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Magnetogram Forecast: An All-Clear Space Weather Forecasting System

Project Manager(s)/Lead(s)

Nasser Barghouty/ZP12
(256) 961–7600

David Falconer/ZP12
The University of Alabama-Huntsville/CSPAR
(256) 961–7616

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Project Description

Solar flares and coronal mass ejections (CMEs) are the drivers of severe space weather. Forecasting the probability of their occurrence is critical in improving space weather forecasts. The National Oceanic and Atmospheric Administration (NOAA) currently uses the McIntosh active region category system, in which each active region on the disk is assigned to one of 60 categories, and uses the historical flare rates of that category to make an initial forecast that can then be adjusted by the NOAA forecaster.

Flares and CMEs are caused by the sudden release of energy from the coronal magnetic field by magnetic reconnection. It is believed that the rate of flare and CME occurrence in an active region is correlated with the free energy of an active region. While the free energy cannot be measured directly with present observations, proxies of the free energy can instead be used to characterize the relative free energy of an active region. The Magnetogram Forecast (MAG4) (output is available at the Community Coordinated Modeling Center) was conceived and designed to be a databased, all-clear forecasting system to support the operational goals of NASA's Space Radiation Analysis Group.

The MAG4 system automatically downloads near-real-time line-of-sight Helioseismic and Magnetic Imager (HMI) magnetograms on the Solar Dynamics Observatory (SDO) satellite, identifies active regions on the solar disk, measures a free-energy proxy, and then applies forecasting curves to convert the free-energy proxy into predicted event rates for X-class flares, M- and X-class flares, CMEs, fast CMEs, and solar energetic particle events (SPEs). The forecast curves themselves are derived from a sample of 40,000 magnetograms from 1,300 active region samples, observed by the Solar and Heliospheric Observatory Michelson Doppler Imager. Figure 1 is an example of MAG4 visual output.

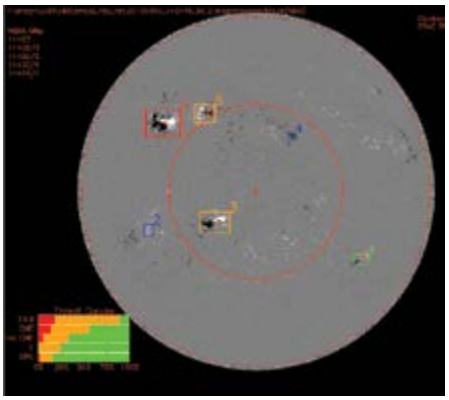

Figure 1: The graphical display of MAG4 forecast.

Each strong magnetic field area is outlined by a polygon. The polygon is color coded by threat level (green, yellow, and red, with blue showing strong magnetic field areas that do not belong to an active region). The full disk forecast with confidence levels (yellow bar) are shown graphically in the lower left. The particular date shown in figure 1 is a 'high threat day.' Figure 2 shows the same flare as seen by SDO/Atmospheric Imaging Assembly, the CME as seen by STEREO-B, and the resulting identifying SPE that the active region in the red box produced hours after the forecast. MAG4 also creates datasets that are used to further research and analysis, and to improve the forecast curves.

MAG4 free-energy proxy forecasts have been compared to forecasts using McIntosh categories, total magnetic flux, free-energy proxy, and previous flare activity. We have found that forecasts are best for active regions within 30 heliocentric degrees of disk center

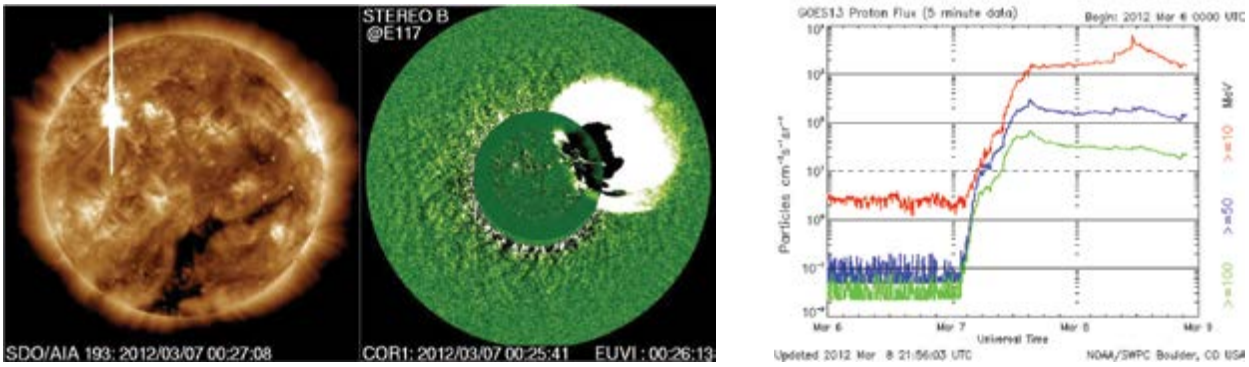

Figure 2: The flare, CME, and SPE that the upper-right active region in figure 1 produced.

when using both the free-energy proxy and previous flare activity. Figure 3 shows the difference of the Heidki Skill Score (HSS) both in standard deviations and in overall amount.

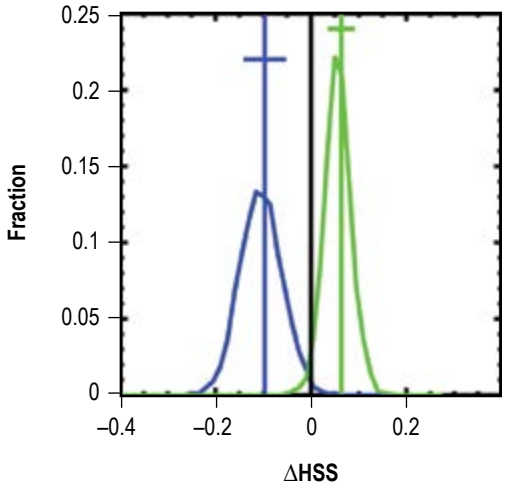

Figure 3: Plot showing clear improvement HSS in forecasts based on McIntosh system (blue relative to free-energy proxy alone), and free-energy proxy plus previous flare history (green relative to free-energy proxy alone). Each curve shows the results from 2,000 Monte Carlo runs, with the vertical bar being the average, and the horizontal bar being one standard deviation; the black line would be as good as free-energy proxy forecast only.

Anticipated Benefits

Anticipated benefits include improvements to forecasts, especially for active regions that are far from disk center. Due to projection effects, MAG4 measurements of active regions far from disk center from line-of-sight magnetograms are less accurate, and thus the forecasts are less certain that use of vector magnetograms will improve the forecasts.

Potential Applications

MAG4 can be incorporated into any operational forecasts to supplement or replace the McIntosh forecasts.

Notable Accomplishments

Forecasts based not just on the free-energy proxy but also using previous flare history were implemented in FY 2014 (Falconer, 2014). During FY 2015, the MAG4 project has begun deprojecting HMI vector magnetograms. A pilot study was conducted that indicates the possibility of far side coronal imagers measuring the total magnetic flux of far side active regions, and thus a predicted event rate.

References

Falconer, D.A.; Barghouty, A.F.; Khazanov, I.; and Moore, R.L.: "A tool for empirical forecasting of major flares, coronal mass ejections, and solar particle events from a proxy of active-region free magnetic energy," *Space Weather,* Vol. 9, No. 4, 2011.

Falconer, D.A.; Moore, R.L.; Barghouty, A.F.; and Khazanov, I.: "Prior flaring as a complement to free magnetic energy for forecasting solar eruptions," *Astrophys. J.*, Vol. 757, No. 1, pp. 32, 2012.

Falconer, D.A.; Moore, R.L.; Barghouty, A.F.; and Khazanov, I.: "MAG4 versus alternative techniques for forecasting active region flare productivity," *Space Weather*, Vol. 12, No. 5, pp. 306–317, 2014.

McIntosh, P.S.: "The classification of sunspot groups," *Sol. Phys*., Vol. 125, pp. 251–267, 1990.