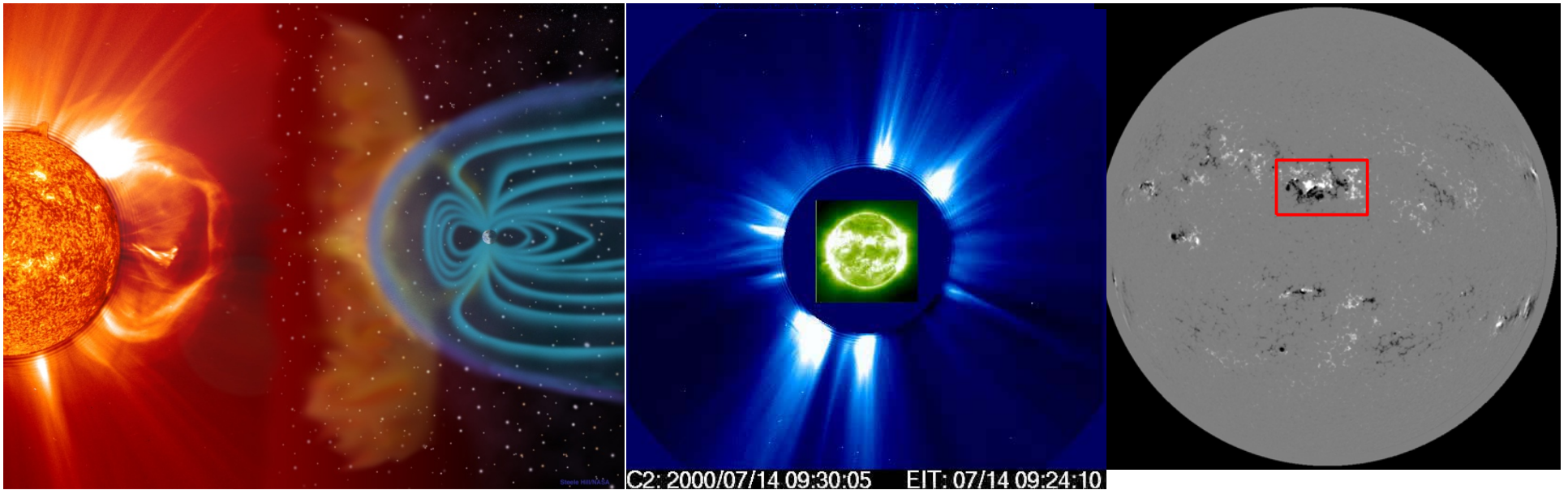


Forecasting the Solar Drivers of Severe Space Weather from Active-Region Magnetograms and Recent Flare Activity

David A. Falconer (UAHuntsville/MSFC), Ronald L. Moore(MSFC),
Abdulnasser F. Barghouty(MSFC), and Igor Khazanov(UAHuntsville)



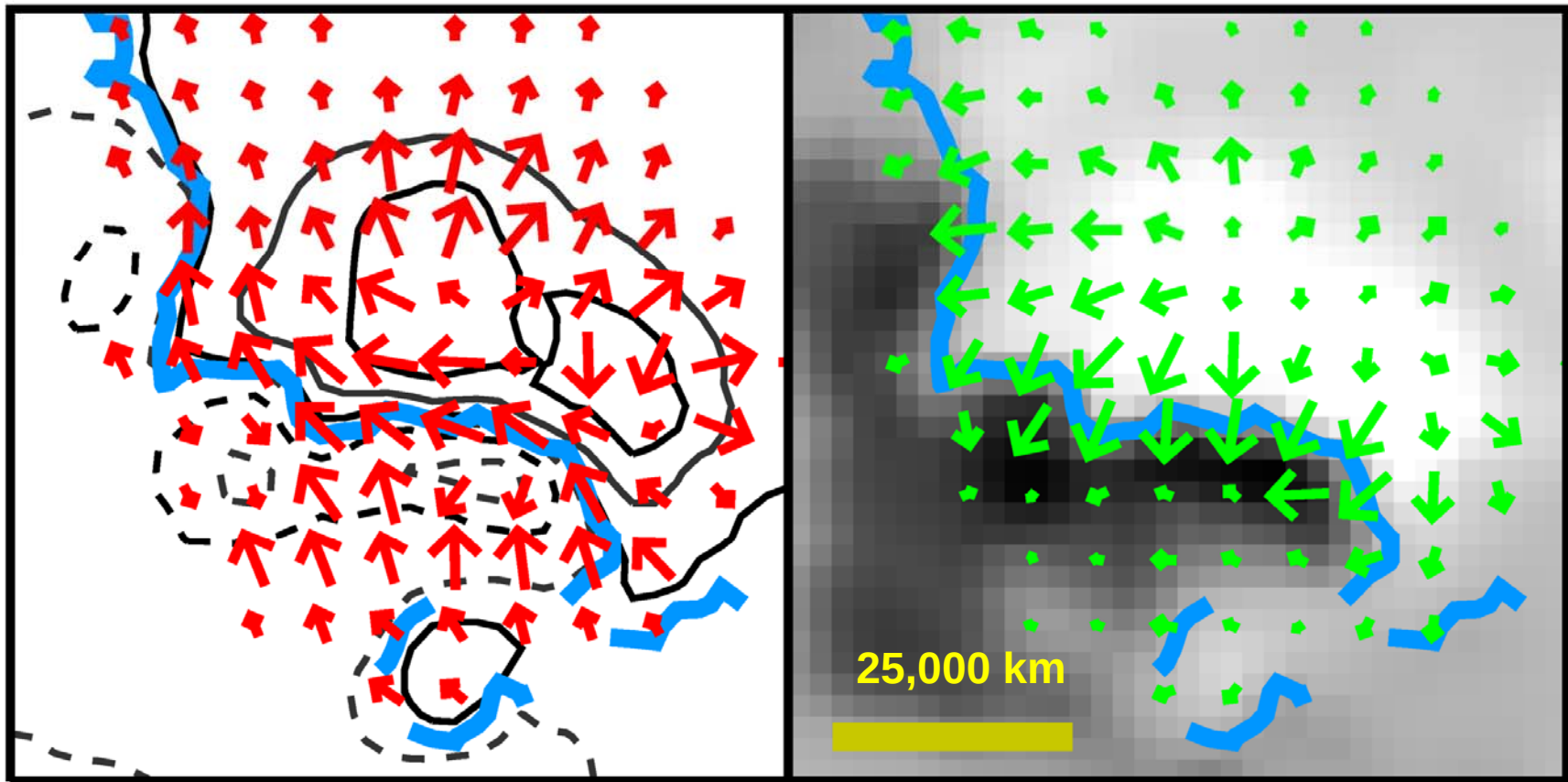
Our Main Finding:

New empirical evidence shows that, in addition to depending strongly on the free magnetic energy, an active region's chance of having a major eruption depends strongly on other aspects of the evolving magnetic field (e.g., its complexity and flux emergence).

Overview

- Describe the free-energy proxy
- Show the free-energy forecast curves for major flares and fast CMEs
- Show forecast curves for active regions that have recently produced X and M class flares

MSFC Vector Magnetogram of δ -Sunspot Source Region of a Major CME/Flare Eruption (2000 June 6)



An active-region field's horizontal shear is concentrated along neutral lines where the field's horizontal component is strong and the vertical component's horizontal gradient is steep.

Observed-field upward (downward) vert. comp. is shown by solid contours or light shading (dashed contours or dark shading); red arrows show observed hor. comp. ; green arrows show hor. comp. of pot. field computed from obs. vert. comp. ; strong-observed-field ($>150\text{G}$) intervals of neutral lines are blue.

Free-energy proxy from vertical-field component of vector magnetogram or from line-of-sight magnetogram:

- Active-region field's free energy is concentrated in horizontal shear along neutral-lines intervals on which the horizontal component is strong and the vertical component's horizontal gradient is steep.

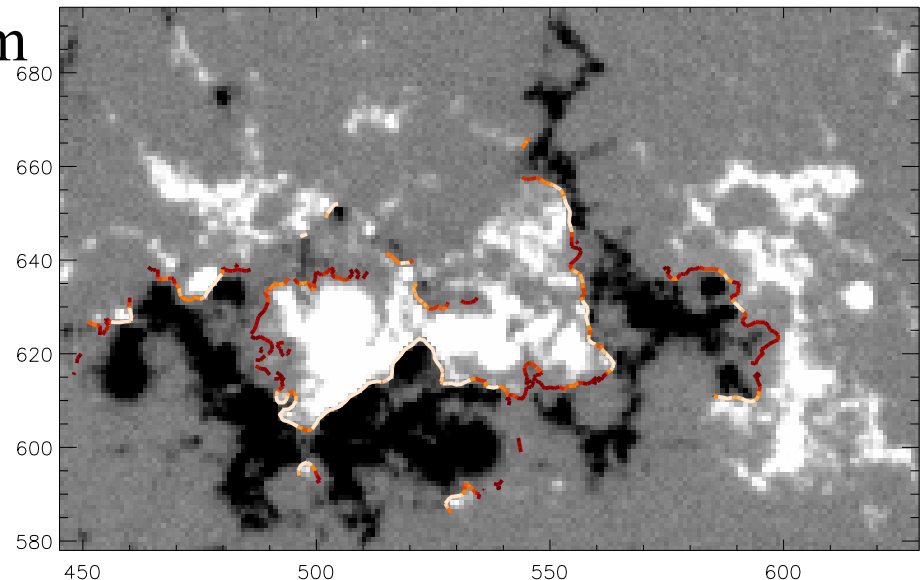
- Deprojected vector magnetogram version

$$WL_{SG} = \int (\nabla B_z) dl$$

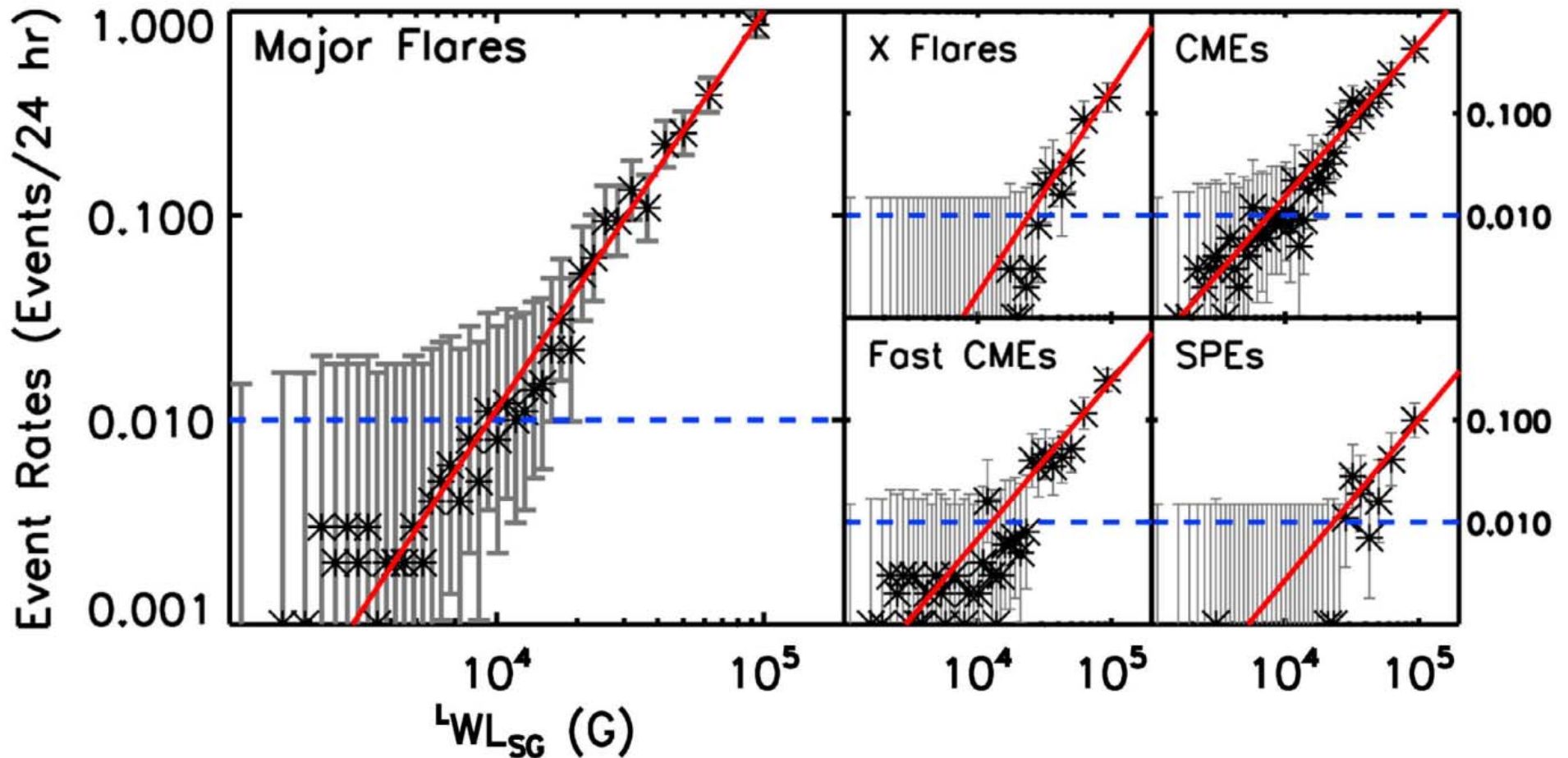
or line-of-sight approximation

$$^LWL_{SG} = \int (\nabla B_{LOS}) dl.$$

integration is along strong-field intervals of the AR neutral lines.

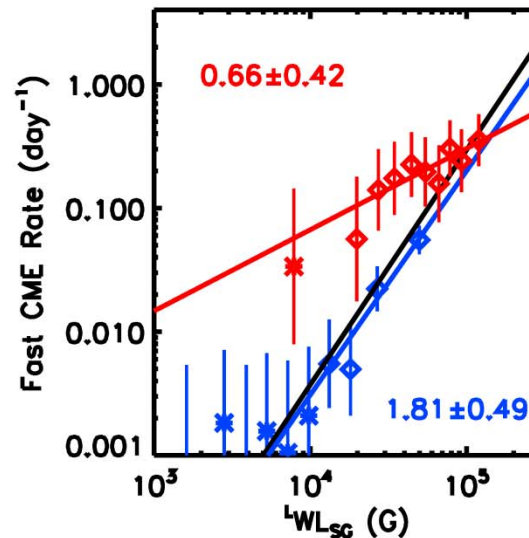
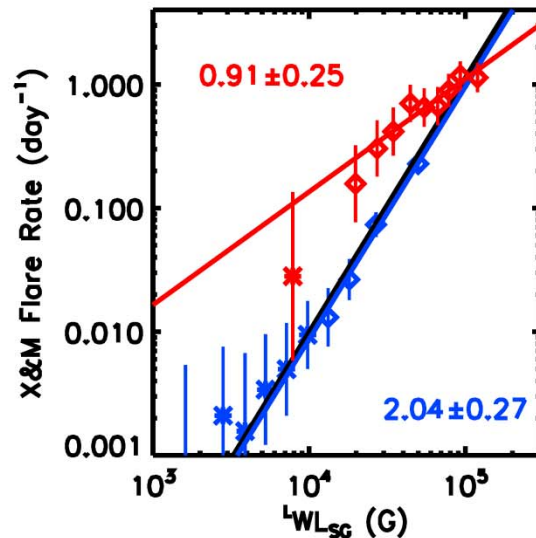
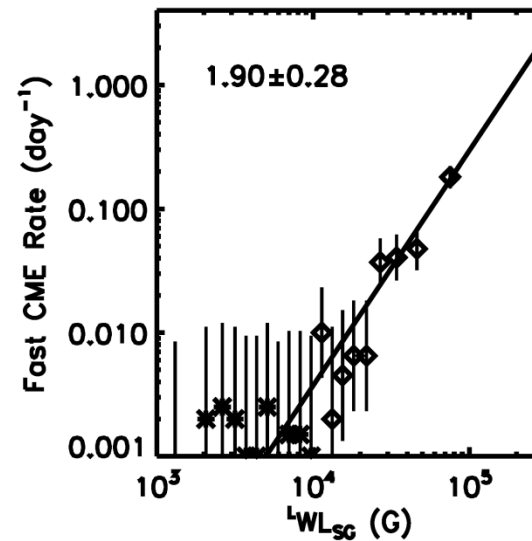
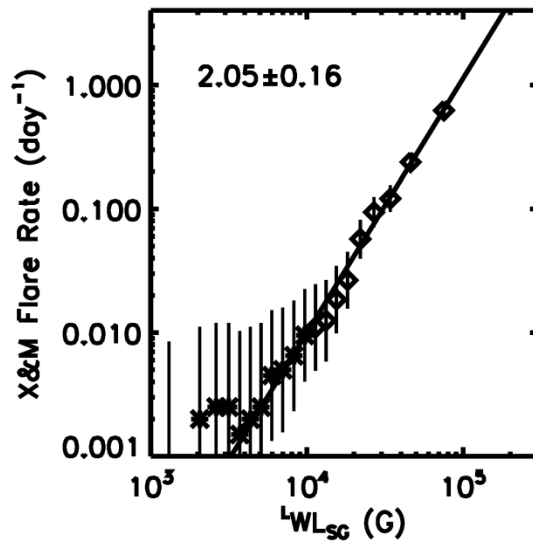


Forecast Curves (Ignoring Prior Flaring)



Only active regions that have a large free energy are likely to produce major events in the next 24 hours.

Prior Flaring is Partly Separate from Free Energy as a Predictor of an Active Region CME/Flare Productivity



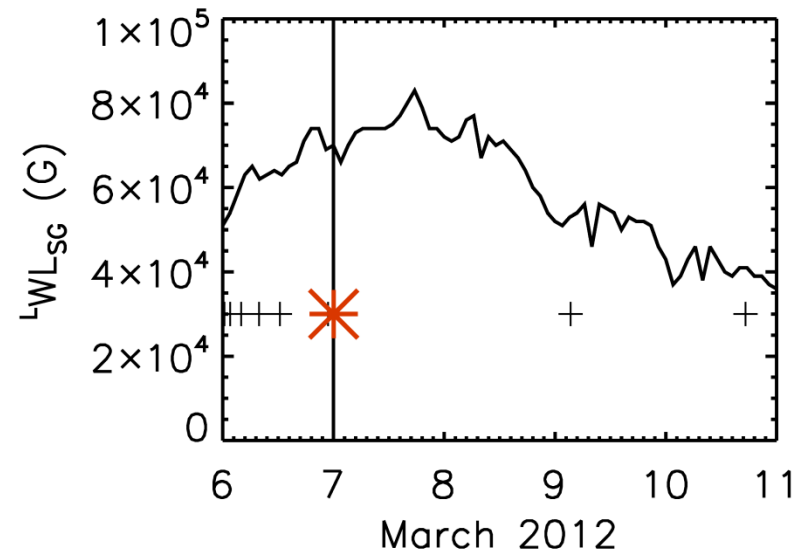
Free Energy Only —

Recently Flaring —

Recently Non-flaring —

Forecast of March 7 X-Flare/SEP Eruption

- **Top panel:** Free Energy proxy level and evolution.

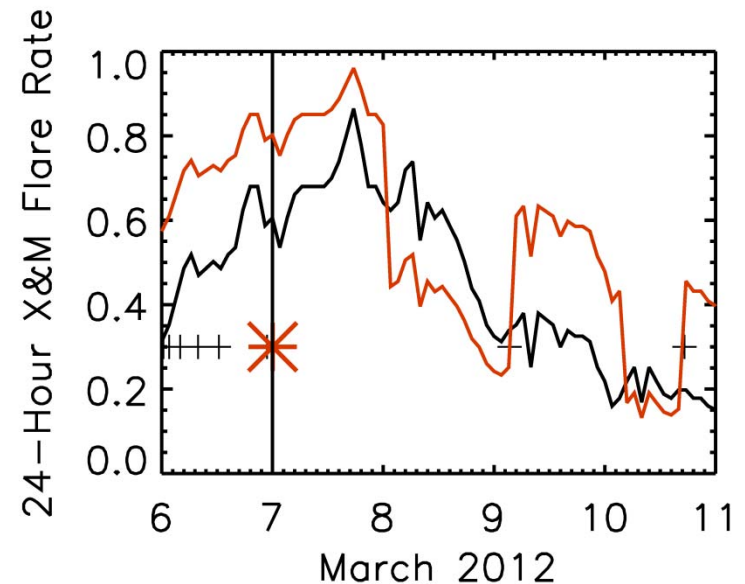


- **Lower Panel:** Forecast M&X flare rate

- Forecast using free-energy proxy only
- Forecast using Free-energy proxy and previous Flare History

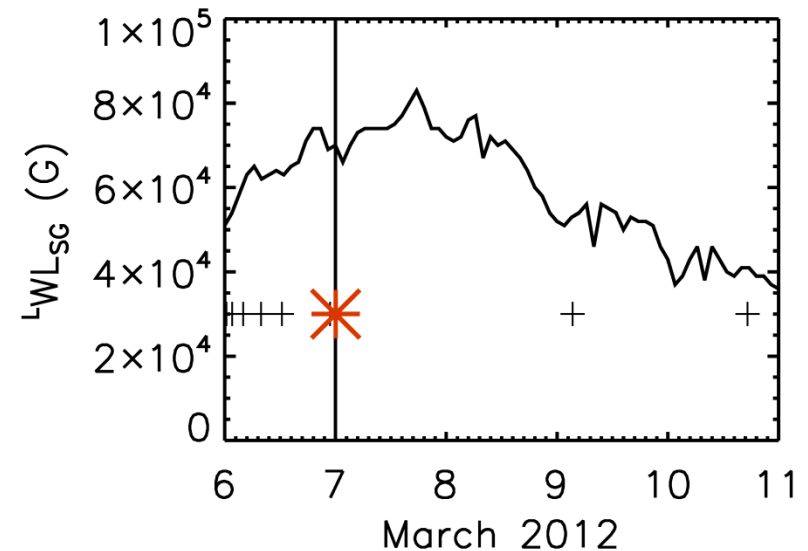
- **Symbols**

- + M-class Flares
- * X-class Flare & SEP



In Addition to Free-Energy, Something else that Persists on Periods of Days must be an Important Factor

- Free-energy level of an active region persists over a timescale of days!
- This persistence might have explained why previous flare activity is a good predictor of future flare activity.
- But, after accounting for the free-energy proxy, prior flaring still has, additional predictive ability.
- **This shows that some other persistent factors must also play a role in causing eruptions.**



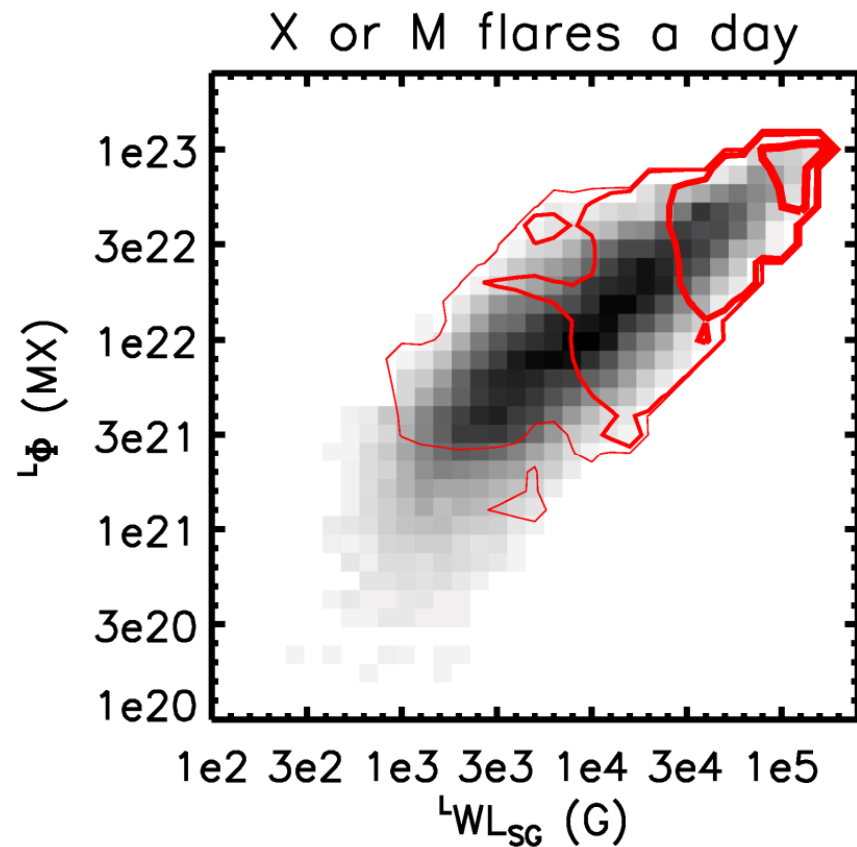
Next Step: Find the additional Factors

- Study active regions that have similar values of the free-energy proxy.
- Identify which active regions are more flare productive and which active regions are less productive.
- Determined what factors differ between the two subsets
 - (not total magnetic flux/active region size)
 - Evolution
 - Complexity

Backup Slides

Flux Content is Not an Important Additional Determinant

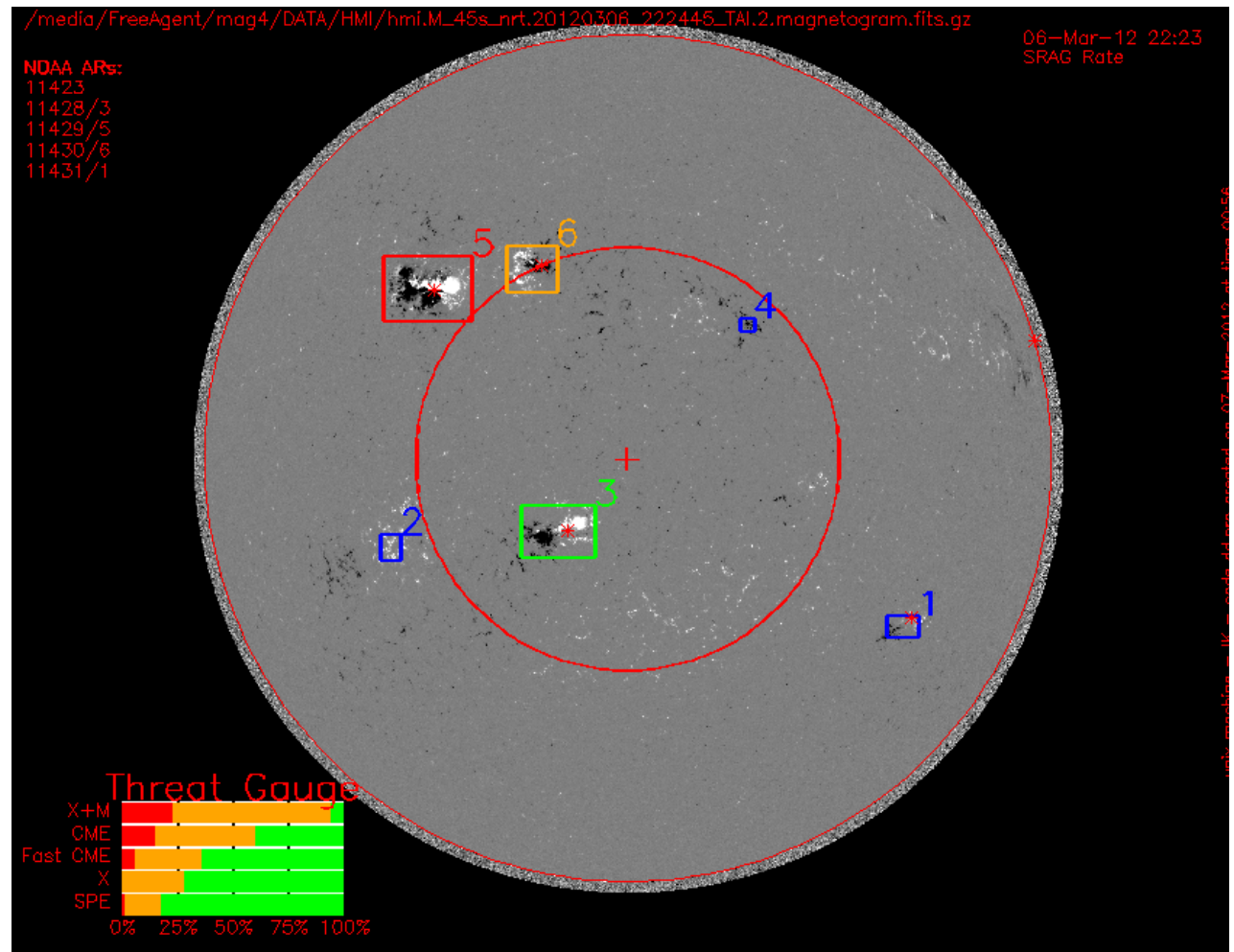
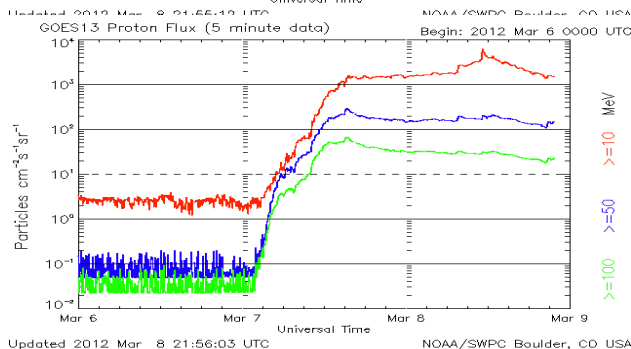
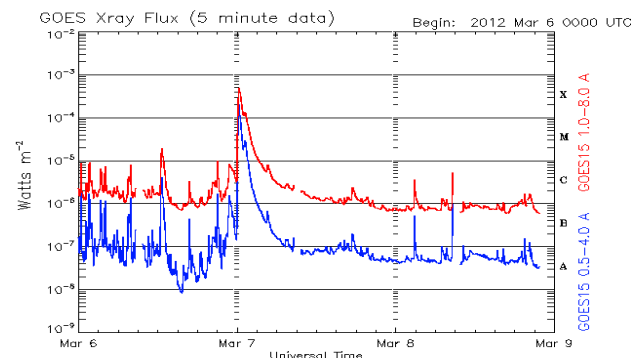
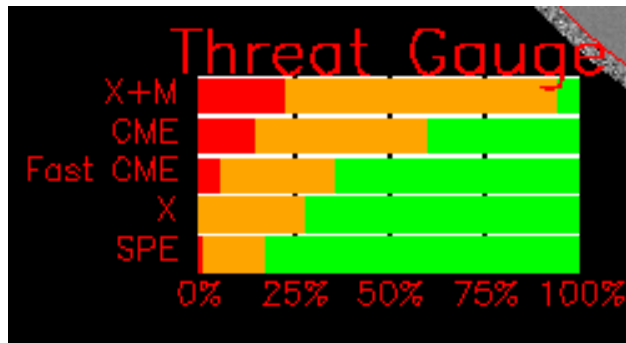
Gray scale plot shows free energy/magnetic size distribution of 40,000 magnetograms of 1,300 active regions. Red contours are 0.001, 0.01, and 0.1, and 0.5 event/day levels.



SRAG MAG4 Forecast Tool

Example Display (March 6, 2012)

- Active region in upper-left corner produced the March 7 Solar Energetic particle event and geo-effective CME



Backup

SRAG MAG4 Tool Forecast Before X5 Flare

2012/03/06 22:23

#	AR#	WL!DSG!N	Lng	Lat	24 Hour Event Rate					Dist
		(kG)	(deg)		M&X	CME	FCME	X	SPE	(deg)
3	11428	8	-21	-17	0.010	0.020	0.007	0.002	0.003	27
5	11429	69	-41	17	0.800	0.400	0.200	0.100	0.090	44!
6	11430	14	-25	20	0.040	0.040	0.020	0.006	0.007	32!
Disk Forecast Rates					0.900	0.500	0.200	0.100	0.100	
Multiplicative Uncertainties					2.7x	2.1x	2.3x	3.0x	2.5x	
Disk All-Clear Forecast Probabilities					40.00%	60.00%	80.00%	90.00%	91.00%	
Uncertainties					40.00%	20.00%	10.00%	10.00%	8.00%	