Activities in Sunspot Group NOAA 9393

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ABSTRACT

Watukosek Aeronautics and Space Observing Site (WKSO, LAPAN), observed sunspot in daily basis since 1987 using a sketch method. Sunspot group NOAA 9393 (or WKSO 0123) have been observed in March to early of April 2001. The region showed a rapid development during its appearance on the solar disk. The magnetic field of this active region evolved from a simple to a complex configuration (sunspot group type F) within a short period (days). WKSO recognized the sunspot group remains as type F (very active) as long as 8 days. Based on GOES data the active region released as much as 56 flares of type C (small), M (moderate) and X (large) to amount of 28, 24 and 3, respectively, during its appearance from 24 March to 4 April 2001. It is found that prior to X-class flare, there was an increase of activity in C and M-class flare. A rapid emergence of the active region may cause instability in magnetic configuration, and therefore released the magnetic energy in the form of solar flares.

Keywords*: Sunspot group, active region, solar flares, solar activity*

1. Introduction

Sunspot group resembles an intersection of a magnetic flux tube with the photosphere. It appears darker than surrounding photosphere as the temperature of sunspot lower compared to its surrounding. Based on observations and theoretical studies it is found that the magnetic field of sunspot group is the source of explosion energy at the Sun, namely flare.

Study on morphological evolution of sunspot group and its relation to the flare occurrences can be applied to practical use such as forecasting when a flare will occur as well as to understand its impact to the Earth's space environment. National Institute of Aeronautics and Space (LAPAN) is developing a space early warning system for solar-originated disturbances (Setiahadi, 2006; Setiahadi *et.al*, 2006; Anwar, 2004; Anwar, 2007a). It is expected that this work will contribute to a better understanding on the evolution of sunspot group and its relation to flare occurrences, particularly X-class

flare, to support space early warning system at LAPAN (Setiahadi, 2007; Anwar, 2007b; Anwar, 2008).

Section 2 describes observation data used in this study. Data analysis is given in section 3 while section 4 provides the results and discussions.

2. Observation Data

In order to study the evolution of sunspot group NOAA 9393, we have utilized the sunspot data from Watukosek Aeronautics and Space Observing Site (WKSO) and flare data from Geostationary Operational Environmental Satellite (GOES).

2.1. Sunspot data

WKSO observes the Sun in optical wavelength using a refractor telescope of 30 cm in diameter. The image of the Sun is projected to a focal plane where the observer recognizes the appearance of sunspots. The sunspots are drawn manually and then are processed to determine their locations, sunspot types as well as their number within each sunspot group. WKSO sunspot type follows Zürich sunspot classification. A newly birth of sunspot is classify as type A. As the sunspot develops in number and area it evolves to type B, C, D, E and F (very active). After it reaches its maximum in area, the sunspot group gradually decays and finally forms a simple configuration as type J or H.

The results data reduction and analysis are recorded into ASCII format file. Querying a particular data directly from text files is not efficient. Therefore, we have developed a database system for WKSO sunspot data based on web technologies such as Apache web server, MySQL server, HTML and PHP (Anwar, 2004; Anwar 2008; Greenspan and Bulger, 2001). We created a Perl (Practical Extraction and Report Language) scripts to read the ASCII data and convert into SQL commands to insert the data into MySQL database (Medinets, 1998).

Sunspot group WKSO 0123 was recorded in WKSO observations from 24 March to 3 April 2001. The sunspot group evolved from a simple form in the beginning of observation and developed into type F on 27 March 2001 and remains the same type up to 3 April 2001. The change of sunspot type resembles the activity of the sunspot group. In the following days, the active region was getting closer to the solar limb and therefore can not be sketched.

2.2. Flare events data

Space Environment Center (SEC), National Oceanic and Atmospheric Administration (NOAA) catalogues flare events based on observations of GOES that orbits the Earth. The catalogue are available as ASCII file containing information on the date of observation, start time, end time as well maximum time of flare. The location of flare and its corresponding active region are also listed. The x-ray classification and x-ray intensity are available along with optical class when there is ground-based observation for the event. The flare events files are read by PHP scripts and recorded into MySQL database. By this way, we can easily query a particular data based on a category and a keyword.

3. Data analysis

As we utilize the sunspot data from WKSO that catalogues the sunspot group number in different way from NOAA does, a comparison is done for the coordinate of sunspot group in WKSO data and flare location in NOAA data to find their relationship. It is obvious that WKSO active region 0123 observed on 27 March 2001 at WKSO coordinate (Longitude, Latitude) is (22^o,17^o) corresponds to NOAA sunspot group 9393. Based on this fact, a query is performed to extract flares of type C, M and X as follows:

```
select * from flare where x_class='c' and noaa_number='9393'
```

to find C-class flare that occurred in NOAA active region 9393. To find flares of type M and X then change criteria x_flare='m' and x_flare='x', respectively. To count the number of flares of type C each day, for example, the following SQL command is used:

```
select obs_date, count(obs_date) from flare where x_class='c' and
noaa_number='9393' group by (obs_date)
```

We compared the sunspot group type and number of sunspots within sunspot group to number of flares of type C, M and X to find their relationship.

4. Results and discussions

In this section we describe the results of data analysis. Table 1 shows the active region of WKSO 0123 or NOAA 9393 during its appearance on the solar disk as sunspot type F. There was a significant change in the number of spots within the sunspot group from 27 March to 3 April 2001. This change indicates that sunspot group evolved very quickly from day to day.

Table 1. WKSO Sunspot group 0123 was classified as type F in 27 March to 3 April 2001.

JD	ObsDate	GroupNo	NumberOfSpot	type	CMDLon	Lat	Observer
2451995.5	2001-03-27	0123	73	F	22	17	AS
2451996.5	2001-03-28	0123	40	F	14.5	19	MR
2451997.5	2001-03-29	0123	65	F	-4	17	DR
2451998.5	2001-03-30	0123	78	F	-17.5	16.5	AS
2452000.5	2001-04-01	0123	120	F	-43.6	15.9	BS
2452001.5	2001-04-02	0123	49	F	-56	16.5	AS
2452002.5	2001-04-03	0123	17	F	-68.5	18.5	MR

It should be noted that the number of sunspots may contain an error as the observers have different skill in doing sketch. A significant error occurs when the sunspot group located close to the solar limb as a projection effect reduces significantly the area of sunspots and therefore the observer counts lesser sunspots. This may occurred on data taken on 2^{nd} of April where the number of sunspots decreased from 120 in the previous day (1 March) to 49 on 2 March when the sunspot group located at -56^{o} (West) from the central meridian (CMDLon). In the following day, the number of sunspots recorded to 17 when the sunspot located at -68.5^{o} (West).

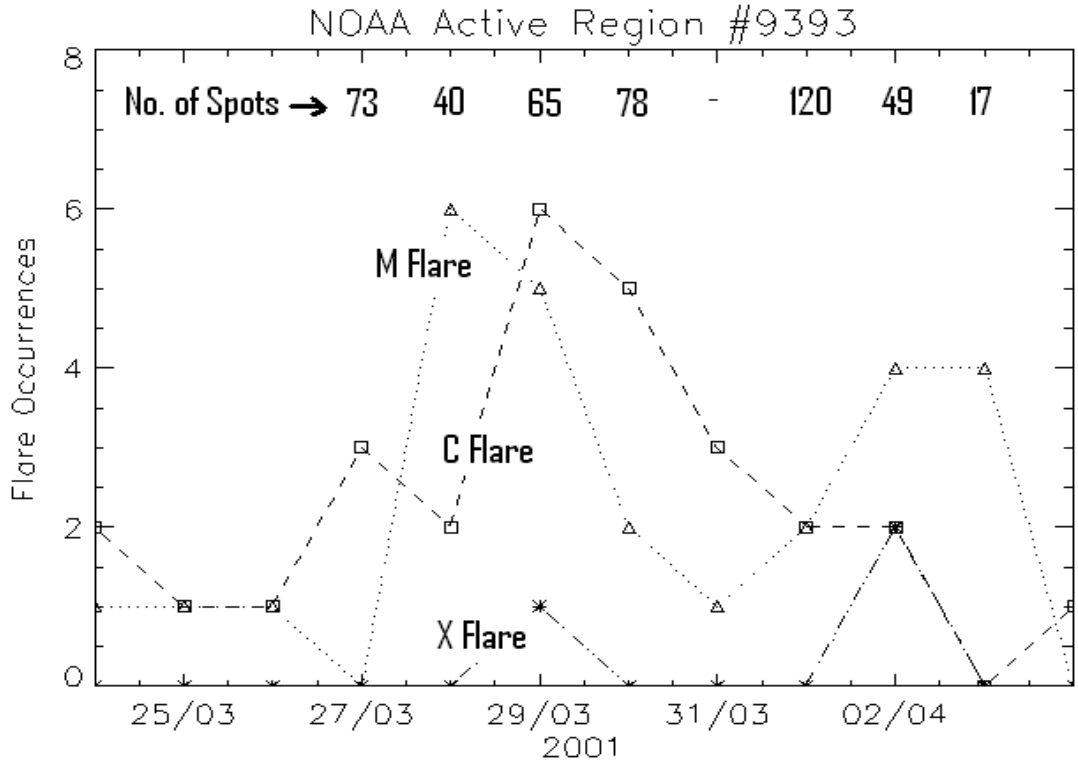

Figure 1. Comparison of flare occurrences of type C (square, dash line), M (triangle, dotted line), and X (star, dash-dot) at NOAA active region #9393.

Figure 1 shows a comparison of the number of flares occurred in NOAA active region 9393 starting from 24 March up to 4 April 2001. It is obvious that flares occurrence of type C and M is more frequent than X-class flare. It can be understood as the magnetic energy released during C or M class is smaller than that of X-class flare. The active region requires longer time to develop its magnetic energy to be large enough to be released as an X-class flare compared to the case of C or M class flare. The magnetic energy build-up can be achieved by increasing the number of spots within sunspot group and / or sunspot area caused by emerging of the existing flux tube as well as new flux tubes from beneath the photosphere. It can also be achieved by increasing the degree of twists of the magnetic flux tube of the active region caused by sunspot proper motions.

Based on WKSO observations, the active region developed to sunspot of type F since 27 March and remained the same type until 3 April 2001 (Table 1). This indicates the sunspot group NOAA 9393 is categorized as a 'very active' for at least 8 days. This

supported by the fact that there were 21 M-class and three X-class flares during the period of time. After an X-class flare, the activity (in this case the occurrence of C and M class flares) tends to decrease (Figure 2).

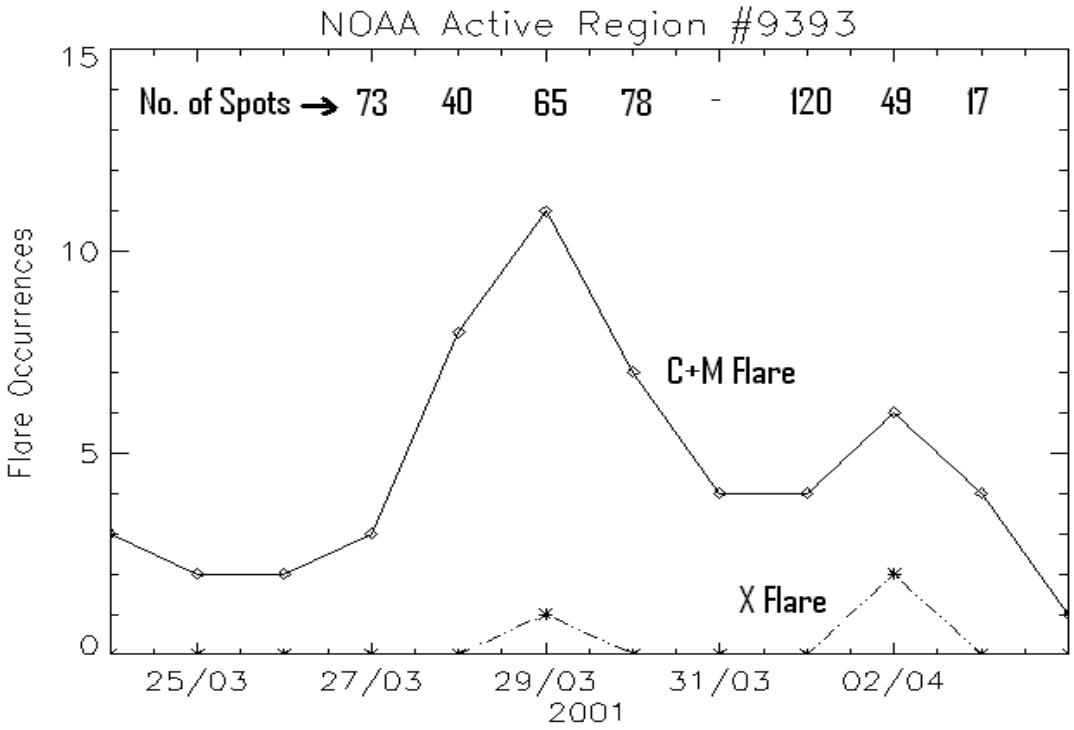

Figure 2. The flare occurrences of type C and M compared to X-class flare.

There was an increasing activity (C or M flare occurrences more frequent) prior to X-class flare as shown in Figure 2. An X-class flare occurred on 29 March at 09:57 UT and two X-class flares occurred on 2 April 2001 at 10:04 UT and 21:32 UT, respectively.

There was an increase of activity from 26 to 29 March before X-class flare that occurred on 29 March at 09:57 UT. There were six M-class flares and two C-class flares in 28 March, while in the previous day (27 March) there was no M-class flare and c-class flare are only three two events. By counting C and M-class flare together, the increase of activity prior to X-class flare is even obvious (Figure 2). Two X-class flare that occurred on 2 April 2001 were also preceded by the increase of M-class flares.

Table 2. Partial list of flares in active region NOAA 9393 during 29-30 March 2001.

obs_date	start_time	end_time	max_time	position	imp_optic	bright_optic	x_class	x_intensity	x_flux	station_name	noaa_number
2001-03-29	0508	0519	0514				C	55	3.1E-03	GOES	9393
2001-03-29	0957	1032	1015	N20W19	S	F	X	17	2.2E-01	GOES	9393
2001-03-29	1129	1139	1135	N15W12	S	F	M	21	1.1E-02	GOES	9393
2001-03-29	1235	1244	1239	N16W13	S	F	C	76	3.7E-03	GOES	9393
2001-03-29	1409	1422	1418				M	16	9.4E-03	GOES	9393
2001-03-29	1452	1505	1458				M	15	9.3E-03	GOES	9393
2001-03-29	1520	1533	1525	N14W15	S	F	M	12	8.7E-03	GOES	9393
2001-03-29	1733	1742	1737	N16W15	S	F	C	54	2.2E-03	GOES	9393
2001-03-29	1812	1820	1817	N15W17	S	F	C	41	1.9E-03	GOES	9393
2001-03-29	1826	1849	1841	N14W17	S	F	C	71	7.5E-03	GOES	9393
2001-03-29	2010	2023	2017	N14W19	S	F	C	69	4.2E-03	GOES	9393
2001-03-30	0107	0113	0110	N13W22	S	F	C	79	2.6E-03	GOES	9393
2001-03-30	0220	0233	0228	N14W22	S	F	C	75	5.2E-03	GOES	9393
2001-03-30	0346	0353	0350	N17W16	S	F	C	44	1.7E-03	GOES	9393
2001-03-30	0511	0520	0515				M	22	1.1E-02	GOES	9393
2001-03-30	0916	0936	0928	N17W20	S	F	M	10	1.0E-02	GOES	9393
2001-03-30	1504	1517	1510	N16W24	S	F	C	47	3.2E-03	GOES	9393
2001-03-30	1819	1853	1840	N17W26	S	F	C	47	8.9E-03	GOES	9393

It is also obvious that a large number of spots in sunspot group are not strongly related to the flare occurrences (number of flares) directly. Rather, a large number of spots can be though the active region is gaining its magnetic energy and therefore it may contribute in increasing a possibility to release a large flare (such as X-ray class).

We can conclude that the occurrences of C-class flares indicate the active region is developing its magnetic energy, while the increase of M-class flares might be an indication that the region has already had magnetic energy to be released as a moderate-

class flare. Importantly, it can also be though as a 'precursor' of X-class flare to be occurred in hours or days to come.

5. Concluding Remarks

We have studied the evolution of active region NOAA 9393 (or WKSO 0123) during its appearance on the solar disk. The region produced as much as 56 flare of type C, M and X, meaning that the active region can be called as a "flare-productive active region". It is found that prior to an X-class flare, there was an increase of activity or the occurrences of flare type C and M. By understanding the pattern of the increase of activity prior to an X-class flare, it might be used as a precursor for the occurrence of X-class flare, as a part of space early warning at LAPAN. This work will be explored further in the future.

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