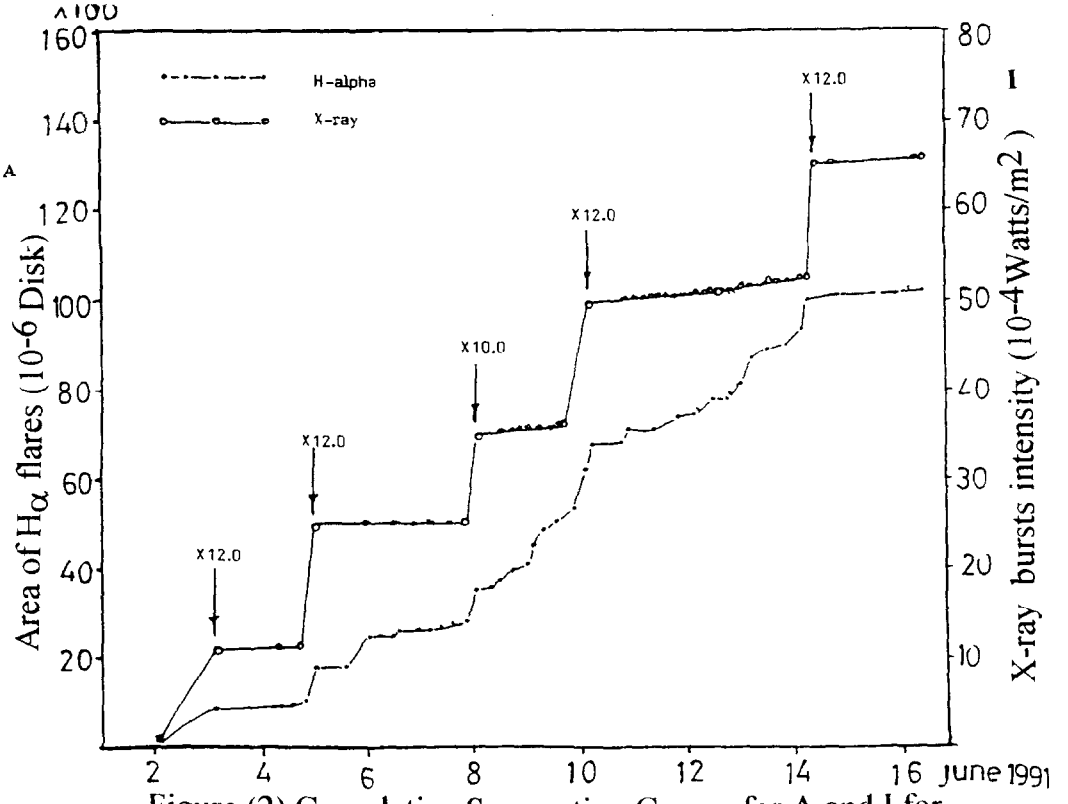

Figure (2) Cumulative Summation Curves for A and I for Region 6659 during June 1991.

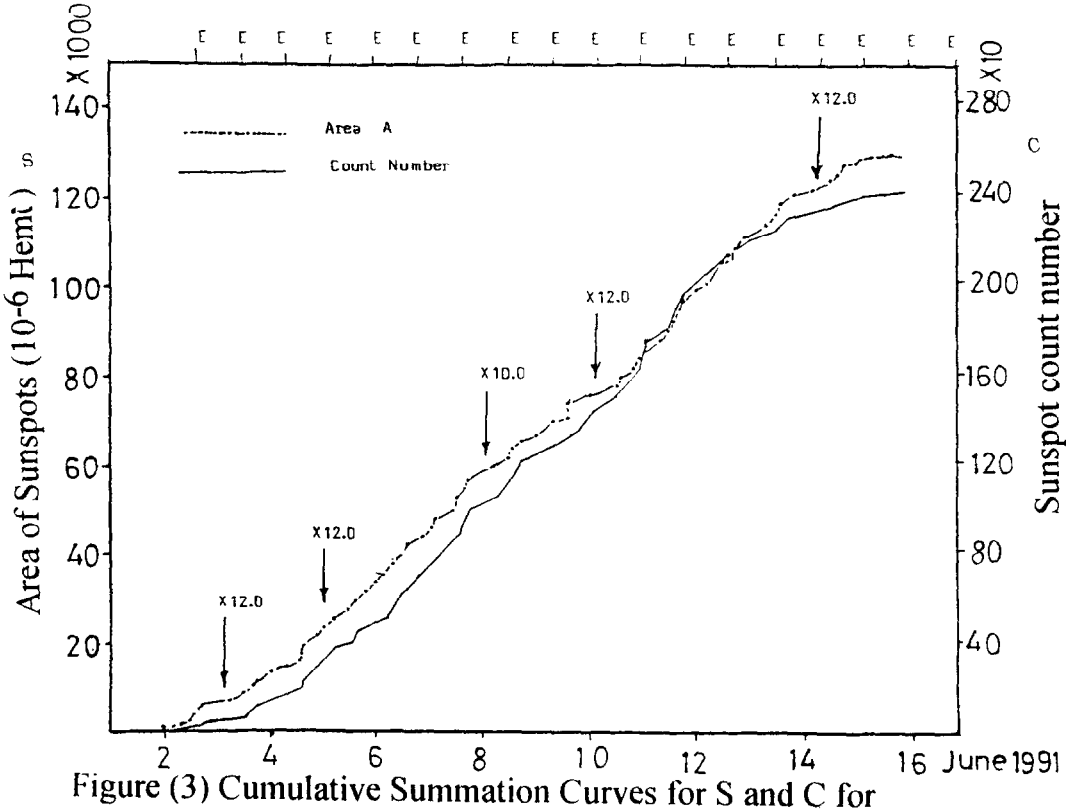

Figure (3) Cumulative Summation Curves for S and C for Region 6659 during June 1991.

In figure (1) the flare parameter F represents solar flares inclusive sub-flares observed in H-alpha in the world station network (Solar-Geophysical Data), defined by the daily summation of area of solar flares in millionths of the solar disk (msd) which occurred in the investigated active region. The parameter X is defined as the daily summation of the peak flux of the X-ray bursts in the 1-8 Å band in Wm^{-2} released in the investigated active region, as observed by the GOES satellite (Solar-Geophysical Data).

In figure (2) the flare parameter A is the cumulative summation for the observed Hα flares areas, while I is the cumulative summation for the observed X-ray bursts intensity.

In figure (3) the sunspots parameter S is the cumulative summation of the sunspots area, while C the cumulative summation for the sunspot count number.

RESULTS

Both the curves of F and X in figure (1) became more steep before the occurrence of each outstanding flares of 4, 6, 9, 11 and 15 June 1991. The changes of these trends are related to the development of the active region and to the type of spot groups, as well as to the configuration of magnetic field, as seen on the head of figure (1). Where D means the spot group have opposite polarity umbrae within single penumbra, 6 means the strength of the magnetic field of sunspot group ranging between 2600 and 3000 Gauss. While 7 means the strength of the magnetic field of sunspot group ranging between 3100 and 3500 Gauss. The type of the sunspot group was D for 3 June 1991, and E for all the period from 4 to 16 June 1991.

Also, the both curves of A and I in figure (2) became more steep at 4, 6, 9, 11 and 15 June 1991 on the days of the occurrence of the outstanding flares.

Both curves of S and C in figure (3) show continuous increasing during all the period of crossing the region 6659 for the solar disk.

CONCLUSION

The results show an increase in the trend of the flare and sunspots activity several tens of hours prior to the occurrence of a high energetic solar flares which can be used together with other methods for forecasting major and high energy particle events.

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