Parameterization of Active Regions For Flare Forecasting Research

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Lofty Goal: Predict solar flares from character and evolution of observed solar magnetic fields

Stark Reality: Despite occasional claims to the contrary, this is a research topic, and not ready for operations.

Two things are needed to make a forecast:

(1) One of more parameters to characterize the properties of the active region

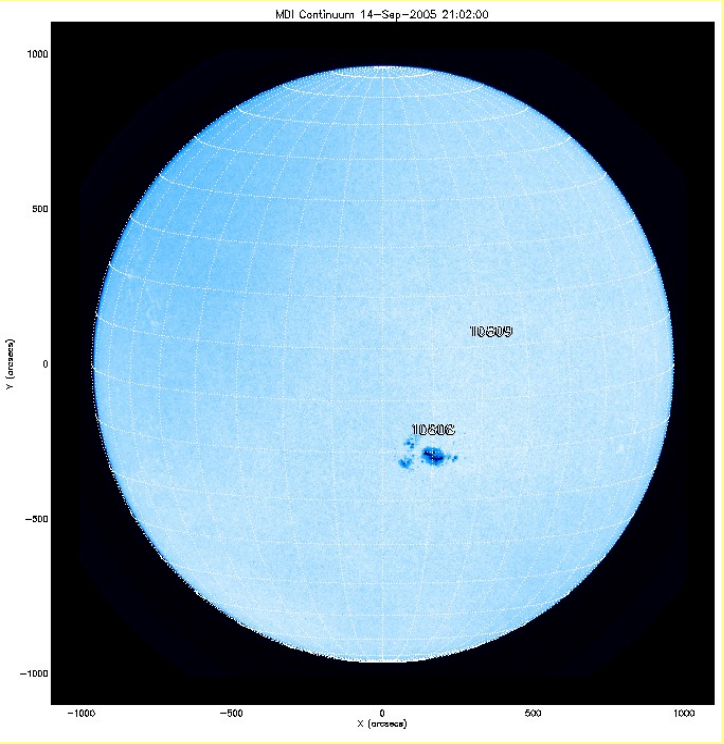
(2) A statistical technique to convert the values of the parameters to an actual forecast.

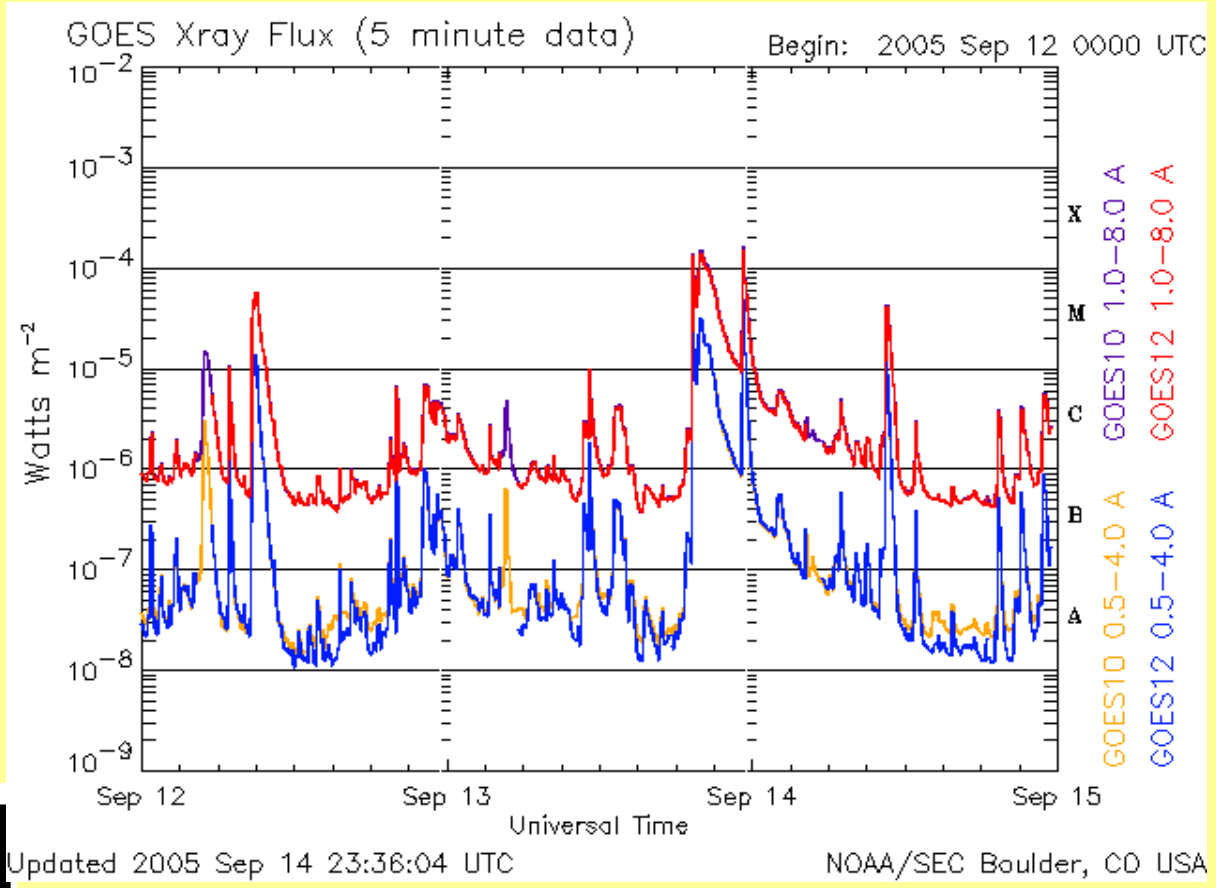
Re: (1) a selection of “well-performing” parameters will be calculated for HMI Quick-look and Science data.

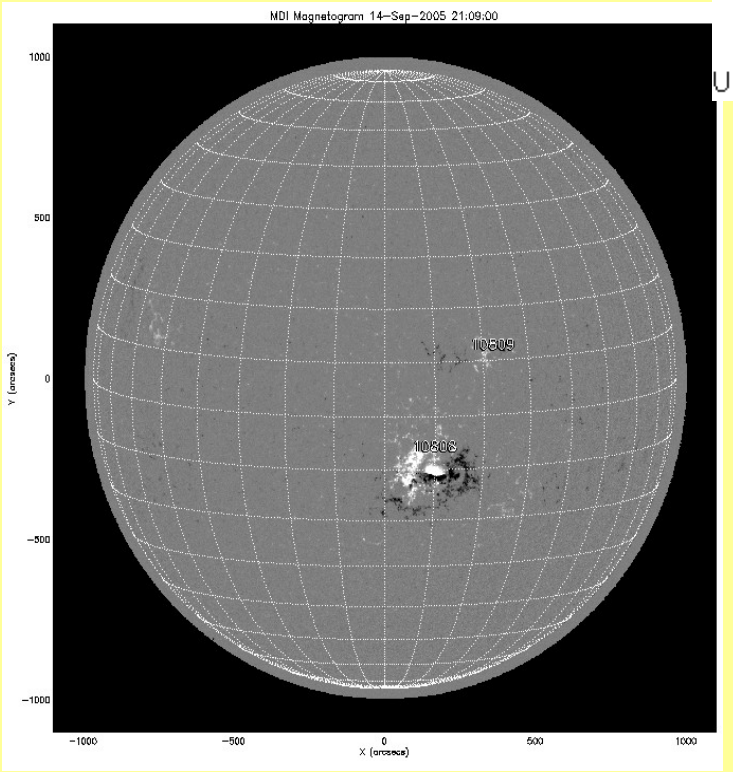
Science-data parameters can be pushed into HEK.

Quick-look parameters: can be DrDoolittled to in-place real-time tools, and saved for later versions of (2)

“Forecaster”: possibly different flavors. Interest may target different flare magnitudes, different latencies, prediction for a flare event or a time of *no* events, etc.


MDI Continuum 14-Sep-2005 21:02:00
10509
10508
X (arcsecs)
Y (arcsecs)


GOES Xray Flux (5 minute data)
Begin: 2005 Sep 12 0000 UTC
Watts m-2
Sep 12
Sep 13
Sep 14
Sep 15
Universal Time
X
M
C
B
A
GOES10 0.5-4.0 A
GOES10 1.0-8.0 A
GOES12 0.5-4.0 A
GOES12 1.0-8.0 A
Updated 2005 Sep 14 23:36:04 UTC
NOAA/SEC Boulder, CO USA


MDI Magnetogram 14-Sep-2005 21:09:00
10509
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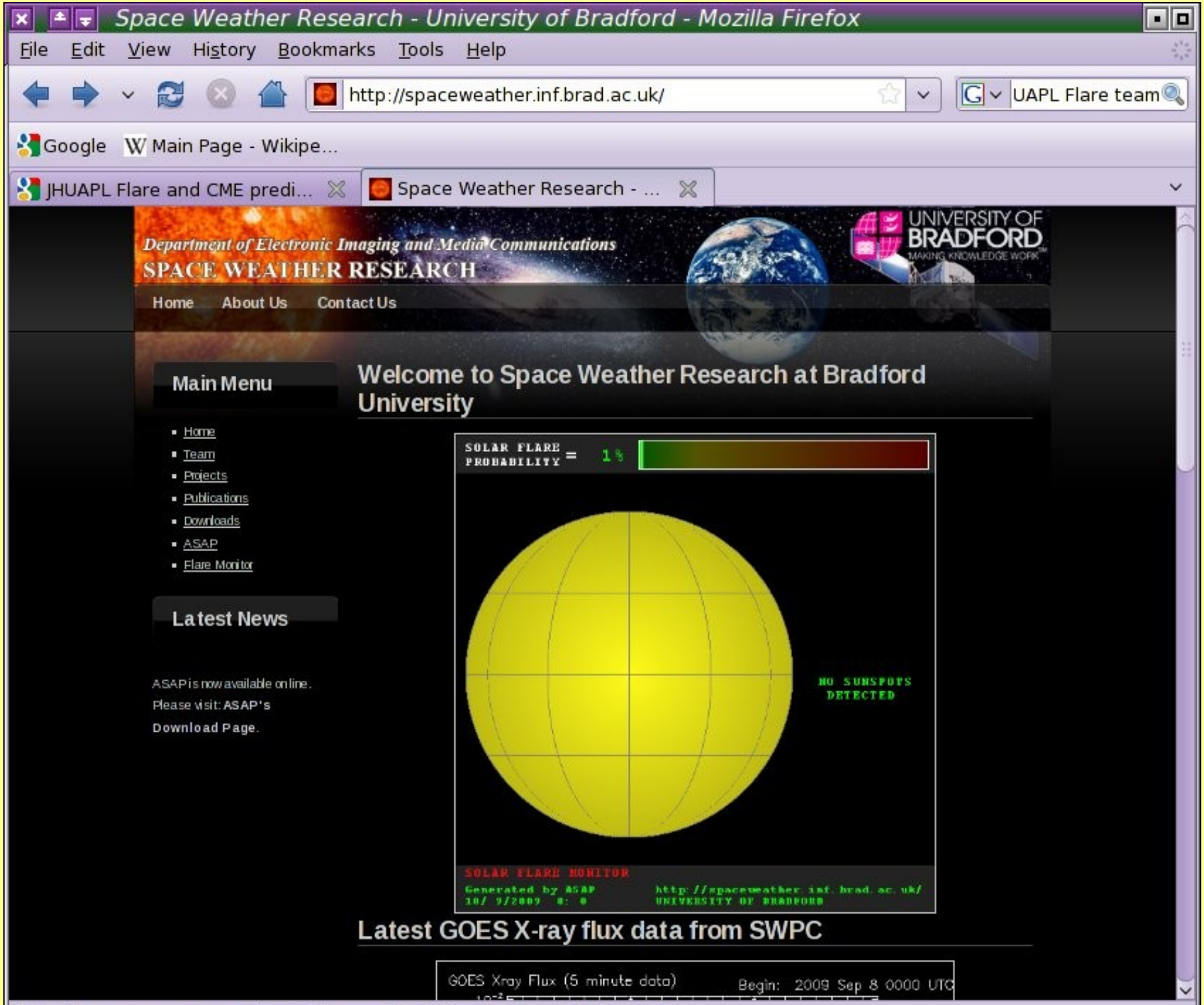
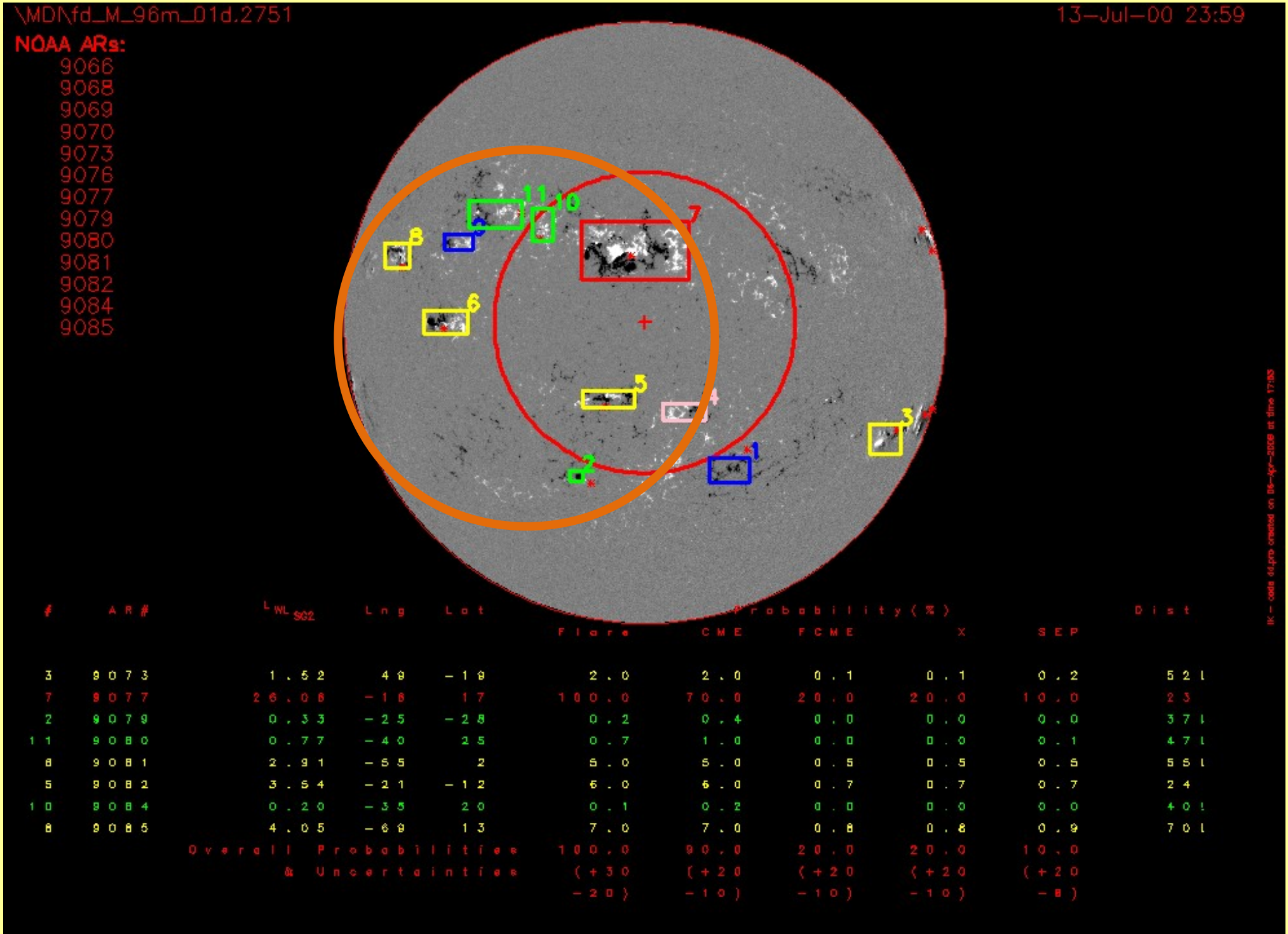
X (arcsecs)
Y (arcsecs)

Real-Time AR classification and activity prediction at U. Bradford.

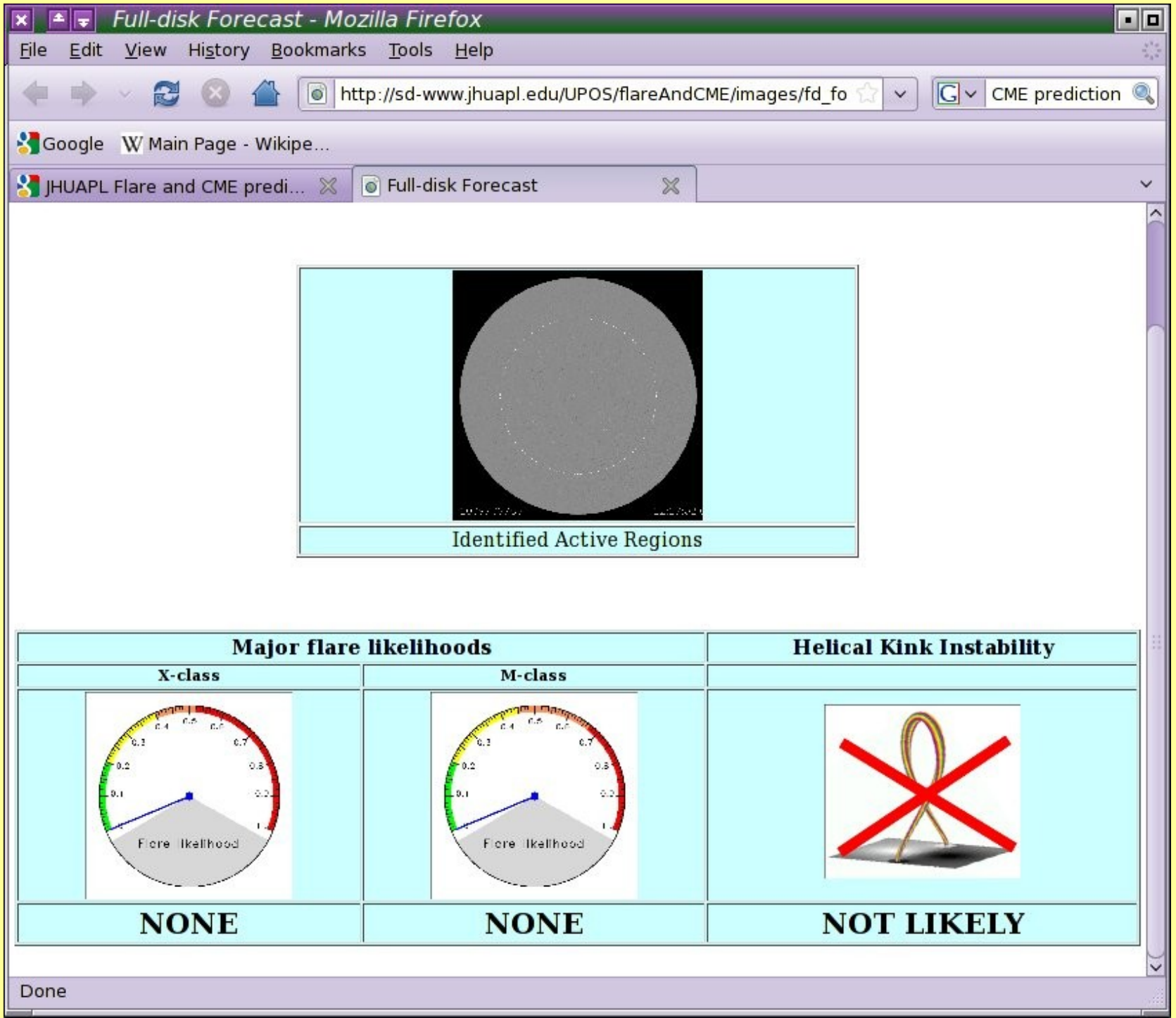


Tool delivered to NASA/SRAG from NASA/MSFC



#	AR #	L WL SG2	Lng	Lat	Probability (%) Flare	CME	FCME	X	SEP	Dist
3	9073	1.52	40	-10	2.0	2.0	0.1	0.1	0.2	521
7	9077	26.08	-16	17	100.0	70.0	20.0	20.0	10.0	23
2	9079	0.33	-25	-28	0.2	0.4	0.0	0.0	0.0	371
11	9080	0.77	-40	25	0.7	1.0	0.0	0.0	0.1	471
8	9081	2.91	-55	2	5.0	5.0	0.5	0.5	0.5	551
5	9082	3.54	-21	-12	6.0	6.0	0.7	0.7	0.7	24
10	9084	0.20	-35	20	0.1	0.2	0.0	0.0	0.0	401
6	9085	4.05	-68	13	7.0	7.0	0.8	0.8	0.9	701
	Overall Probabilities & Uncertainties				100.0 (+30 -20)	90.0 (+20 -10)	20.0 (+20 -10)	20.0 (+20 -10)	10.0 (+20 -8)	

Flare and CME prediction page from JHU/APL



From Tom Bogdan, director of the NOAA/Space Weather Prediction Center:

“From an operational space weather perspective, a baseline threshold requirement for us to make use of the data would be:
•Full disk longitudinal magnetograms 4x per day (better than 6 hour latency) that we could use as input to WSA Enlil.
.....
I think we could find a way to make good use of the following enhanced capabilities:
•Full disk vector magnetograms 4x per day (better than 6 hour latency)
•Full disk longitudinal magnetograms at a higher cadence and smaller latency than 4/day and 6 hours
.....
Right now, we do not have anything we could do with helioseismology data *per se.* We do not have any means to take high resolution images of an active region and do anything with them (except look and puzzle!). This could all change if the research pushes the front forward where viable predictive capabilities could emerge.”

KDL notes:
• at this point I do not know if WSA Enlil can use B_radial, and switching to HMI B_los will require “calibration” for a consistent SWPC forecast.
• HMI can match all of SWPC's requirements
• No similar concise statement from NASA/JSC

Parameters to be routinely calculated:

Compiled from research by:

Leka, Barnes, Georgoulis. Rust, McAteer, Ireland, Conlon, Higgins, Abramenko, Falconer, Moore, Zhang, Schrijver, Colak,Qahwaji, Yuan,Wheatland,

Total Unsigned Flux: $\Phi = \sum Bz\ dA$

Moments of the gradient of the horizontal field distribution:

$M(\nabla Bz)$ where $M \in$ {mean,variance,skew,kurtosis}

Total vertical electric current density: $I = \sum (Jz\ dA)$

Total length of strongly non-potential polarity inversion lines:

Or

$Length(ss) = \sum dL(\Psi > 45^{\circ})$

Total area of strongly non-potential fields

$Area(ss) = \sum dA(\Psi > 45^{\circ})$

Total of the unsigned vertical component of the current helicity:

$Hc\ total = \sum(| Bz\ Jz |)\ dA.$

Proxy for the free energy, "Photospheric Excess Energy":

$Ee = \sum (\boldsymbol{B}^{potential} - \boldsymbol{B}\ observed)^{\wedge}2/8\pi$

Total unsigned flux near high-gradient polarity-inversion lines:

R = $\sum Bz\ (\delta r < 2Mm\ of\ PIL)\ dA$

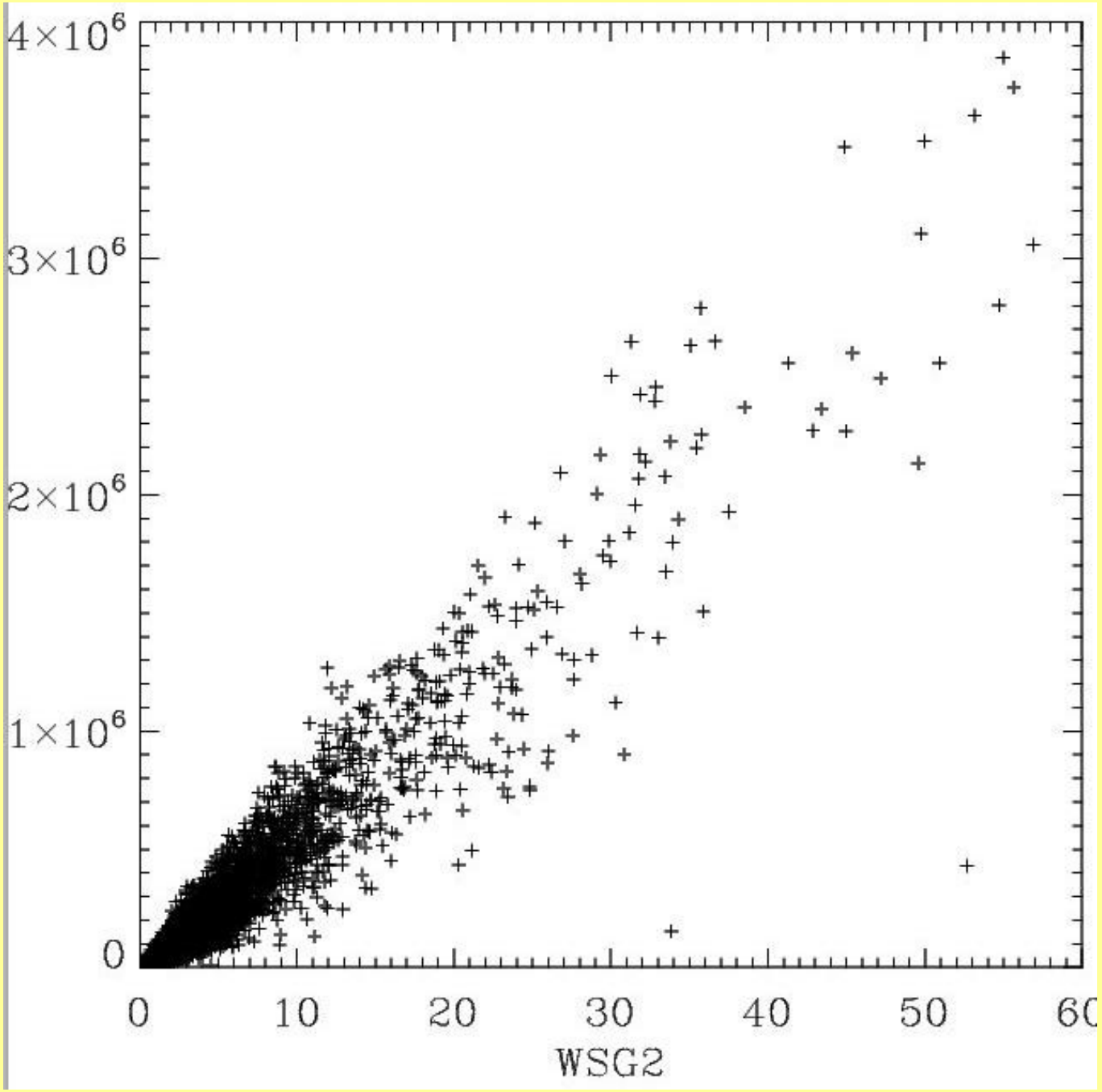
And maybe:

Fractal dimension (someone else needs to provide code for this). *Offered by V. Yurshchyn, yeah!*

NOTE: noise-thresholds will be hard-wired for consistency. New parameter calculations for research using different thresholds can be made 'on-request'

Many parameters are correlated with each other*. Some will be calculated (Total Flux, Total vertical current), some won't be, as they add little “new” information to what a vector map can tell us.

*: (not relating how they are/are not correlated to flaring).



Weighted Strong Gradient (from Falconer, x-axis), vs. total unsigned flux near high-gradient PIL (from Schrijver, y-axis).

Once have parameters, then different statistical methods can be tested, *and validated.*

- Barnes & Leka have directly compared the performance of a few.
- We also have funding to continue comparisons of both parameters and statistical techniques.

Validation tools:

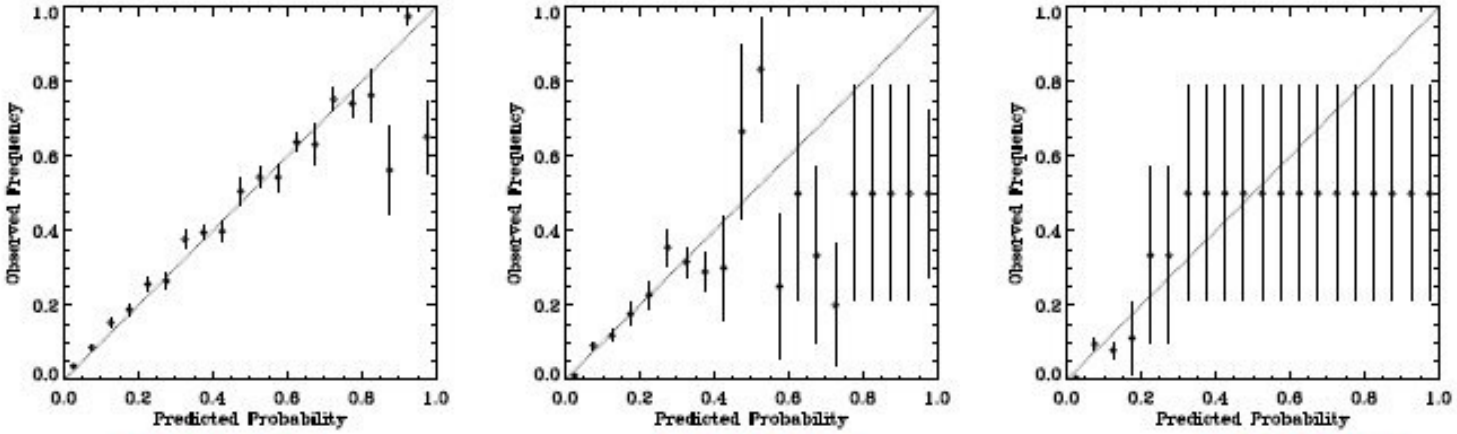
Reliability Plots

Predict vs. Observed Tables

Different flavors of Skill Scores

Reality check

Sample Results



C1.0, 24 hr | M1.0, 12 hr | M5.0, 12 hr

	observed			observed			observed	
predicted	event	no event	predicted	event	no event	predicted	event	no event
event	1028	568	event	6	3	event	1	0
no event	1558	8965	no event	390	11720	no event	92	12026

SS (climatology): 0.178	SS (climatology): 0.008	SS (climatology): 0.011
SS (RMS): 0.264	SS (RMS): 0.131	SS (RMS): 0.059

Probability of detection typically decreases with increasing event size. This is generally true for all the methods.

Final Comments:

- Selection of parameters will be calculated; code is being Fortran-ified.
  - On both Quick-Look and Science data.
- New, exploratory parameters: in the lap of researchers on Science Data.
- Parameters (from Science data) can be in HEK
  - For exploration for new statistical approaches, progress can be made on the second part of forecasting.
- Quick-Look parameters should be saved, as they are the basis for future forecasting bases. But this is an *extremely* small amount of data.