MAG4

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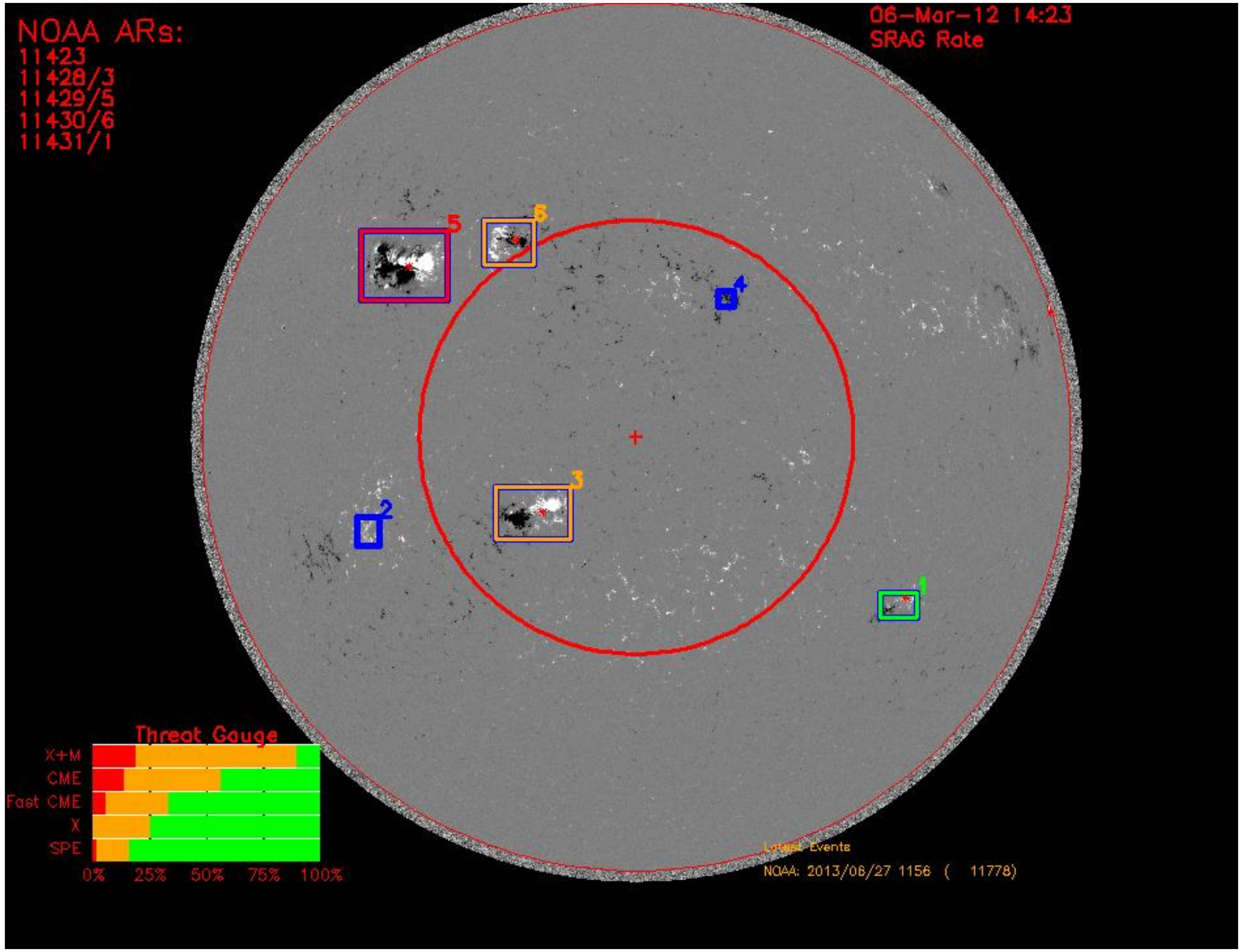


Comparison of Safe and Not Safe Days

June 26, 2013

C1, C1.5 flares

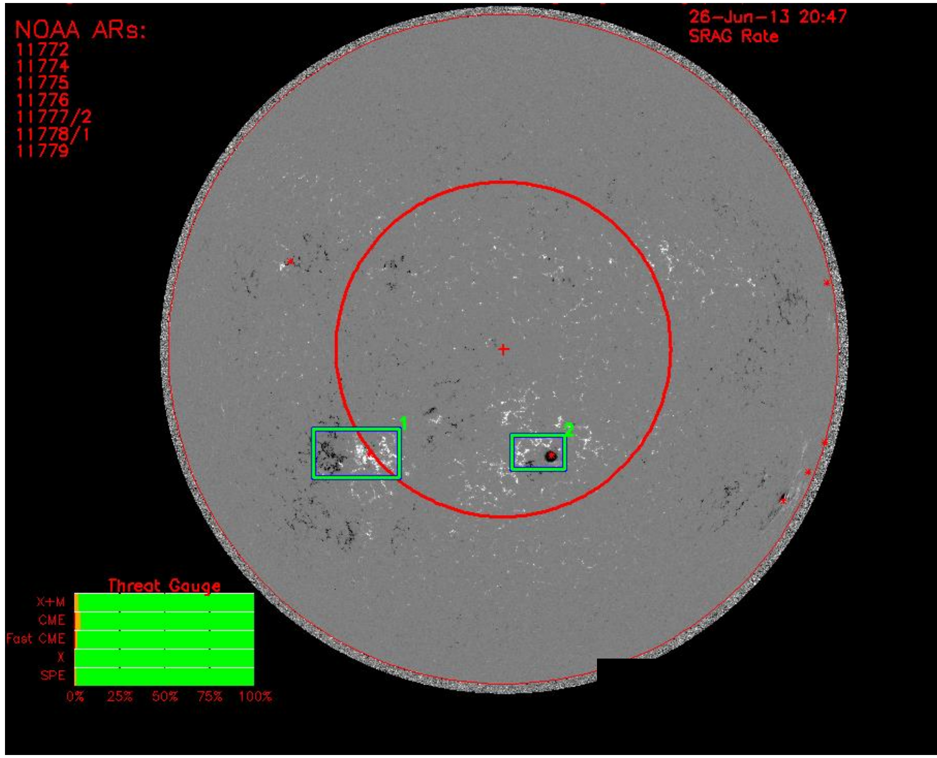
March 7, 2012

X5.4, X1.3, C1.6

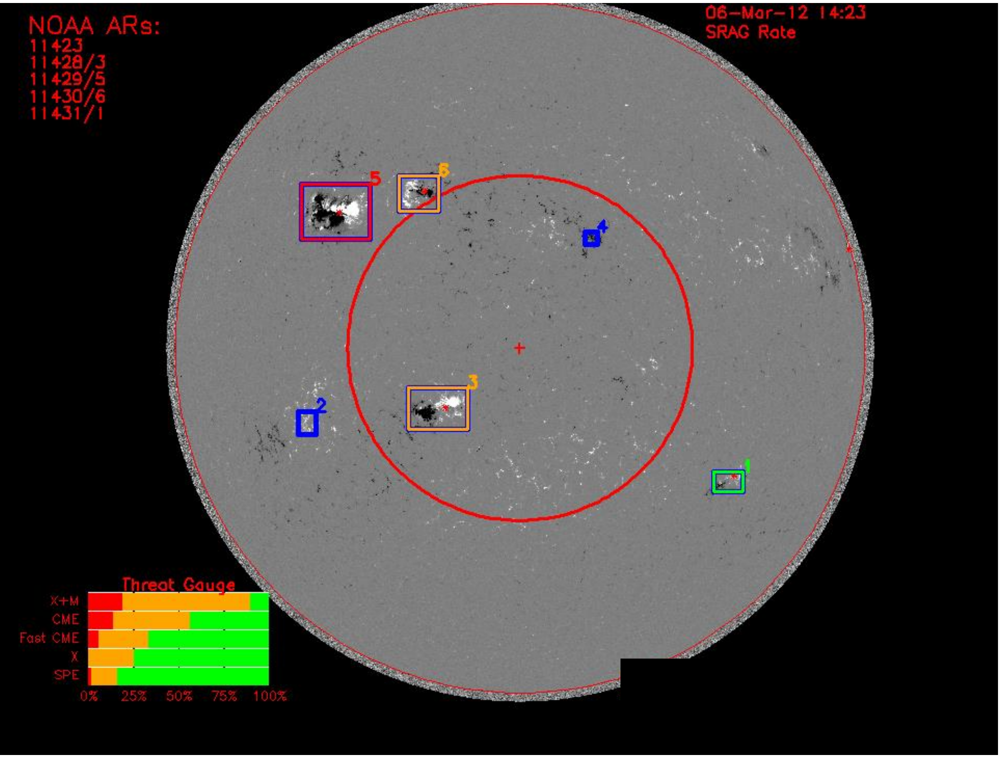
CME 2684, 1825 km/sec,

Solar Energetic Proton Event reaches 6530 particle flux unit >10MeV

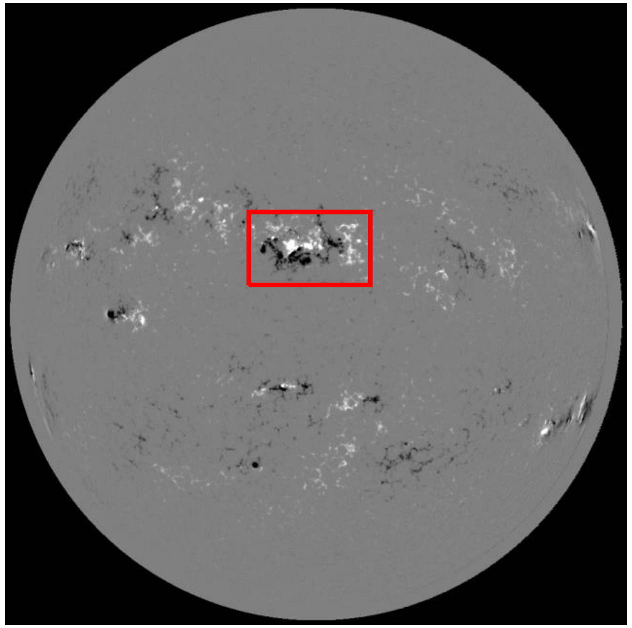
All Clear

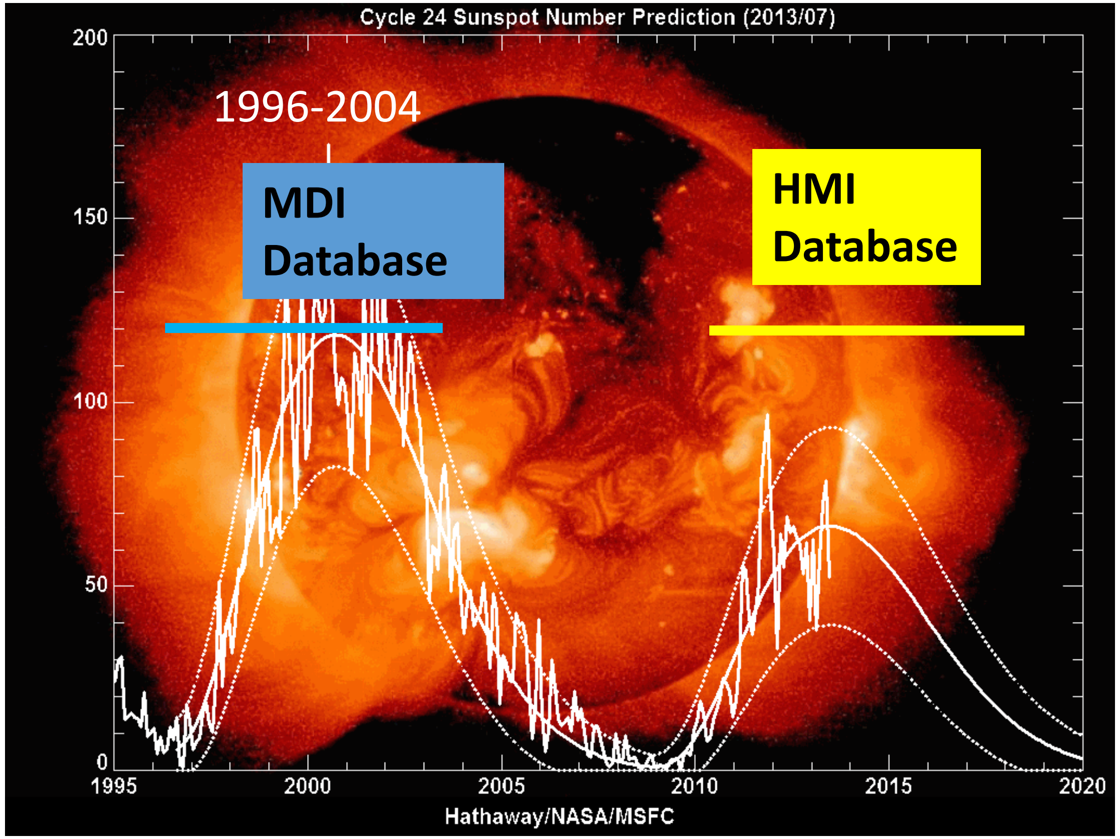


High Threat



Our Forecasting Database of MDI Magnetograms





MDI Sample
1996-2004

40,000 Active-Region Magnetograms
1,300 Active Regions

HMI Sample 2010-

Definition of Magnetic Paramaters

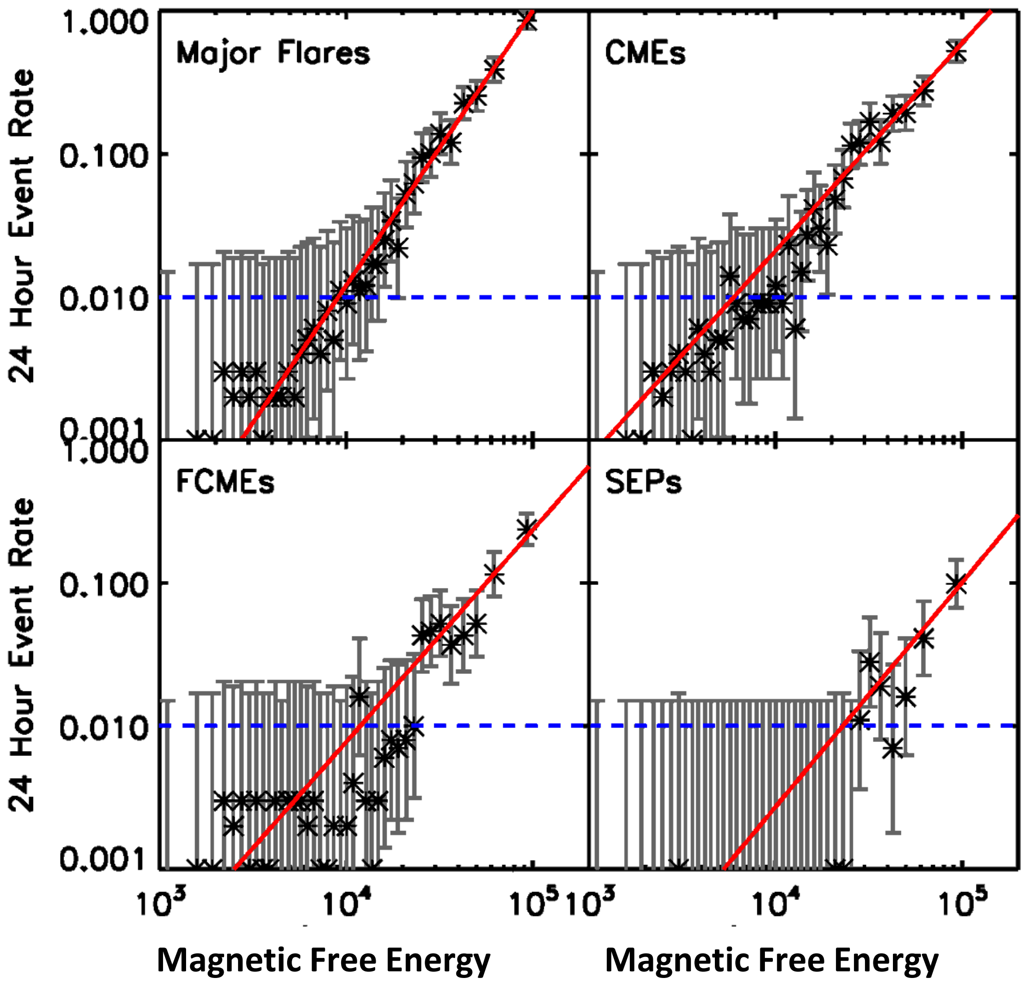
Equation	Name	Integral
• $\Phi = \int \lvert B_Z \rvert da$	Total Magnetic Flux	$\lvert B_Z \rvert > 100$ G
• $A = \int da$	Magnetic Area	$\lvert B_Z \rvert > 100$ G
• **$WL_{SGP} = \int \lvert \nabla B_Z \rvert^p dl$**	**Gradient-Weighted Neutral-Line Length**	**$pB_H > 150$ G**
• $WL_{SS} = \int \lvert \theta \rvert dl$	Shear-Weighted Neutral-Line Length	$pB_H > 150$ G
• R	Schrijver's R (Schrijver 2007))	
• $\alpha_g = \dfrac{\sum \left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y} \right) B_z}{\sum B_z^2}$	B_Z-weighted Magnetic Twist (Tiwari et al 2009)	

Plus several other magnetic parameters

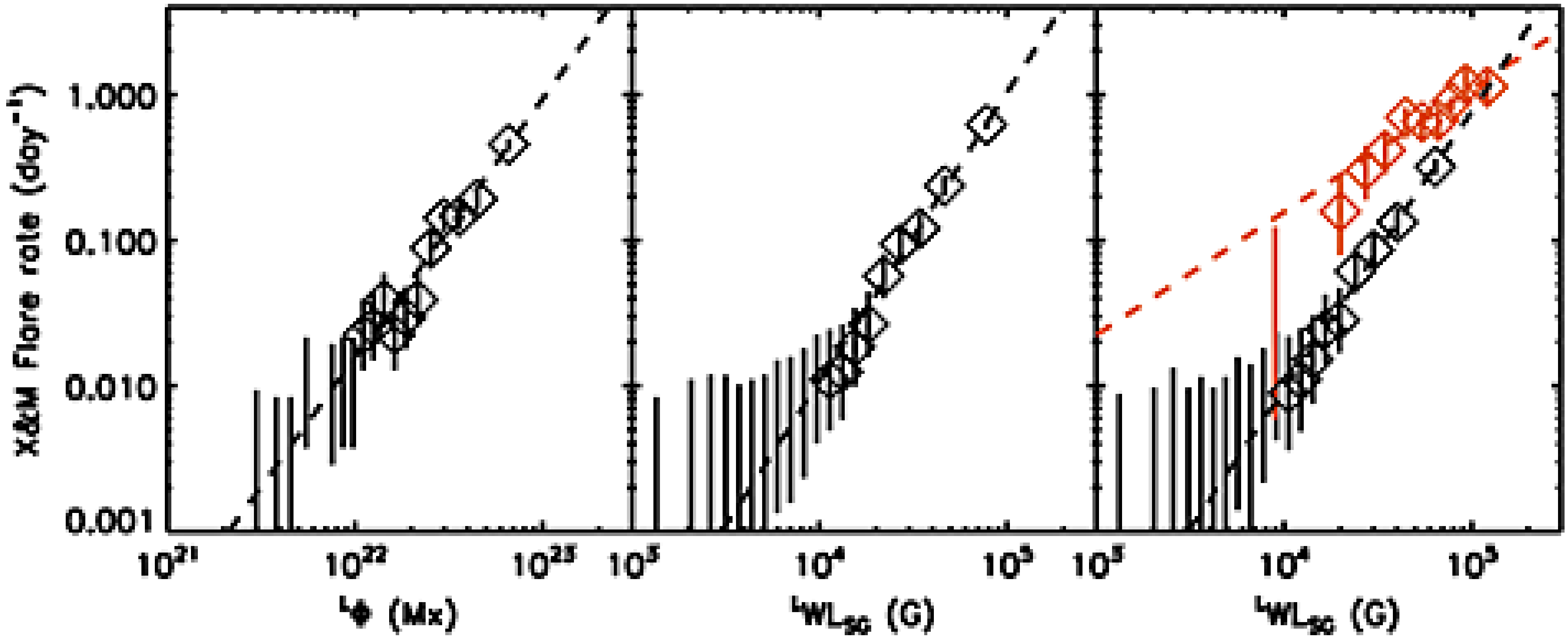
- pB_H potential horizontal field
- B_Z Vertical magnetic field
- θ The angle between the potential and observed transverse field

Space Weather Forecasting Curves

- Have found a power-law relationship between our gauge of the free magnetic energy and event rate.
- This occurs for major flares, CMEs, Fast CMEs, and Solar Energetic Particle Events.
- By using this relationship, we can forecast the chance that an event, will be produced by a newly observed active region for which the free energy gauge is measured. (This method is like that for forecasting the chance of rain tomorrow.)

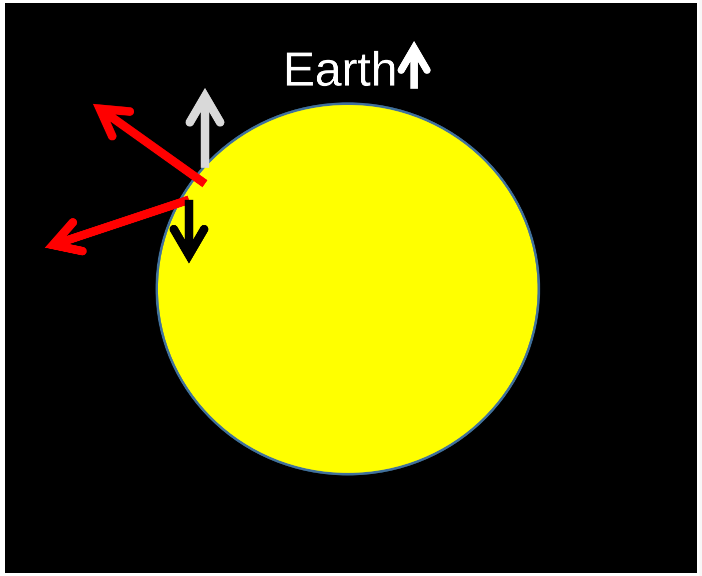


Forecasting Curves Free-Energy Proxy Alone
or Free-Energy Proxy and Prior Flaring



MAG4 Improvements: Vector Magnetograms

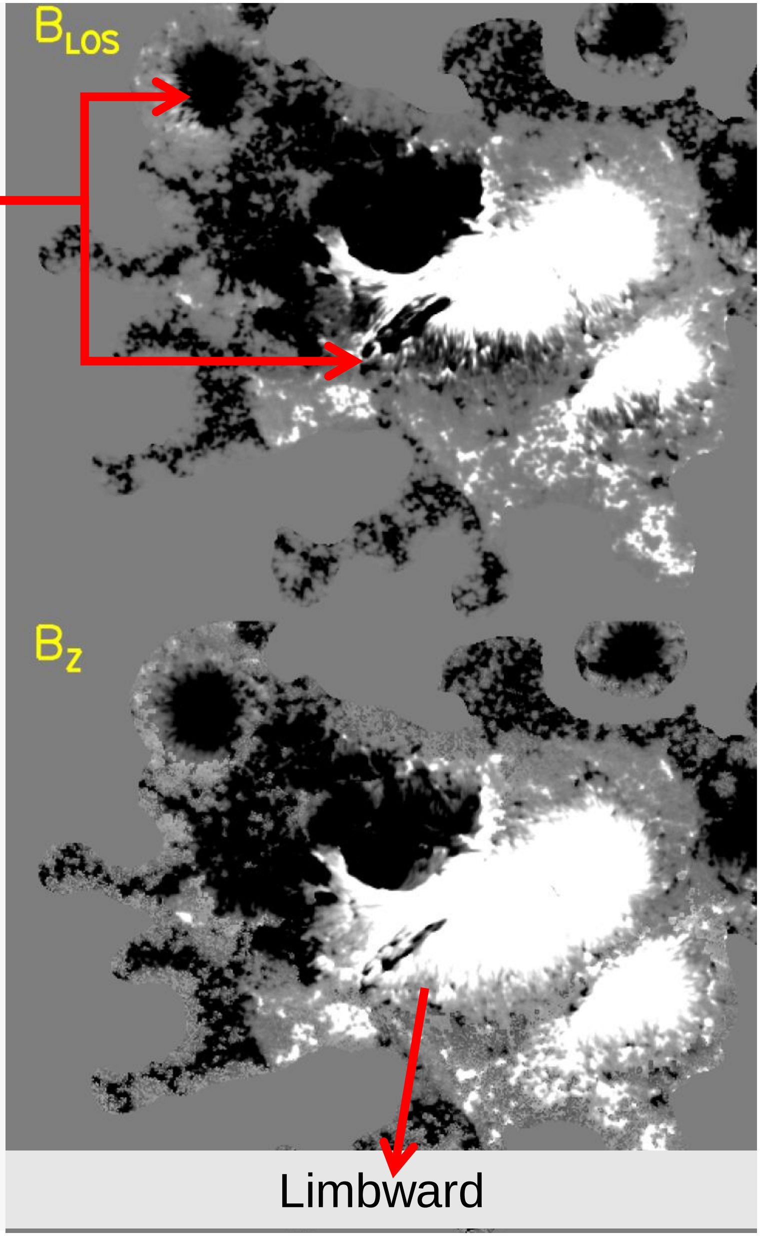
- Both vectors shown in red have positive B_z (magnetic field out of the sun), but have opposite sign B_{LOS} and thus a false (unphysical) neutral line in the line-of-sight (LOS) field.



Actual Examples

False Neutral Lines occur on limbward sides of sunspots.

Problem fixed by converting from B_{LOS} and $B_{Transverse}$ to B_Z and $B_{Horizontal}$



MAG4 Forecasting Modes

1. Free-energy Proxy Only using Line-of-Sight Magnetogram
2. Free-energy Proxy and Previous Flare History using Line-of-Sight Magnetograms
3. Free-energy Proxy Only using Deprojected HMI Vector Magnetogram
4. Free-energy Proxy and Previous Flare History using Deprojected HMI Vector Magnetograms

Outputs

```
 Vector WF=W+Flare        2016-01-04

  #   AR#    WL!DSG!N Lng  Lat              24 Hour Event Rate             Dist     HARP
                (kG)   (deg)          M&X    CME    FCME     X    SPE     (deg)
  3 12476         2   -33  -10         0.001  0.001  0.001  0.000  0.000    34!     6224
  1 12477         1   -47   12         0.000  0.000  0.000  0.000  0.000    48!     6223-1
  4 12478         7   -39    7         0.007  0.008  0.003  0.001  0.002    39!     6227
                    Disk Forecast Rates  0.009  0.010  0.005  0.001  0.002
           Multiplicative Uncertainties    3.4x   2.9x   3.2x   7.8x   6.4x
 Disk All-Clear Forecast Probabilities  99.10% 99.00% 99.50% 99.94% 99.80%
                          Uncertainties   1.00%  1.00%  0.50%  0.10%  0.40%
```

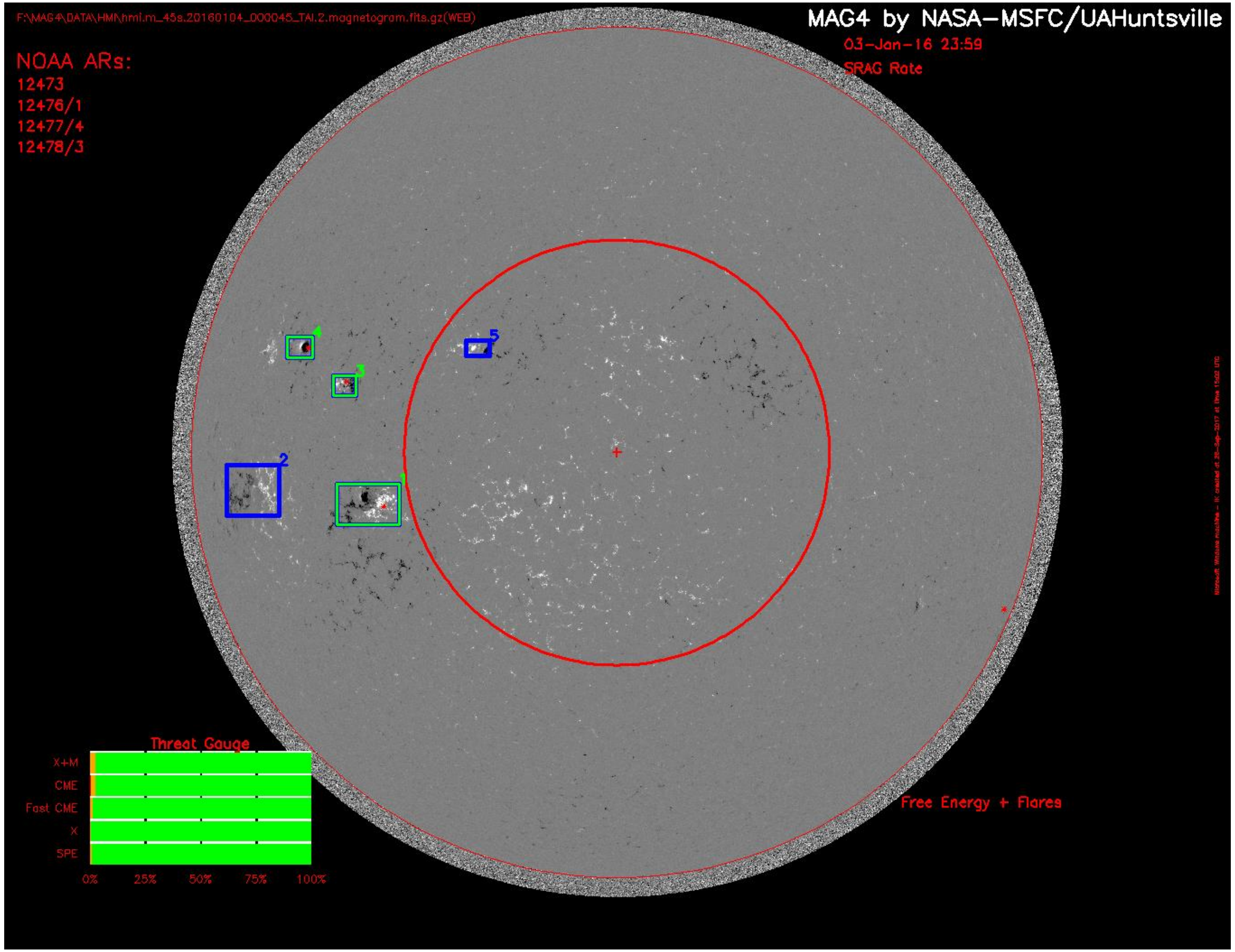
Outputs/Continued

Also an IDL save file is produced that lists the values of each magnetic parameter measured for each AR.

These save files create the HMI era database which can be used for

- O2R
- As inputs to other forecasting tools.
- To improve MAG4 forecasts

Threat Level Plot



Quantifying and Removing Projection Errors