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

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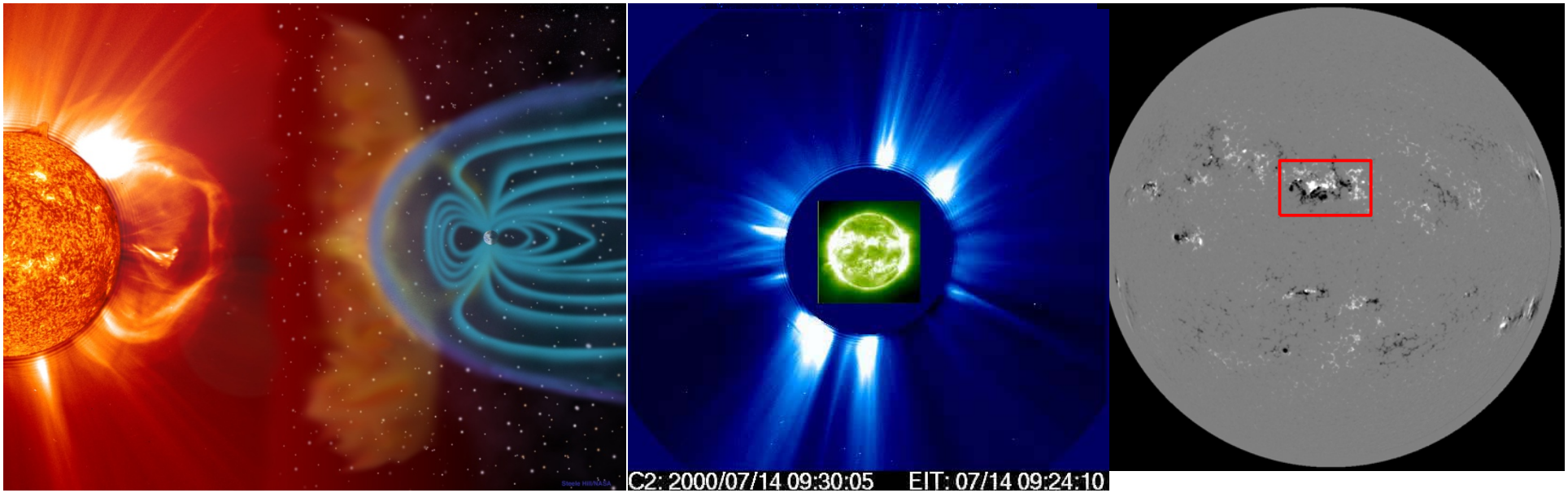


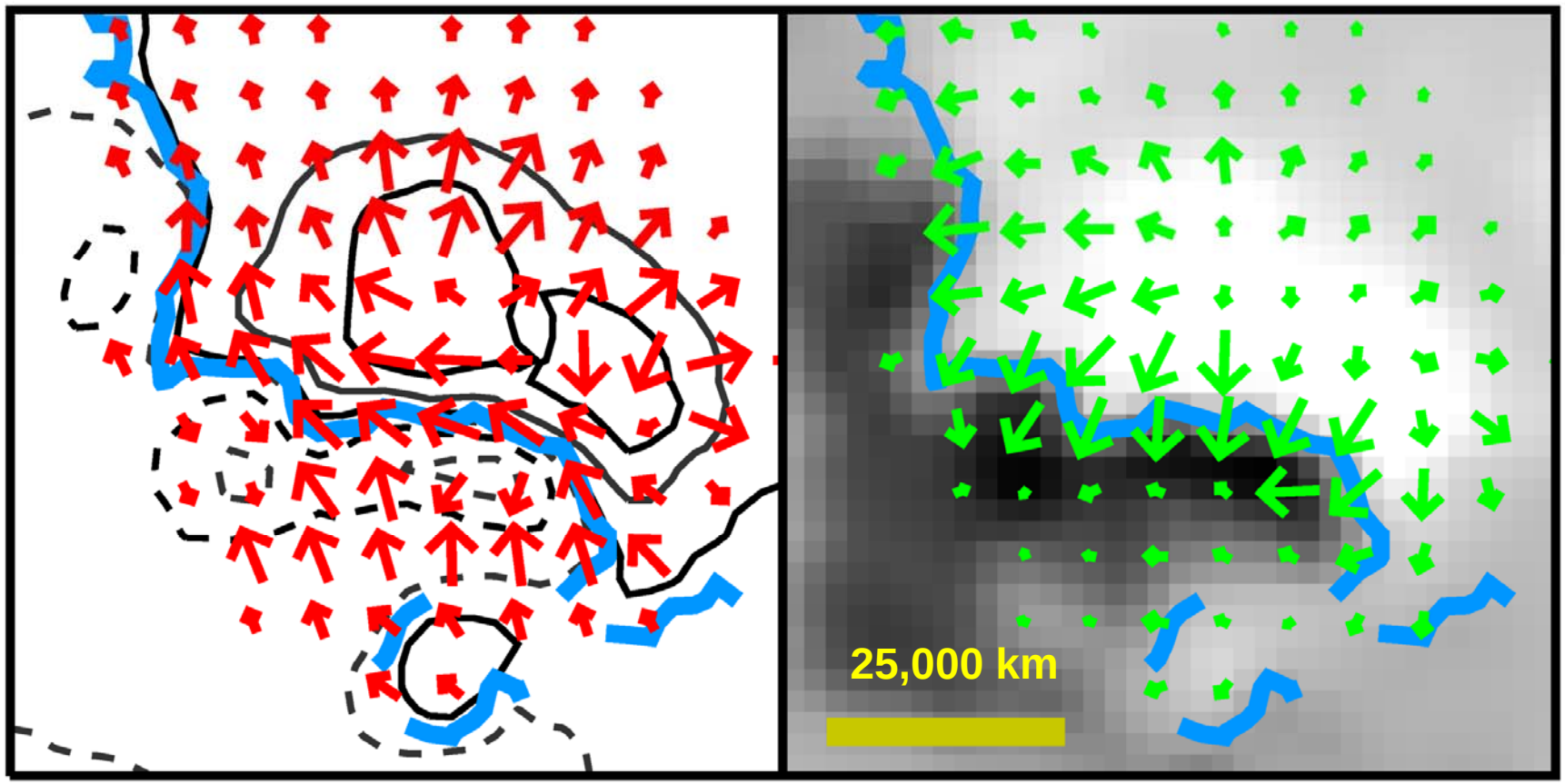
Our Main Finding:

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 (>150G) 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.

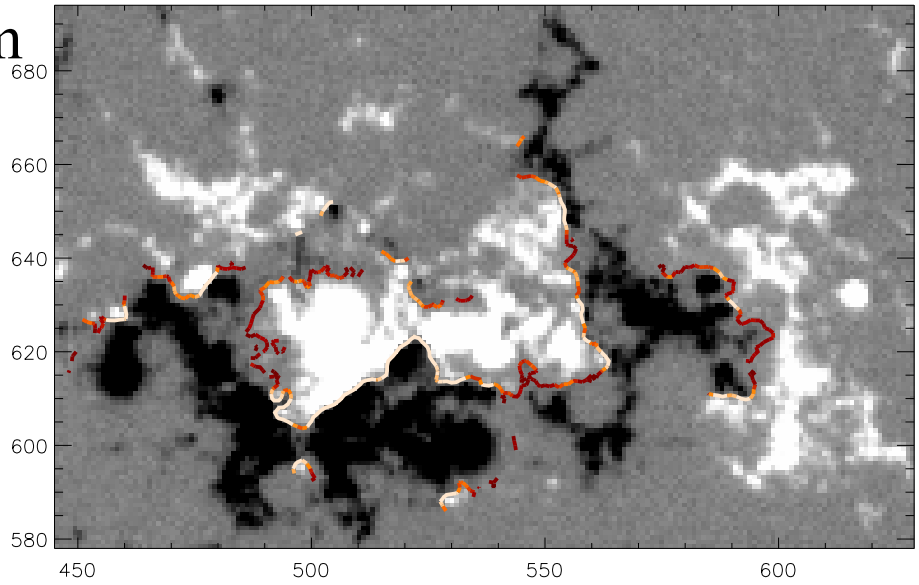
- Deprojected vector magnetogram version

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

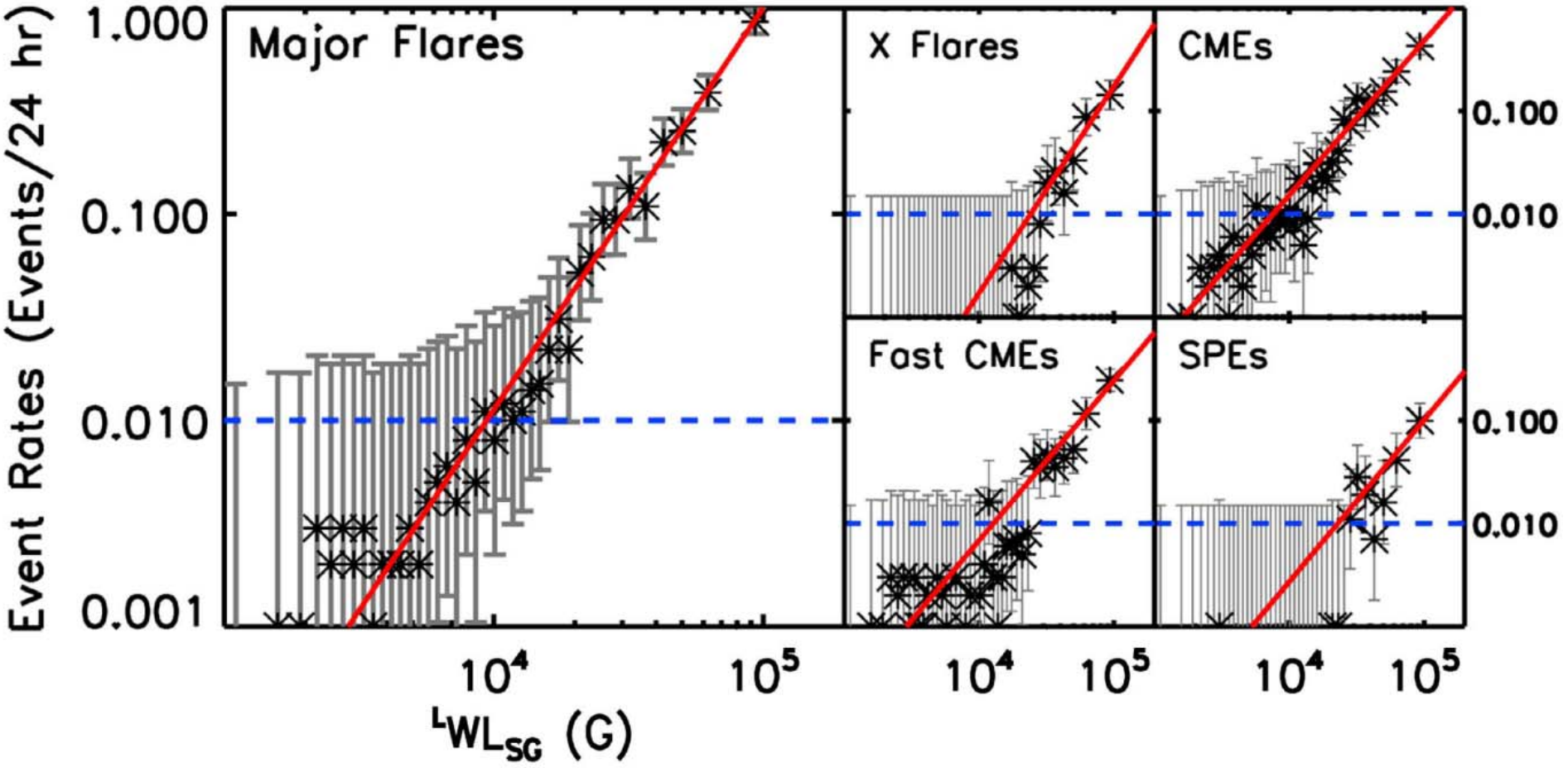
or line-of-sight approximation

$$\mathbf{^{L}WL_{SG}=\int(\nabla B_{LOS})dl}.$$

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

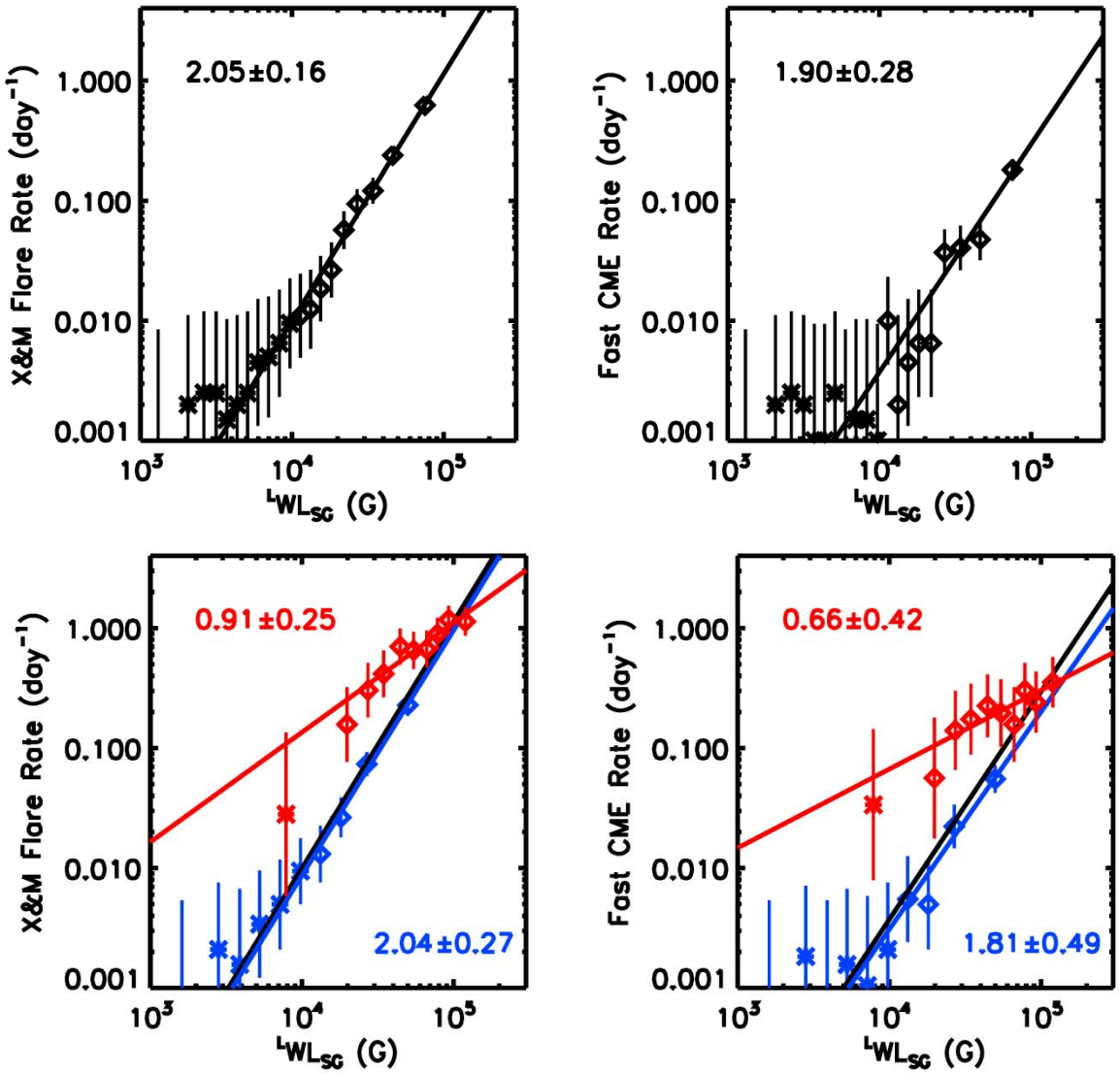


Forecast Curves (Ignoring Prior Flaring)



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



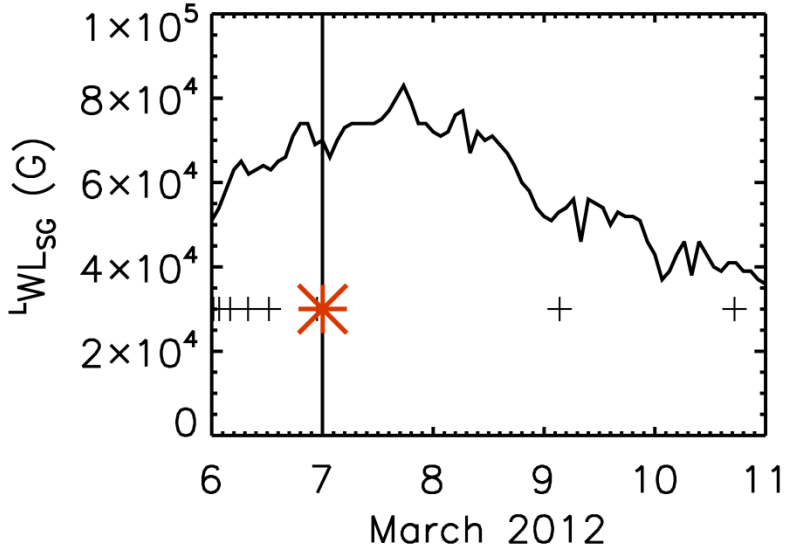
Free Energy Only

Recently Flaring

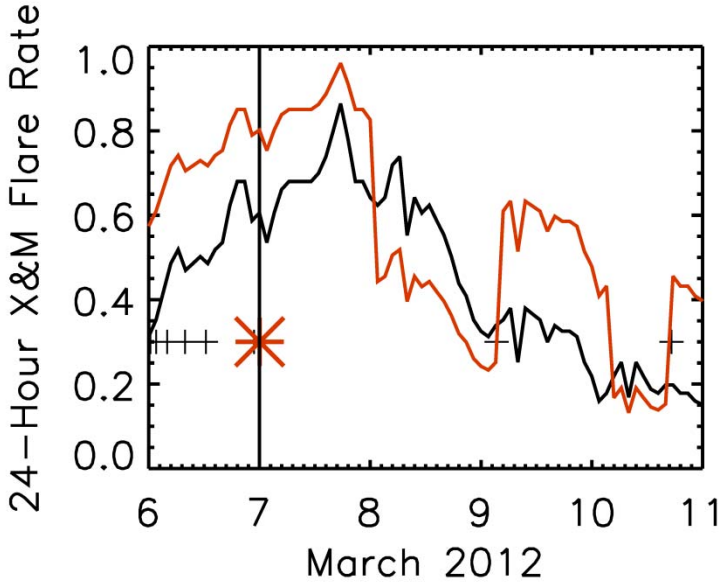
Recently Non-flaring

Forecast of March 7 X-Flare/SEP Eruption

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



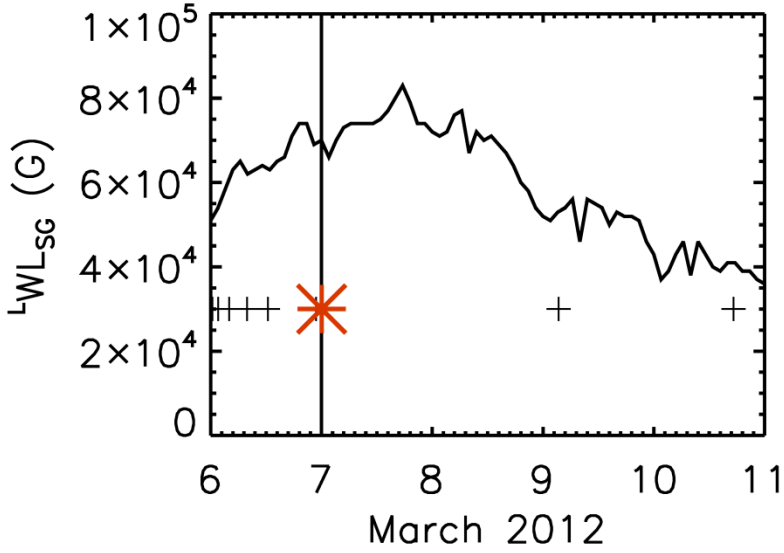
- **Lower Panel:** Forecast M&X flare rate
  - Forecast using free-energy proxy only
  - Forecast using Free-energy proxy and previous Flare History



- **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.**

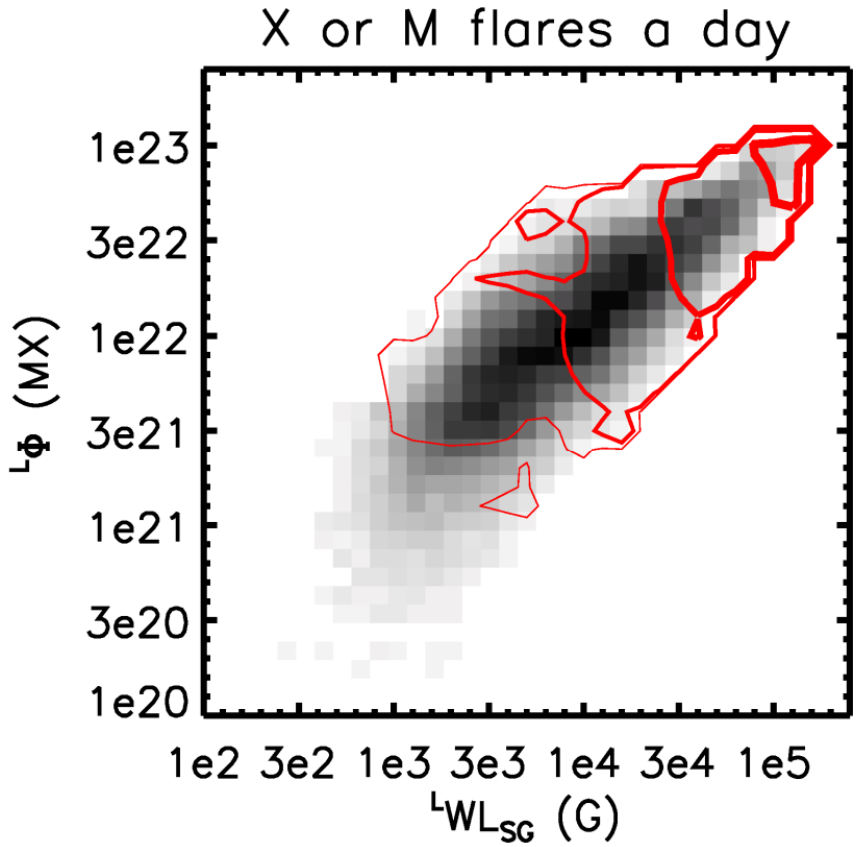
Next Step: Find the additional Factors

- Study active regions that have similar values of the free-energy proxy.
- Indentify 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

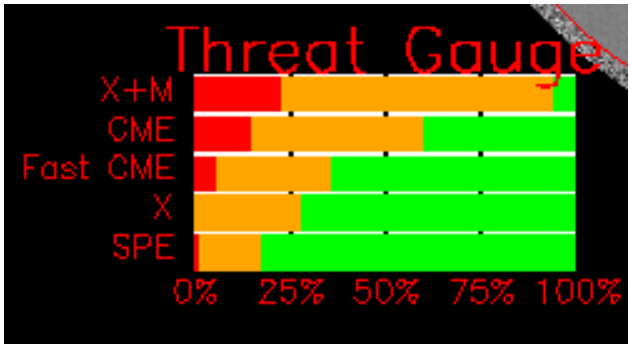
Gray scale plot shows free energy/magnetic size distribution of 40,000 magnetograms of 1,300 active regions. Red contours are 0.001, 0.01, and 0.1, and 0.5 event/day levels.

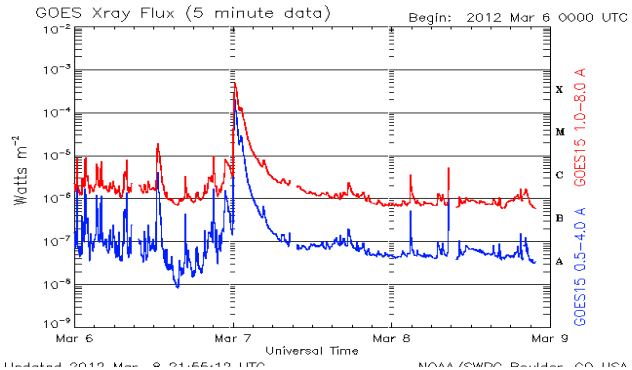


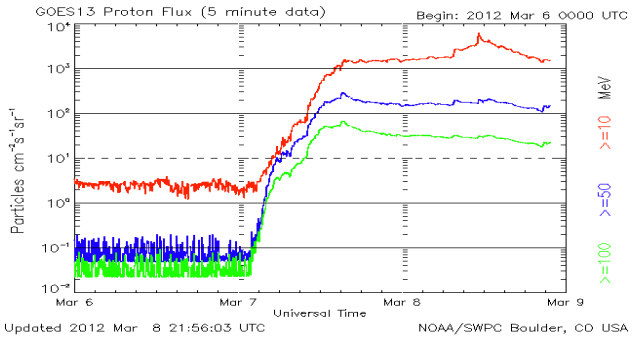
SRAG MAG4 Forecast Tool

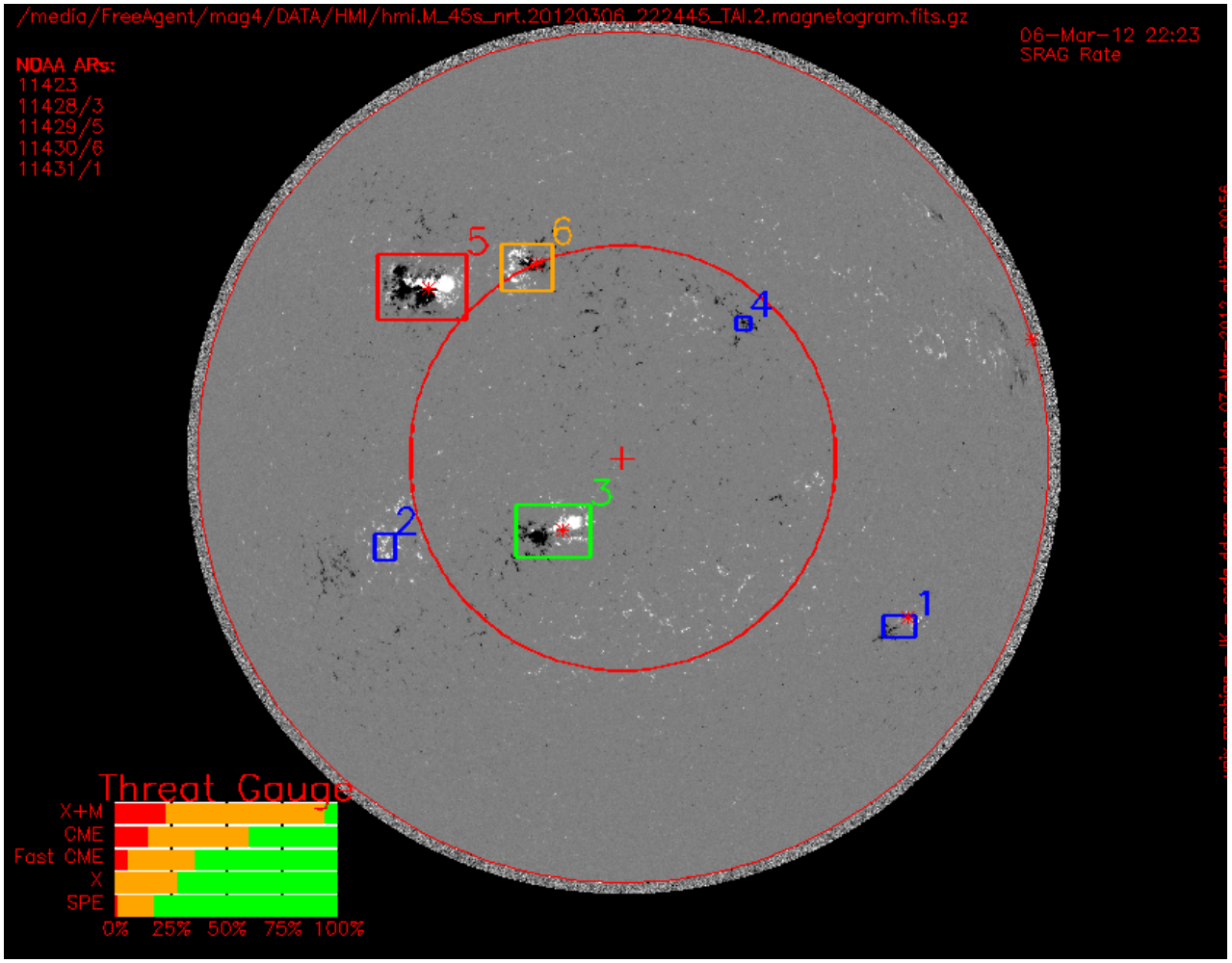
Example Display (March 6, 2012)

- 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 (kG)	Lng (deg)	Lat	24 Hour Event Rate M&X	CME	FCME	X	SPE	Dist (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%	