Applying the NASA SPoRT R2O/O2R Paradigm to Space Weather: MAG4 Applications and Assessment at SWPC

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Short-term Prediction Research and Transition (SPoRT) Center

SPoRT is focused on transitioning <u>unique</u> NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

- o close collaboration with numerous WFOs and National Centers across the country
- o SPoRT activities began in 2002, first products to AWIPS in 2003
- o co-funded by NOAA since 2009 through satellite "proving ground" activities

Proven paradigm for transition of research and experimental data to "operations"
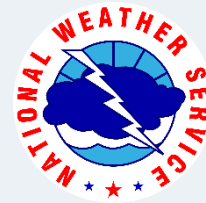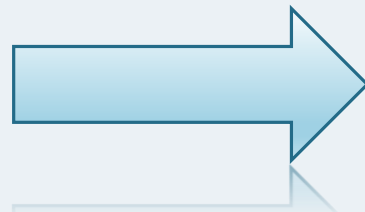
<u>**Benefit**</u>

- o demonstrate capability of NASA and NOAA experimental products to weather applications and societal benefit
- o prepares forecasters for use of data from next generation of operational satellites (JPSS, GOES-R)

NASA Missions and SPoRT Capabilities

Develop and transition/assimilate value-added products
- Terra, Aqua, S-NPP imager and sounder data prepared forecasters for GOES-R and JPSS
- GPM and SMAP fill critical atmospheric and land surface observation gaps

Engage with upcoming missions to leverage R2O/O2R expertise
- Early Adopters for ICESat-2, SWOT, and NISAR
- Science Team participation with ECOSTRESS, TEMPO, and TROPICS

SPoRT O2R/R2O

Match forecast problem with experimental products
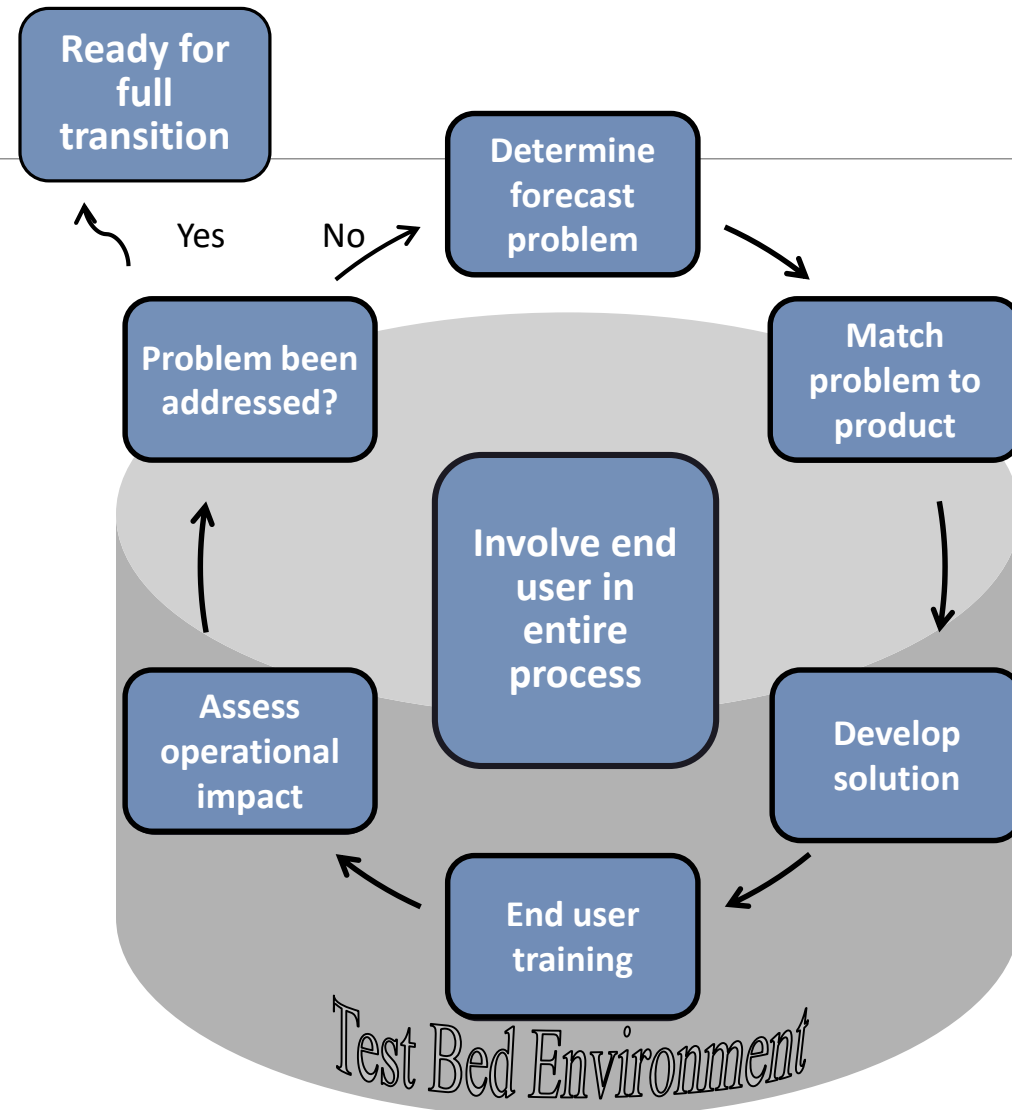
Provide multiple avenues of training
- Tele-training
- Online video and self-guided modules
- Quick Guides
- On-site training (when feasible)
- Wide World of SPoRT blog (peer-to-peer training)

Feedback given in online form, emails, calls, etc.

Trial (testbed)
- For experimental products
- Less intensive assessment

Reports and recommendations published at SPoRT website

Training

Goal: to provide applications-based training that is relatively quick to complete

~Self-paced training modules, Quick guide reference sheets, applications library items, in-person training, blog posts

Forecasters provide helpful feedback to improve training

http://weather.msfc.nasa.gov/sport/training/

Assessment Process

SPoRT Assessments

- Short (4-8 weeks) and intensive (aim for 1 survey per day)

- One or several products that meet similar needs

- Formal assessments preceded by formal teletraining, with product developers whenever possible, and access to training Quick Guides

- Forecasters often share insight during SPoRT partner calls

- Use of online form and email follow-ups to acquire actionable feedback for product developers

MAG4 Background

Near-realtime forecast tool to predict the 24 hour event rate of flares, CMEs, fast CMEs, and SPEs for active regions.

Output is probabilities (not necessarily timing/impact/magnitude)

Comprises a database of MDI/HMI magnetograms
- Approx. 40,000 active region magnetograms
- Approx. 1300 active regions

Forecasting curves (currently using MDI curves)
- Utilizes a power-law relationship between free magnetic energy proxy and event rate
  - Free energy proxy: integral of the gradient along the neutral line in an AR
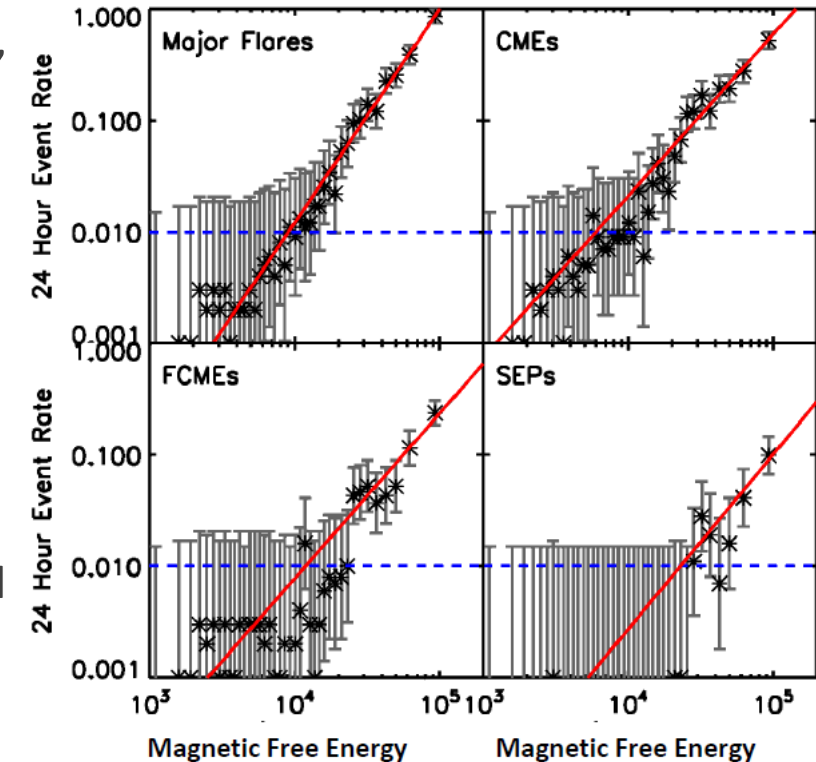
Using Prior Flare Activity

- Active regions that have recently produced an X- or M-class flare are more likely to produce flares in the near future
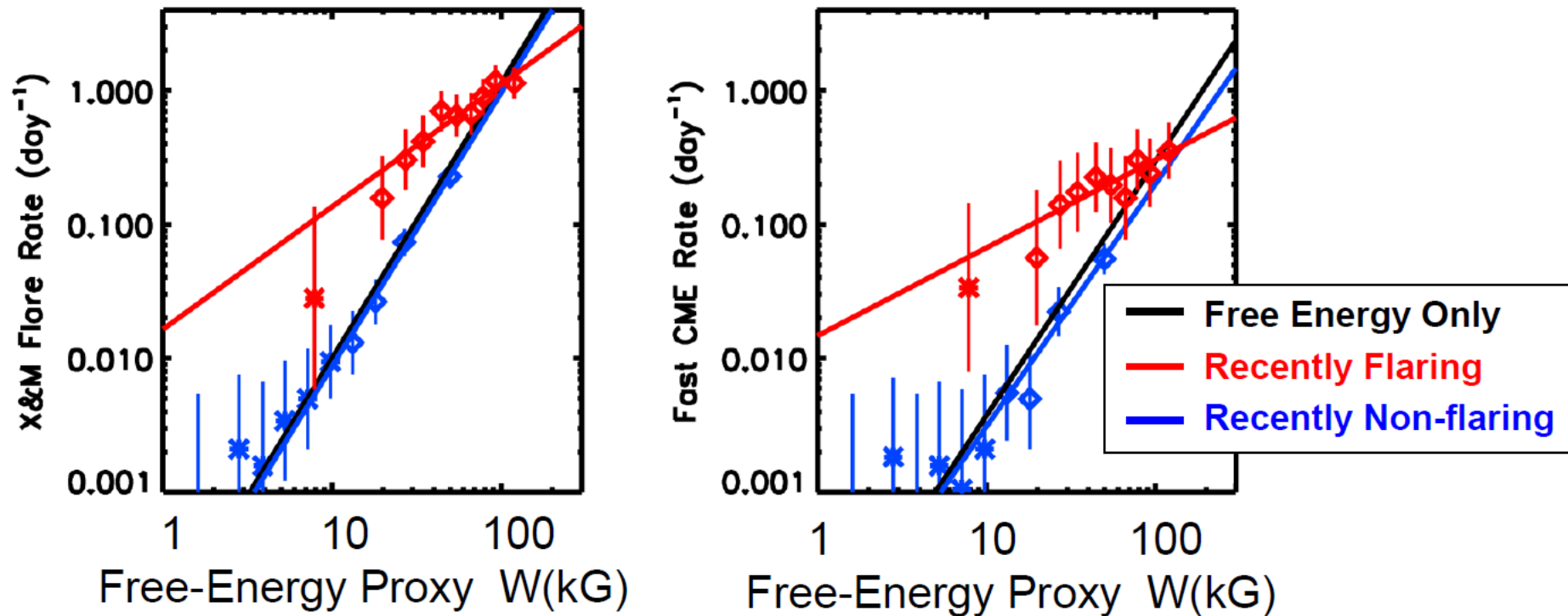
Using Vector Magnetograms

- Vectors out of the sun have positive Bz but opposite sign BLOS

- Leads to an unphysical neutral line in the line-of-sight field

- Vector magnetograms mitigate this effect and improve the event probabilities limbward
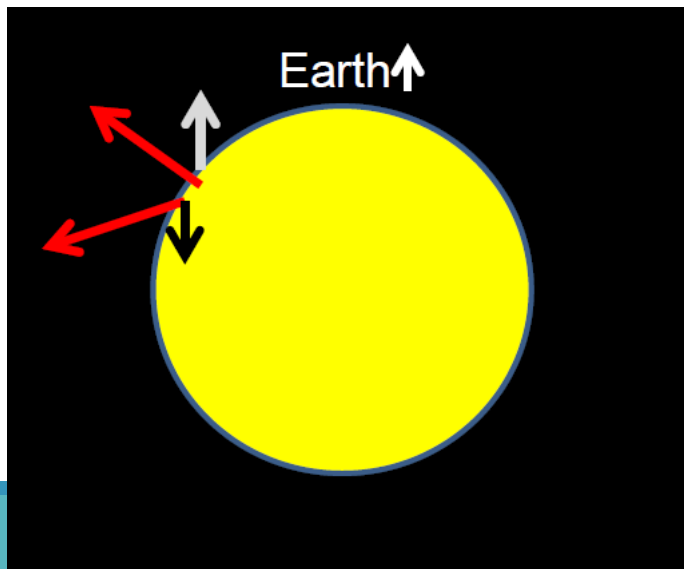
Actual Examples

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 Modes

Using free energy proxy and line-of-sight magnetograms

Using free energy proxy and previous flare history of active region using line-of-sight magnetograms

Using free energy proxy and deprojected HMI vector magnetograms

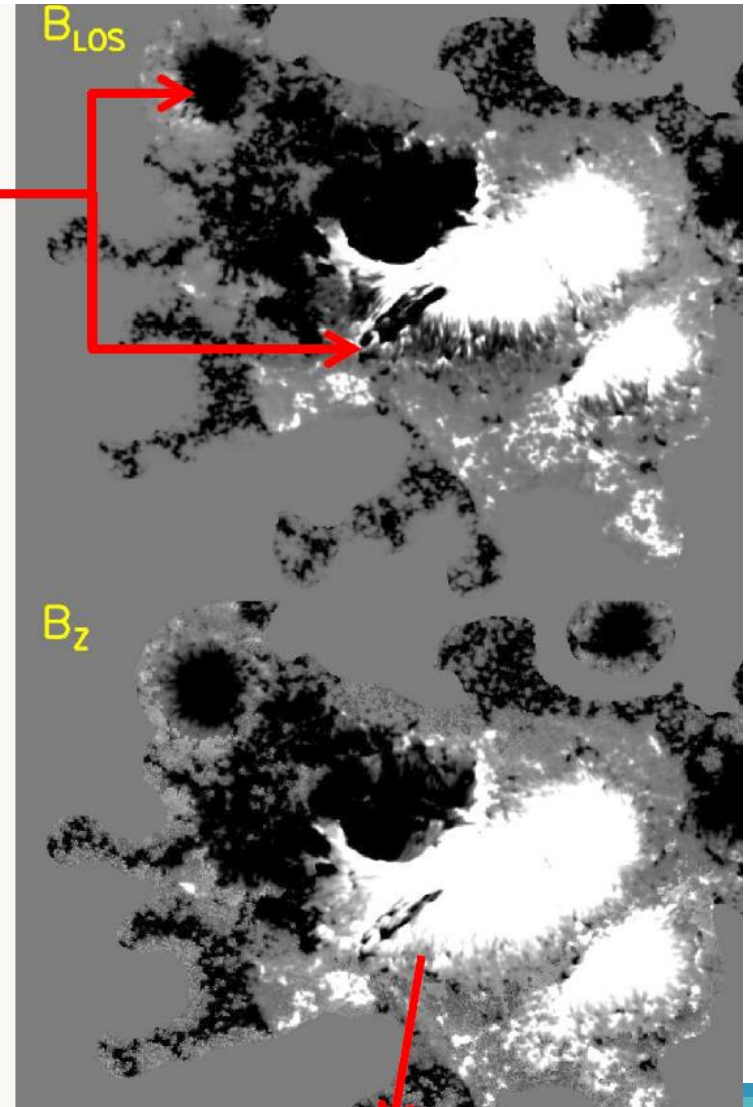Using free energy proxy and previous flare history of active regions using deprojected HMI vector Magnetograms
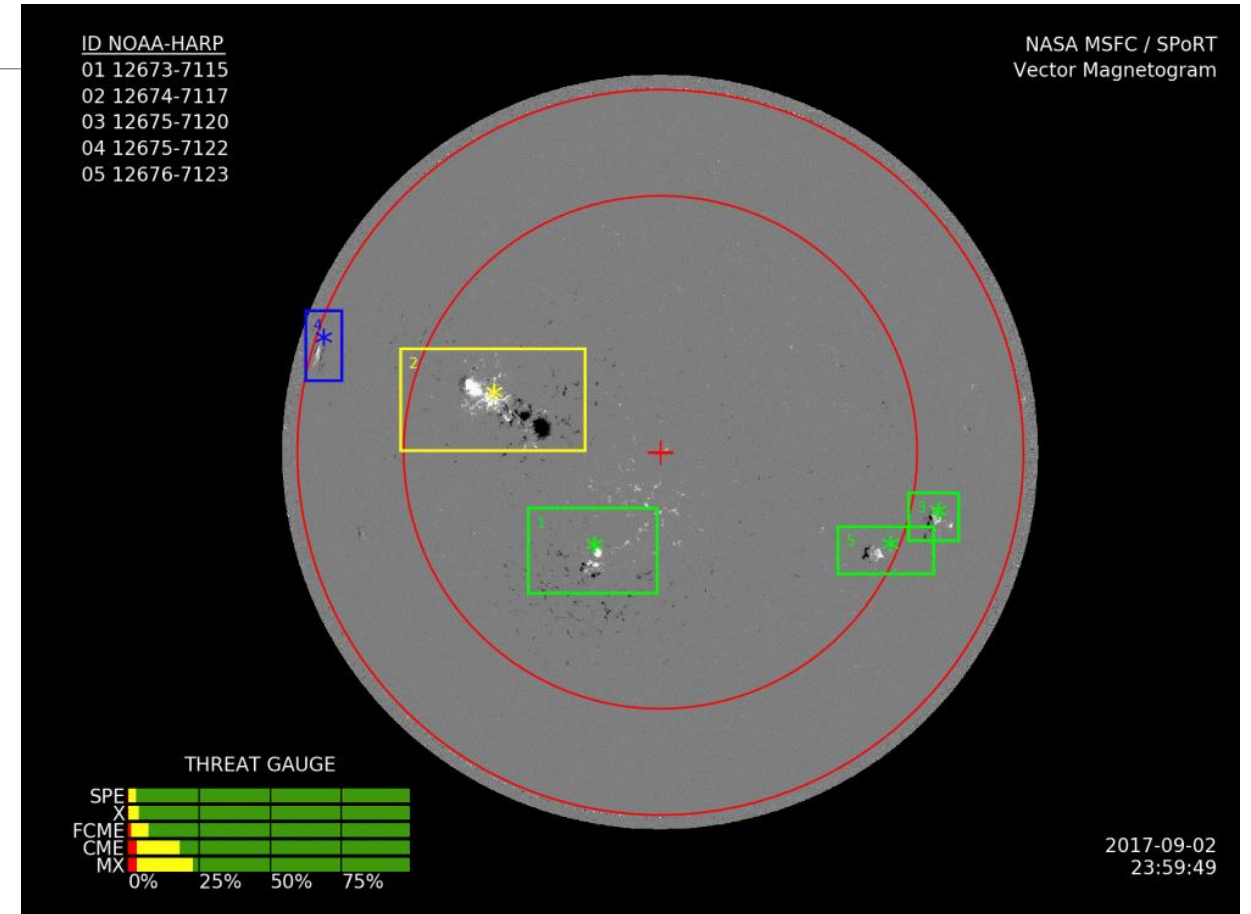
SPoRT version of MAG4 incorporates flare history and can be run in vector or LOS mode

Under development: using HMI forecasting curve (which will likely have smaller error bars than the MDI forecast curve)

MDI forecast curve

SPoRT

MAG4 Display and Threat Gauge

- Numbering shows each AR's MAG4 ID, its NOAA AR number, and its HARP tile number

- Outer circle is the edge of the solar disk

- Inner circle is 45 degree ring, where we expect forecasts to be most accurate

- Boxes are places around ARs
  - Scaled with +/-500 G magnetic flux
  - Green box: < 0.02 events/day
  - Yellow box: 0.02-0.2 events/day
  - Red box: > 0.2 events/day
  - Blue box: no NOAA active region assigned
  - Curved box: When a part of an AR appears in another box (i.e., highly overlapped), HMI active region masks are used instead.

- The Threat Gauge shows the probability of each type of event. Yellow bar is the 1-sigma error for that threat probability

NASA MSFC / SPoRT
Vector Magnetogram

ID NOAA-HARP
01 12673-7115
02 12674-7117
03 12675-7120
04 12675-7122
05 12676-7123

THREAT GAUGE

SPE
X
FCME
CME
MX

0%   25%   50%   75%

2017-09-02
23:59:49

MAG4 Display and Threat Gauge

- Users at SWPC requested some changes to a previous version:

  - Preferred a website

  - Clearer fonts and colors for text

  - Half-hourly cadence of data

  - "Fail gracefully", i.e., messages that indicate whether product is down or product is not producing data due to lack of solar activity
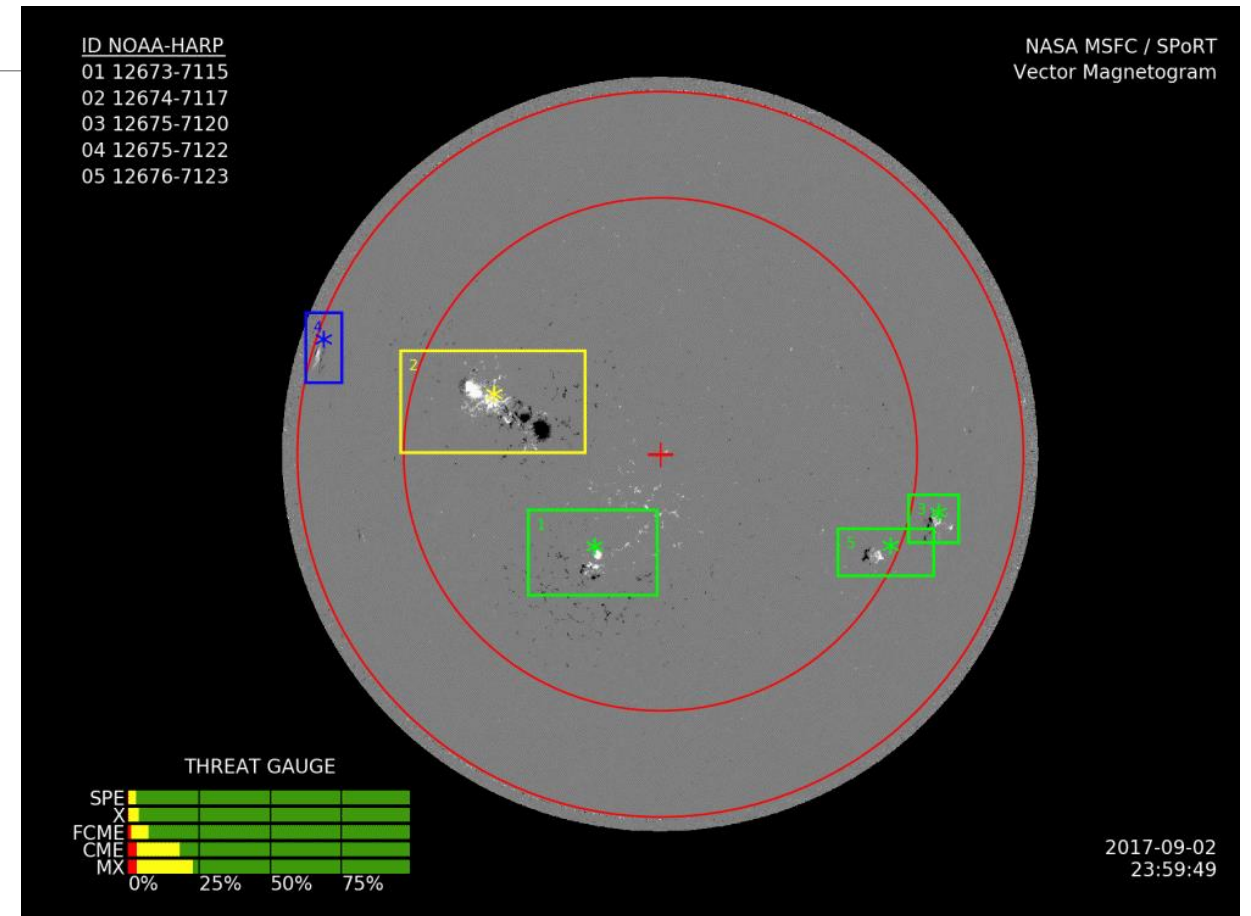
MAG4 Output and Tables

- By request:
  - Trends in ARs
  - Full disk vs AR tables
  - Risk Categories that match end user categories

	M&X	CME	FCME	X	SPE
Active Regions - Rates	**Active Regions - Probabilites**		**Full Disk - Rates**		**Full Disk - Probabilities**
Disk All-Clear Forecast Probabilities	97%	98%	99%	99%	99%
Disk Probability of Event	3%	2%	1%	1%	1%
Uncertainties	3%	2%	1%	1%	1%
Risk Category	Null				

NASA-MSFC/UAHuntsville MAG4 M&X Event Rate and Probability
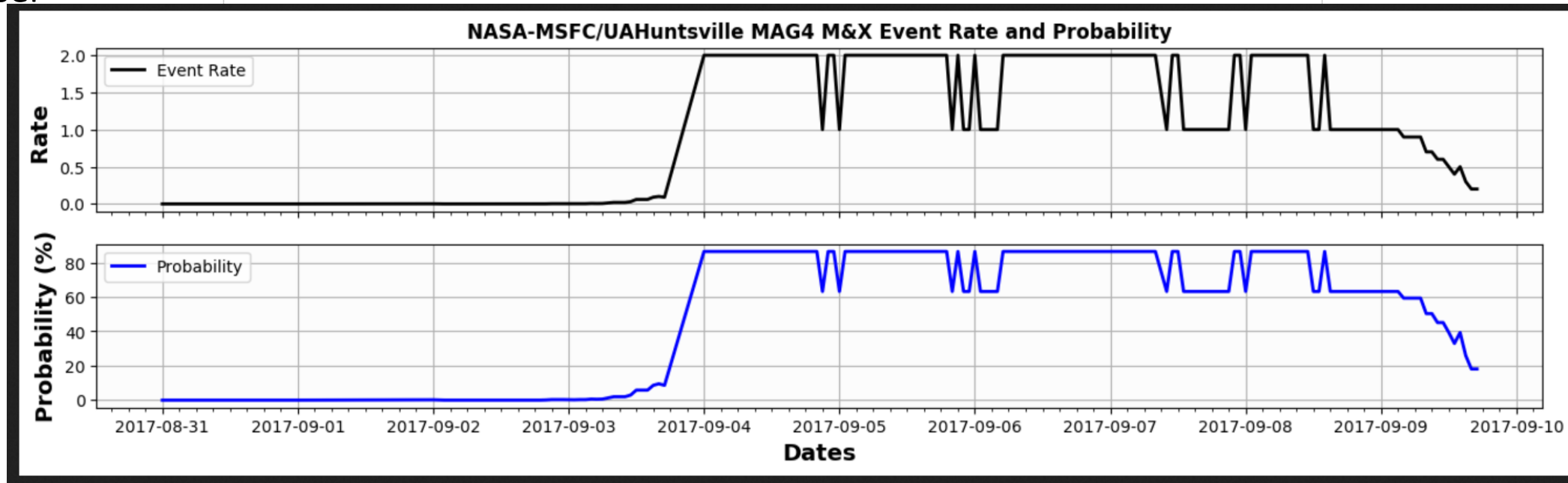
MAG4 Webpage

Can be found here:
https://weather.msfc.nasa.gov/cgi-bin/sportPublishMAG4.pl?dataset=mag4realtime

Available in Realtime and Archived modes

Training Link available on the page

Training is "applications-based" and self-paced

Conclusions

- SPoRT transition center is working to evaluate the MAG4 product in operations

- MAG4 forecasts X and M flares, CMEs, Fast CMEs, and SPEs

- Forecasts are probabilistic

- Operational product produces an output display, a threat gauge, quantitative tables, and a timeline of AR activity