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Solar flare forecasting using photospheric active region properties

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Summary. — Daily observations of the photosphere are performed by the Equatorial Spar of INAF- Catania Astrophysical Observatory (INAF-OACt). In this poster we describe the results obtained by a tool developed for solar flare forecasting on the base of photospheric active region properties. We measured five parameters describing the morphology of the active regions appeared on the solar disc from January 2002 up today: area, Zurich class, number of pores and sunspots, relative importance between leading spot and density of the sunspot population and type of penumbra of the main sunspot. By means of a linear combination of these parameters we determined the probability that a flare of C-, M- and X- class occurs in such active regions. Comparing our forecasting with the number of flares registered by GOES satellites in the 1 - 8 Å X-ray band during the subsequent 24 hrs we evaluate the accuracy of our method using different skill scores.

1. – Introduction

The solar activity has its main manifestation and impact on Earth environment by means flares, filament eruptions and Coronal Mass Ejections (CMEs) (e.g., [1], [2], [3]). Their effects involve technology and economical interests, so many efforts of the scientific community have been addressed to forecast solar eruptions with enough advance to prevent damages to technological systems. Many approaches to flare forecasting have been produced in last decades. Many of them are based on photospheric conditions of the Sun, while few of them consider the magnetic field configuration of the corona, where actually most of the solar eruptions begin. There is also a method based on the flaring history of the observed ARs developed by [4]. Recently, [5] performed a comparison of the above mentioned flare forecasting methods reaching the conclusion that it may be possible to obtain the best prediction by combining a method that characterizes an AR by one or more parameters and a method that uses a statistical technique.

In this work, we describe the INAF-OACt flare forecasting method based on particular configuration, size and fragmentation of the sunspot groups hosting flares [6].

2. – Data description

We used data collected by the Equatorial Spar of INAF - OACt from January 2002 up today. When the weather conditions permit, this telescope allows the observation of the photosphere in White Light (WL) by a Cooke refractor (150mm/2230 mm) which projects a 24.5 cm diameter image of the Sun with a spatial resolution of about 4 arcsec. Every day each sunspot group visible on the disk is characterized by registering some information as heliographic latitude and longitude of its baricenter, number of sunspots and pores in the group (SS), projected area of sunspot group in tens of millionths of the solar hemisphere (AA), type of penumbra of the main sunspot ($t1$), relative importance between leading spot and density of the sunspot population ($t2$) and group type ($t3$) according to Zurich classification [7] (see [8] for details). We used these parameters to determine the probability that a flare of occurs in a sunspot group.

3. – Forecasting method

Our method investigating the sunspot groups capability of hosting flares during their evolution assumes that the flare event frequency follows the Poisson statistics. It is based on five sunspot group parameters: SS, AA, $t1$, $t2$ and $t3$. For each parameter, indicated generically by k, we compute the flare rate, FR, by the ratio between the number of sunspot groups which hosted at least a flare and were characterized by a specific value of that parameter, $Nf(x_k)$, and the total number of sunspot groups characterized by the same value of that parameter $N(x_k)$: $FR_k(x_k) = N_f(x_k)/N(x_k)$.

The average among the flare rates for all parameters:

$$FR = \frac{FR_{AA}(x_{AA}) + FR_{SS}(x_{SS}) + FR_{t1}(x_{t1}) + FR_{t2}(x_{t2}) + FR_{t3}(x_{t3})}{5} \tag{1}$$

provides an estimation of the capability of hosting flares for sunspot groups characterized by a particular configuration, size and fragmentation.

Following the Poisson statistics, the event probability is given by: $p_f = 1 - exp(-FR)$.

We compute the flare probability for three different samples of flare energies: for C1.0 class and greater (C1.0+), for M1.0 class and greater (M1.0+), for X1.0 class and greater (X1.0+). These probabilities are daily published at http://ssa.oact.inaf.it/oact/Flare_forecasting.php (see Fig. 1).

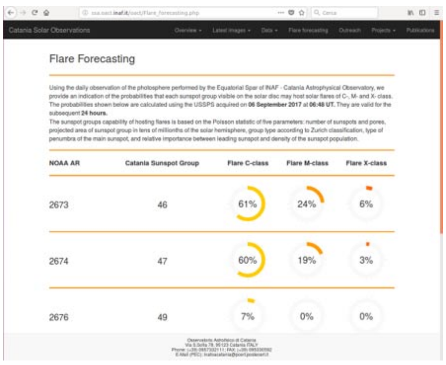

Fig. 1. – Snapshot of the INAF-OACt webpage dedicated to the flare forecasting.

TABLE I. – *Performance results.*

Flare class	H&KSS	ApSS	BSS
C 1.0+	0.45 (0.25)	0.16 (0.40)	0.20
M 1.0+	0.56 (0.05)	0.04 (0.27)	0.12
X 1.0+	0.70 (0.01)	-	0.04

4. – Forecasting performance measures

To evaluate the performance of our forecasting method we compared our flare probabilities with the flare records obtained by the GOES satellites and collected in the Space Weather Prediction Center Reports. We considered 8598 sunspot groups. Among them, the sunspot groups hosting C1.0+, M1.0+ and X1.0+ class flares were 1841, 347 and 47, respectively.

We measured the accuracy of our probabilistic forecasts by a variety of skill scores (see [5] for details.): the Appleman's Skill Score (ApSS), the Hanssen & Kuipers' Discriminant (H&KSS) and the Barier Skill Score (BSS). We determined a threshold probability to build a contingency table and generate the binary categorical classification to maximize ApSS and H&KSS. Any forecast probability over the threshold was considered to be a forecast for an event, and anything less was considered to be a forecast for non-event. The performance results and the probability thresholds are reported in Table I.

5. – Conclusions

When weather conditions permit, INAF-OACt provides daily an indication of the probabilities that each sunspot group visible on the solar disc may host solar flares of C1.0+, M1.0+ and X1.0+ class.

We found that almost all scores show values corresponding to a better performance than the considered reference forecasts. The present method of validation seems to be more accurate at predicting stronger events, which are more important for their Space Weather effects.

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