Solar Flares Forescast: log R magnetic proxy

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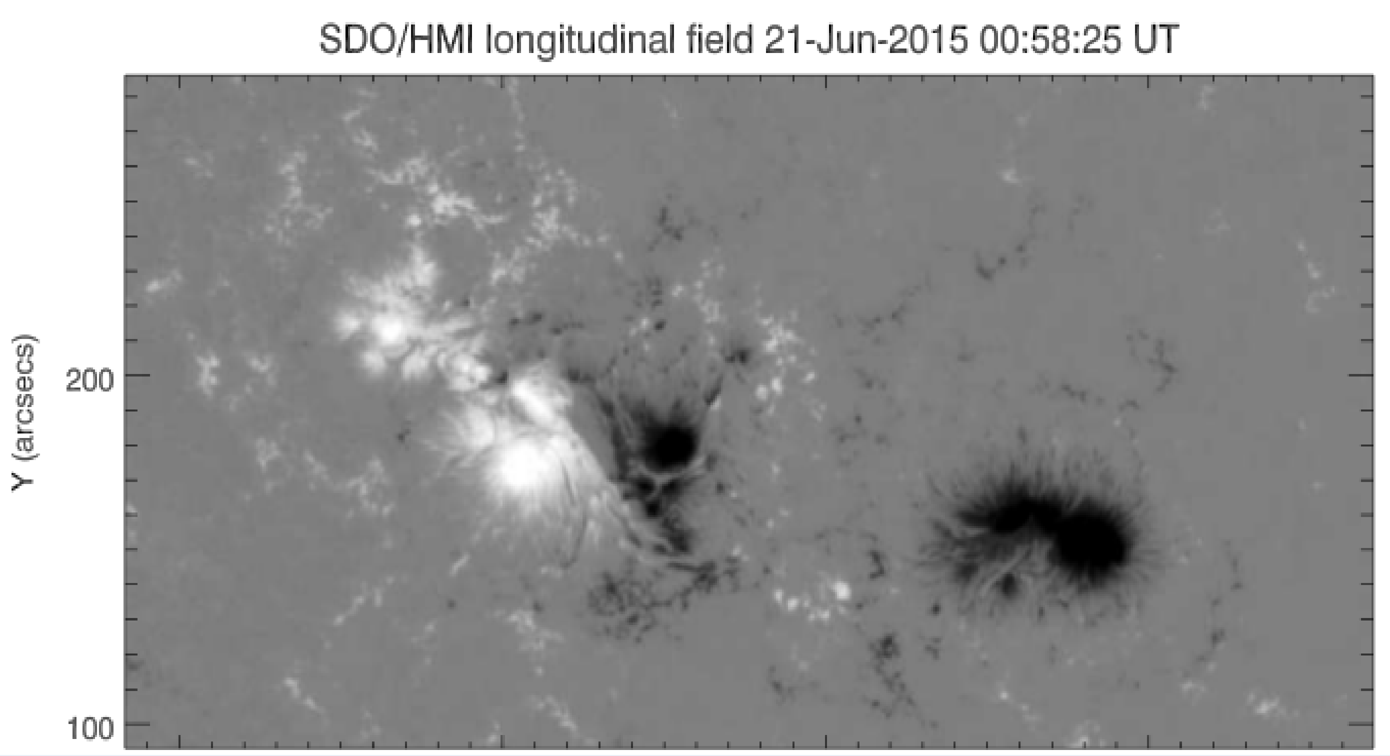
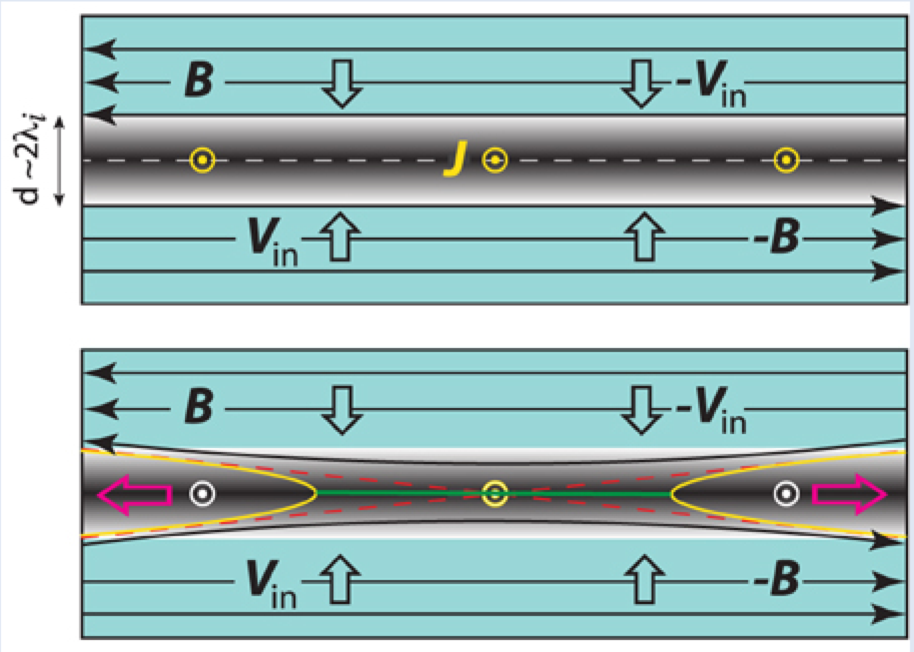
- Description of the log R proxy (Schrijver 2007)
- Other proxies
- Case study: 21 june 2015 solar flare



Electrical Currents and Flares

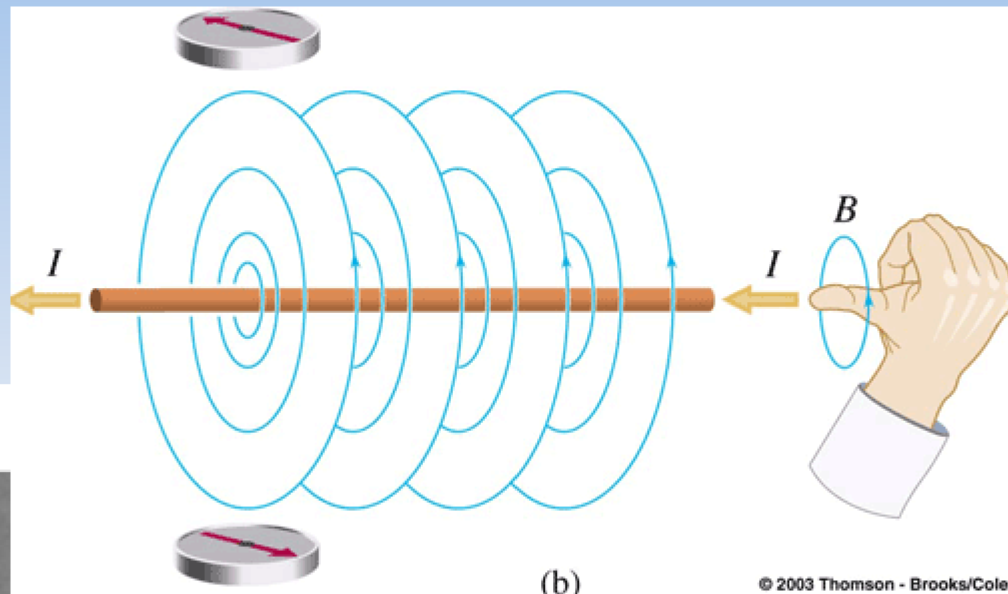
- The emergence of electrical currents embedded in magnetic flux, rather than surface shear flows or other purely atmospheric effects, appears to be key in driving active region flaring



Magnetograms and electrical currents in the photosphere

- Although LOS magnetograms do not allow the measurement of electrical currents, they certainly can be quite revealing of their presence
- A compact current, emerging through the photosphere with a magnetic field winding helically about it, would show up in cross section within the photosphere as an elongated polarity-inversion line, with narrow ridges of strong opposite-polarity fields immediately adjacent to it.

Current sheet and magnetic field



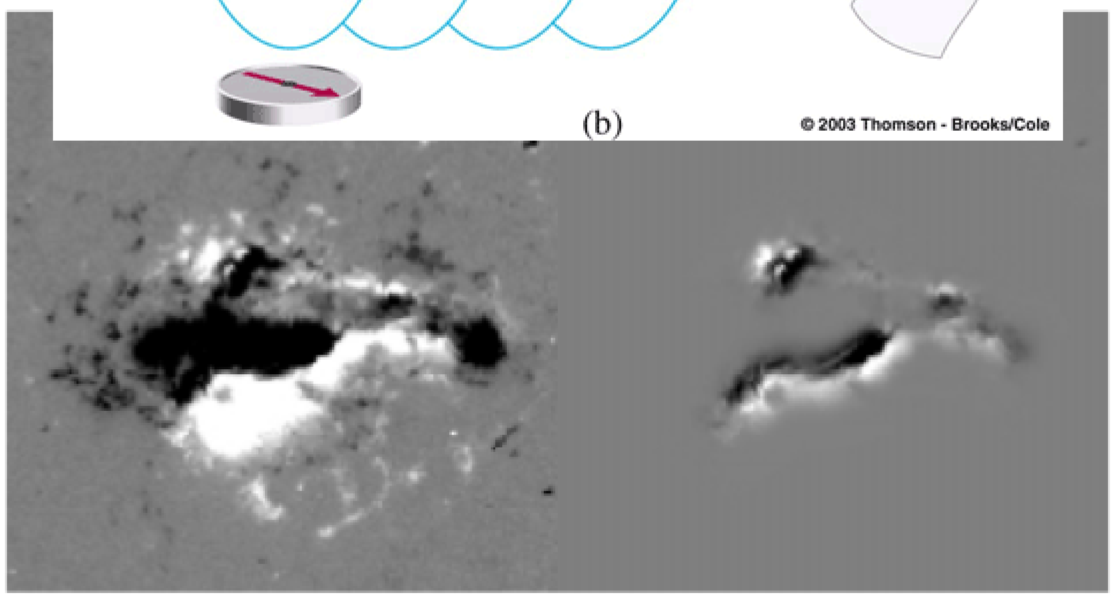
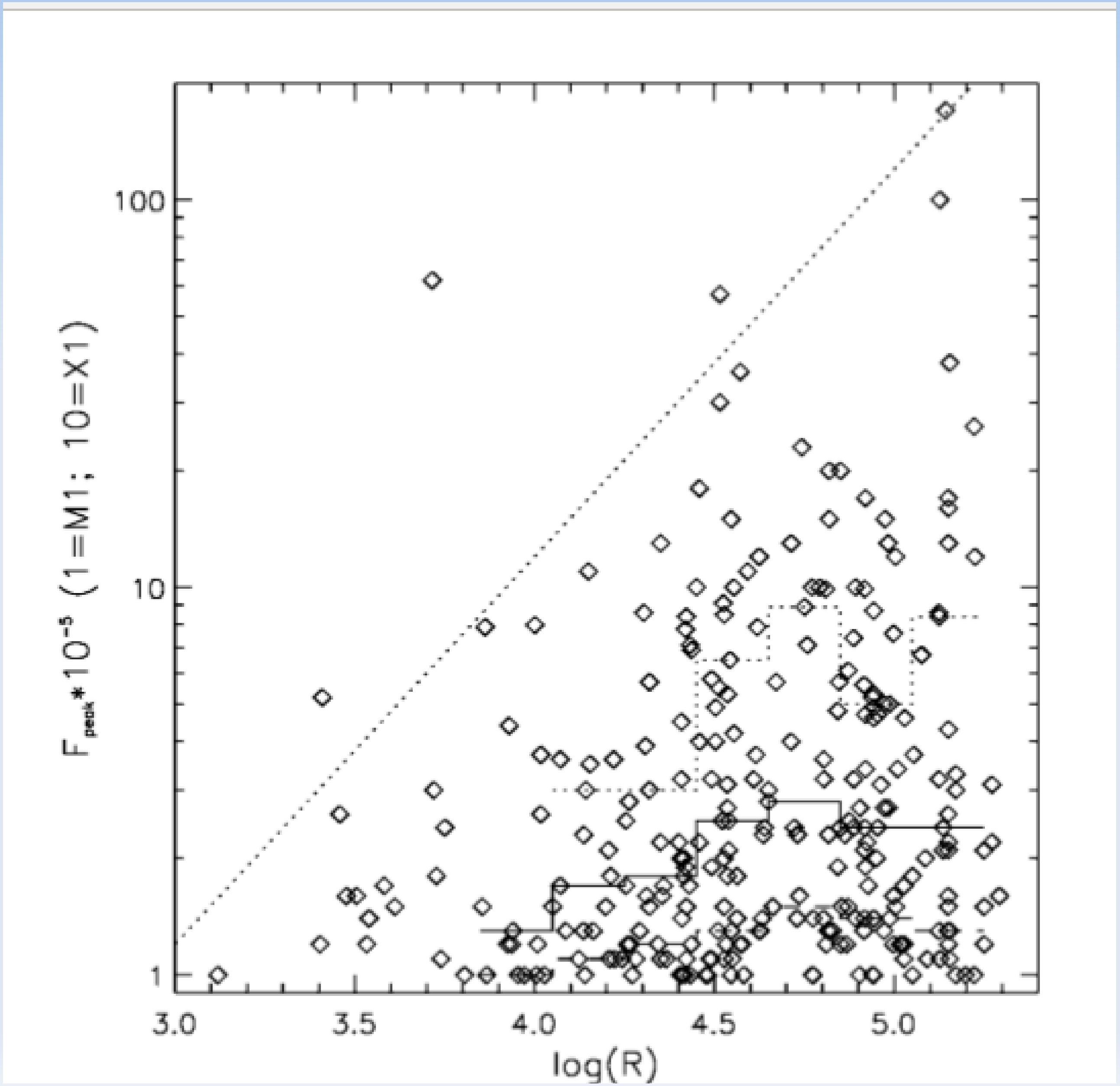


FIG. 1.—*Left*: Example of a *SOHO* MDI magnetogram (cutout of 160 × 160 pixels of 2″ square) around the time of the M4.6 flare on 2005 September 14 10 UT (log R = 5.03). *Right*: Magnetogram multiplied with the weighted map W of the field near high-gradient, strong-field, polarity-separation lines, which, after summing their absolute values, yields R.

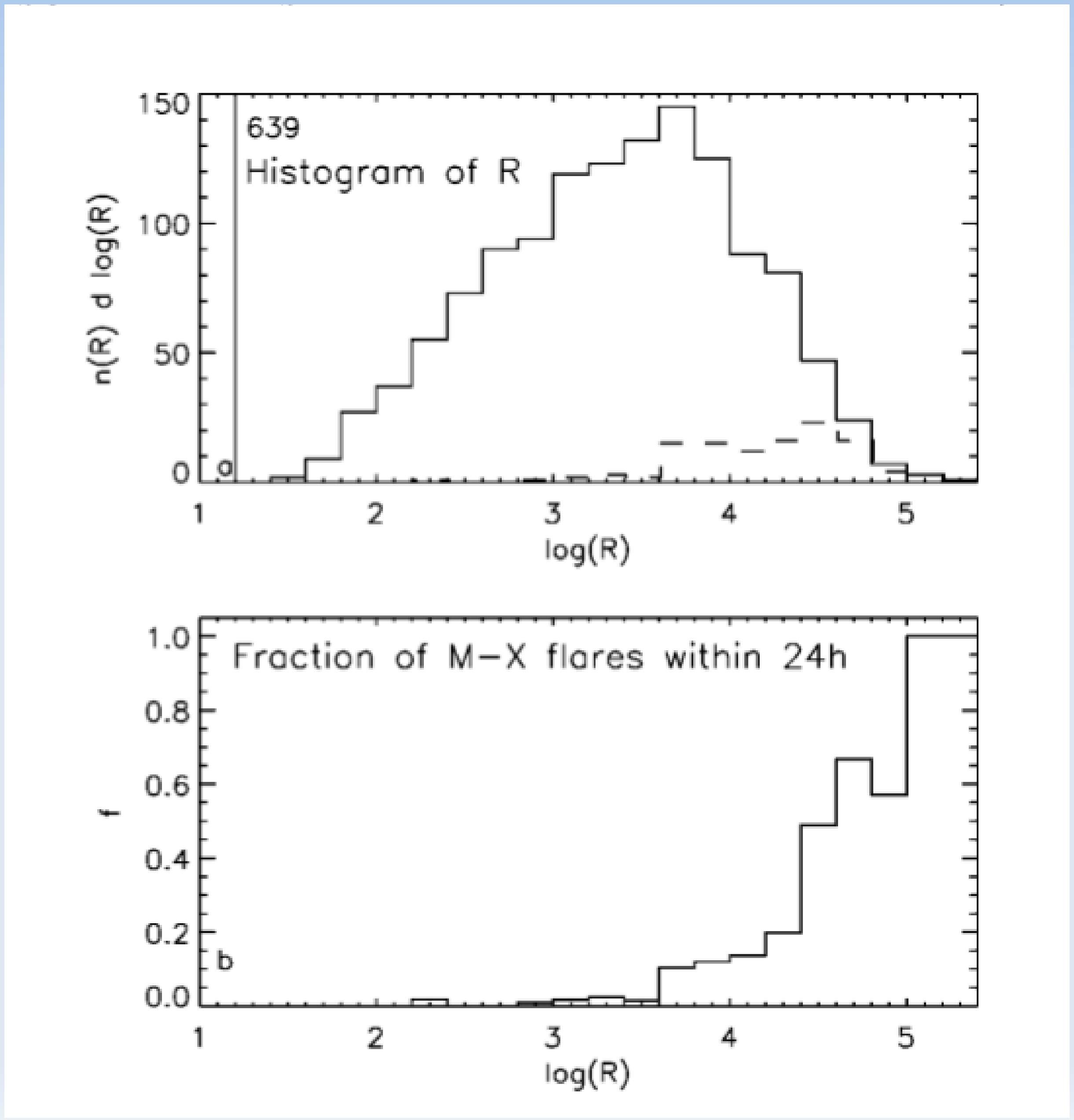
R definition

- ”To quantify the association of flares with flux near high-gradient, strong-field polarity-separation lines, I measure the unsigned flux R near the polarity-separation lines”
- Test on SOHO MDI data

X-ray flux vs log R



FLARE LIKELIHOOD AND FORECASTING



FLARE LIKELIHOOD AND FORECASTING

TABLE 1

FLARE PROBABILITIES

CLASS	PROBABILITY log $R \approx <3.0$ (%)	log $R \approx 3.0$ (%)	log $R \approx 3.5$ (%)	log $R \approx 4.0$ (%)	log $R \approx 4.5$ (%)	log $R \approx 5.0$ (%)
>M1	...	2	5	12	50	~80
>M3	...	~0	<1	3	20	35
>X1	...	0	~0	~1	10	20
>X3	...	0	0	~0	1	1–2
Maximum	<C9	<M1	<M4	<X1	<X4	<X10

NOTES.—Likelihood of major (X or M) flares within 24 hr of the determination of the unsigned, weighted magnetic flux R within 15 Mm of high-gradient, strong-field polarity-separation lines. Also listed is the maximum expected flare class.

Classify magnetic proxies

- Solar Flare Prediction Using SDO/HMI Vector Magnetic Field Data with a Machine-Learning Algorithm (M. G. Bobra and S. Couvidat 2014)

Table 1. SHARP active region parameter formulae.

Keyword	Description	Formula	F-Score	Selection
TOTUSJH	Total unsigned current helicity	$H_{c_{total}} \propto \sum \lvert B_z \cdot J_z \rvert$	3560	Included
TOTBSQ	Total magnitude of Lorentz force	$F \propto \sum B^2$	3051	Included
TOTPOT	Total photospheric magnetic free energy density	$\rho_{tot} \propto \sum \left(\vec{B}^{\mathrm{Obs}} - \vec{B}^{\mathrm{Pot}}\right)^2 dA$	2996	Included
TOTUSJZ	Total unsigned vertical current	$J_{z_{total}} = \sum \lvert J_z \rvert dA$	2733	Included
ABSNJZH	Absolute value of the net current helicity	$H_{c_{abs}} \propto \lvert \sum B_z \cdot J_z \rvert$	2618	Included
SAVNCPP	Sum of the modulus of the net current per polarity	$J_{z_{sum}} \propto \left\lvert \sum^{B_z^+} J_z dA \right\rvert + \left\lvert \sum^{B_z^-} J_z dA \right\rvert$	2448	Included
USFLUX	Total unsigned flux	$\Phi = \sum \lvert B_z \rvert dA$	2437	Included
AREA_ACR	Area of strong field pixels in the active region	$\mathrm{Area} = \sum \mathrm{Pixels}$	2047	Included
TOTFZ	Sum of z-component of Lorentz force	$F_z \propto \sum (B_x^2 + B_y^2 - B_z^2) dA$	1371	Included
MEANPOT	Mean photospheric magnetic free energy	$\overline{\rho} \propto \frac{1}{N} \sum \left(\vec{B}^{\mathrm{Obs}} - \vec{B}^{\mathrm{Pot}}\right)^2$	1064	Included
R_VALUE	Sum of flux near polarity inversion line	$\Phi = \sum \lvert B_{LoS} \rvert dA$ within R mask	1057	Included
EPSZ	Sum of z-component of normalized Lorentz force	$\delta F_z \propto \frac{\sum (B_x^2 + B_y^2 - B_z^2)}{\sum B^2}$	864.1	Included
SHRGT45	Fraction of Area with Shear > 45°	Area with Shear > 45° / Total Area	740.8	Included
MEANSHR	Mean shear angle	$\overline{\Gamma} = \frac{1}{N} \sum \arccos \left(\frac{\vec{B}^{\mathrm{Obs}} \cdot \vec{B}^{\mathrm{Pot}}}{\lvert B^{\mathrm{Obs}} \rvert \lvert B^{\mathrm{Pot}} \rvert} \right)$	727.9	Discarded

SHARP

Joint Science Operations Center (JSOC)

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HMI Vector Magnetic Field Products

For the most up-to-date information on all the vector data products, including current release information, see the wiki.

The vector magnetic field is derived from full-disk filtergrams collected in a 135-second sequence. The observations are obtained in polarized light at several wavelengths across a spectral line. The filtergrams are calibrated and registered to account for solar rotation before being combined to provide Stokes polarization parameters. The parameters are used to determine the magnetic and other plasma parameters using VFISV, a Milne-Eddington inversion code. The final step is to disambiguate the data, that is infer the azimuthal direction of the transverse field.

Vector Field Quantities Described in More Detail Below

- **Stokes Vector:** The Stokes parameters are available for the whole mission.
- **ME Inversion:** The full disk inverted quantities are available since April, 2012 and earlier for selected intervals.
- **Full Disk Vector B:** The full disk vector field is not yet available.
- **SHARP for Space Weather:** Definitive vector field in HMI Active Region Patches (HARPS) will be available starting in the fall of 2012. Starting 14 September, 2012 quick-look vector analysis of near-real time HARPS is being completed for space-weather purposes. The vector field and a set of quantities useful for predictions are computed quickly using HMI nrt data. These data are available in both native CCD coordinates and Cartesian heliographic coordinates.
  Early Vector B in HARPs: Science-grade vector field is currently available only for selected regions. The first region for science data was AR 11158, observed in February, 2011. Since then a few regions have been fully processed, most with early versions of code. These are desribed at ReleaseNotes2.

SHARP Data - Tracked Space-weather HMI Active Region Patches. *Available Fall, 2012.*

- HMI Data Products
- AIA Data Products
- MDI Data Products
- SHA Data Products
- IRIS Data Products
- SID Data Products

** Useful Links **

- SDO Data Use Policy
- HMI Coverage Tables
- HMI Support Information
- AIA Coverage Tables & Release Notes

2015 June 21 event

- Comprehensive Sun-to-Earth analysis of the Geoeffective Solar event of June 21, 2015: Effects on the Magnetosphere Plasmasphere Ionosphere system. (SWICo 2016, submitted)

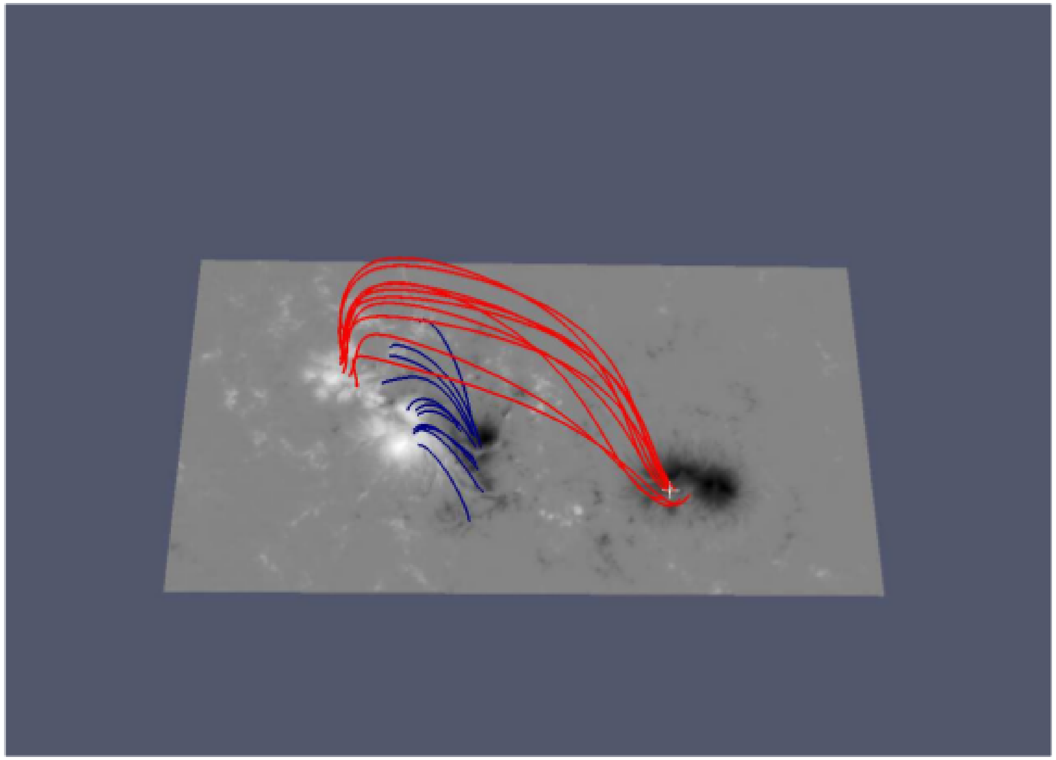
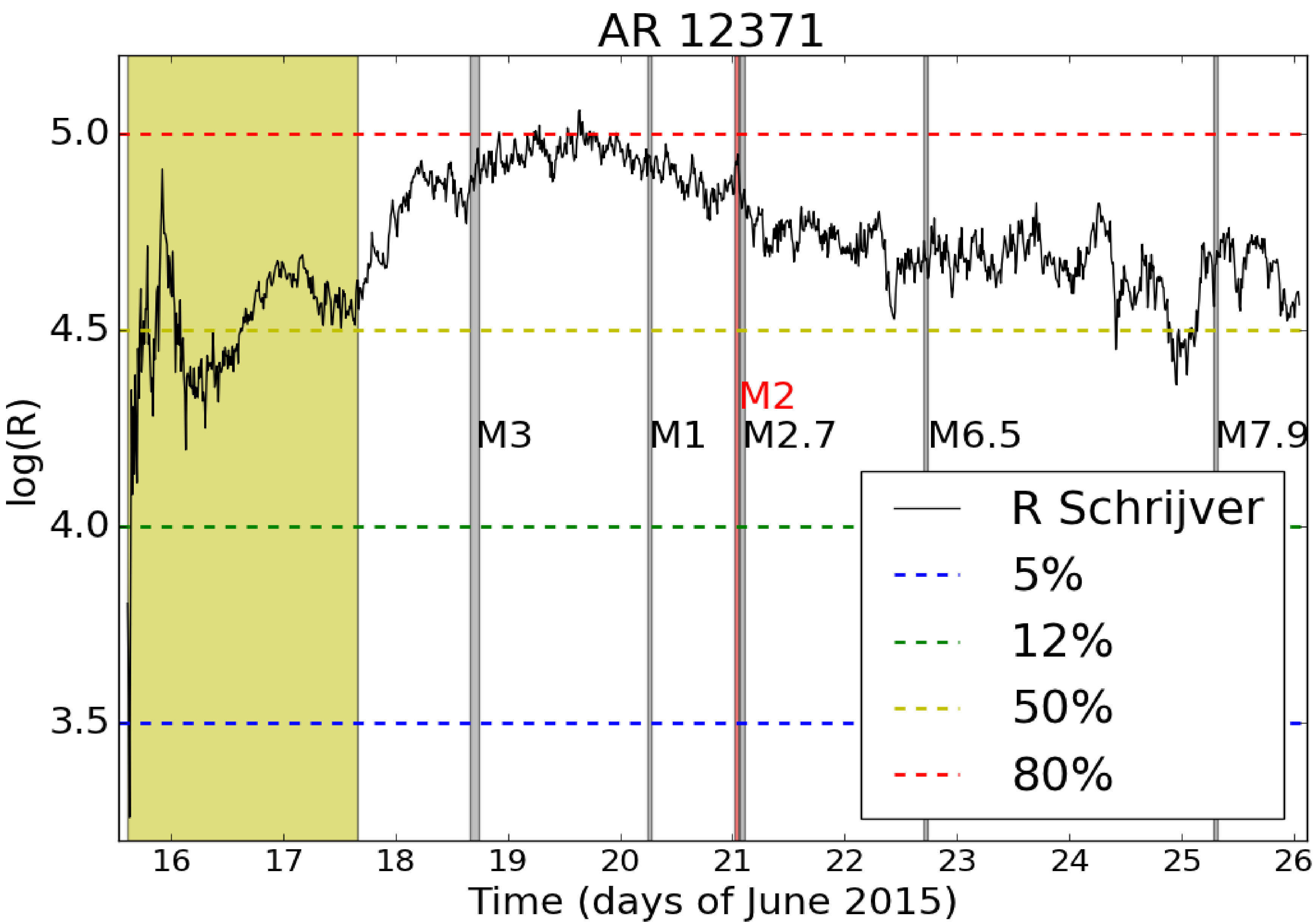
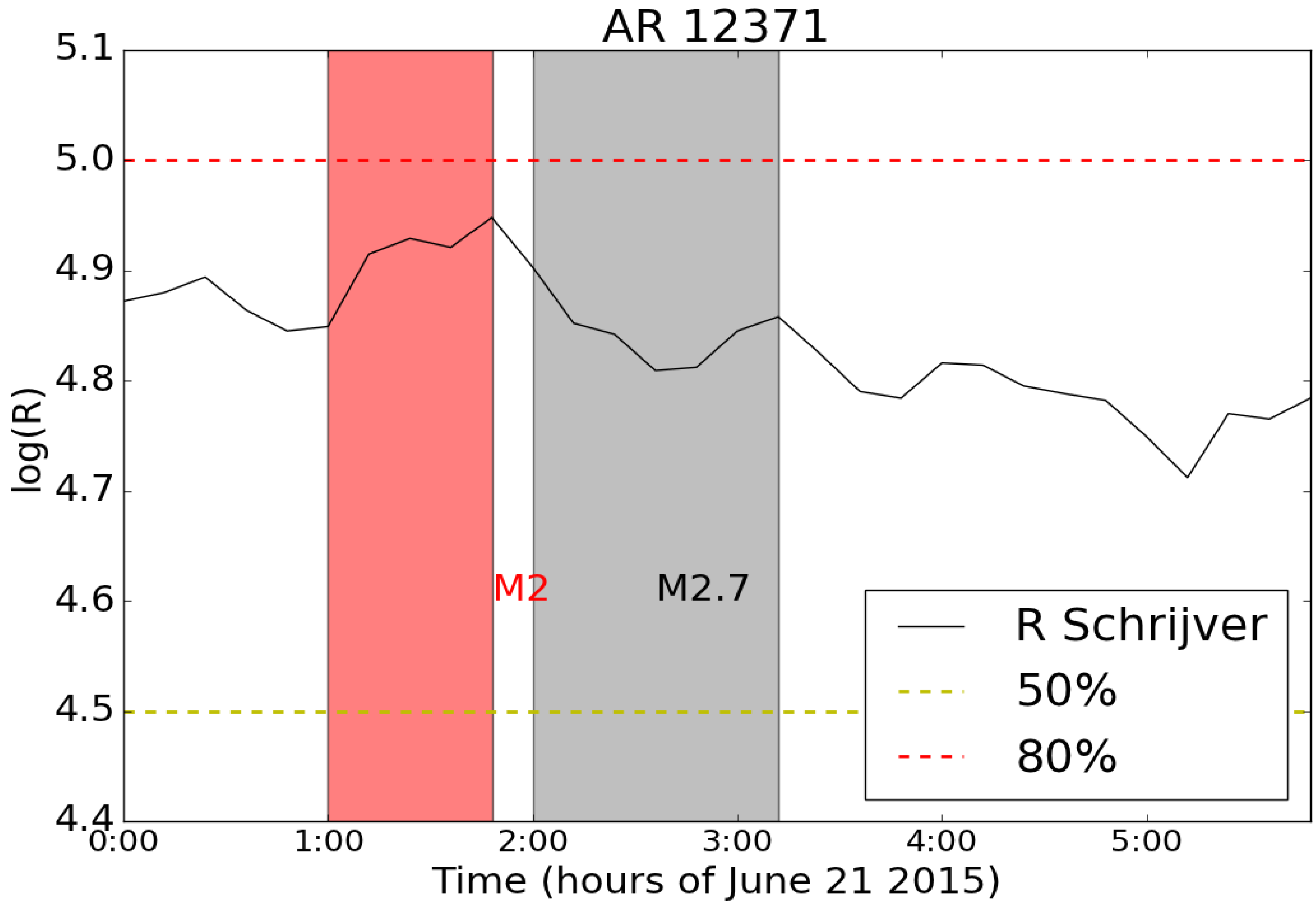


Figure 10. Linear force free extrapolation of the photospheric magnetic field of the AR NOAA 12371.

Log R

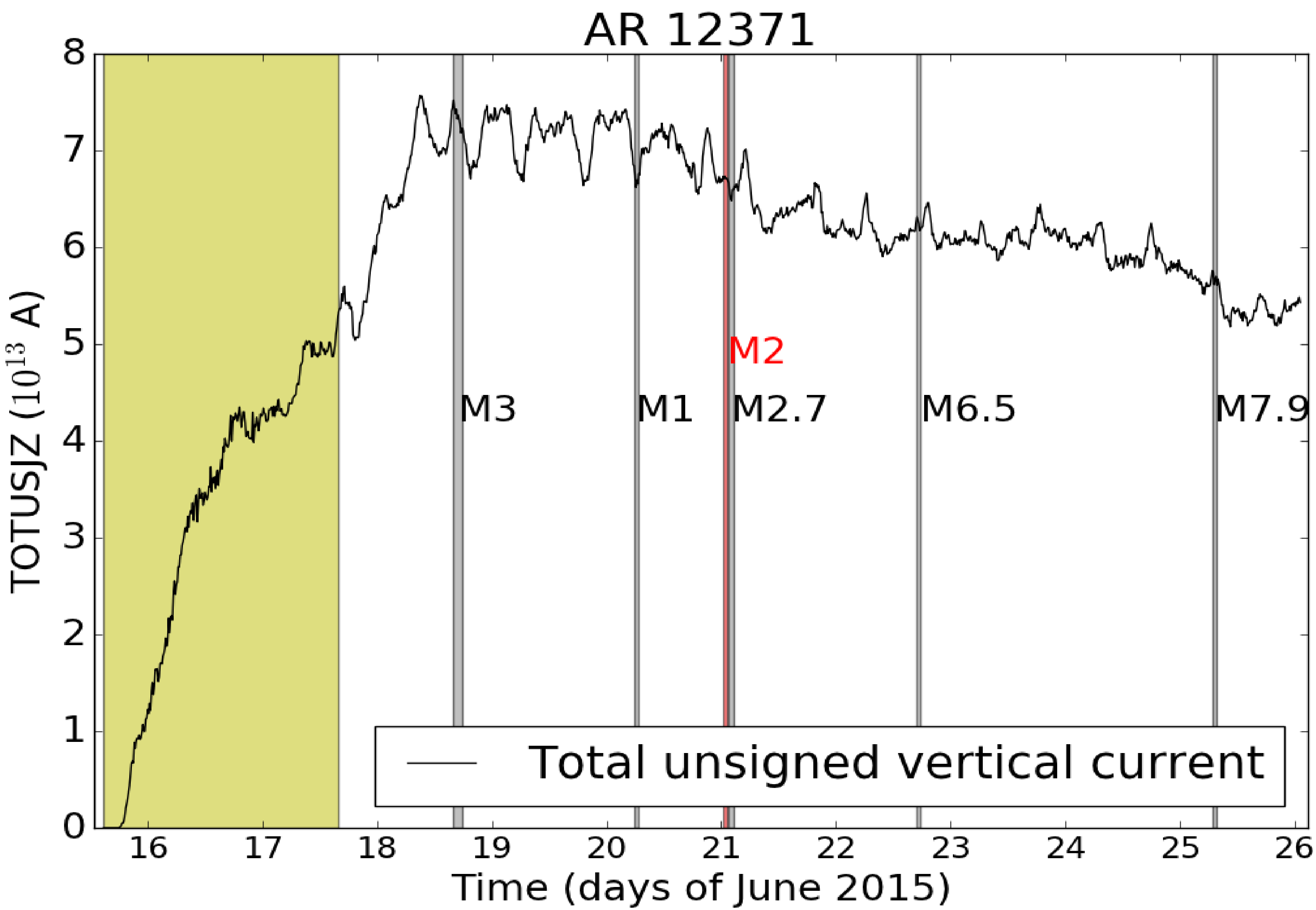

AR 12371
log(R)
5.0
4.5
4.0
3.5
16
17
18
19
20
21
22
23
24
25
26
Time (days of June 2015)
M3
M1
M2
M2.7
M6.5
M7.9
R Schrijver
5%
12%
50%
80%

Log R zoom

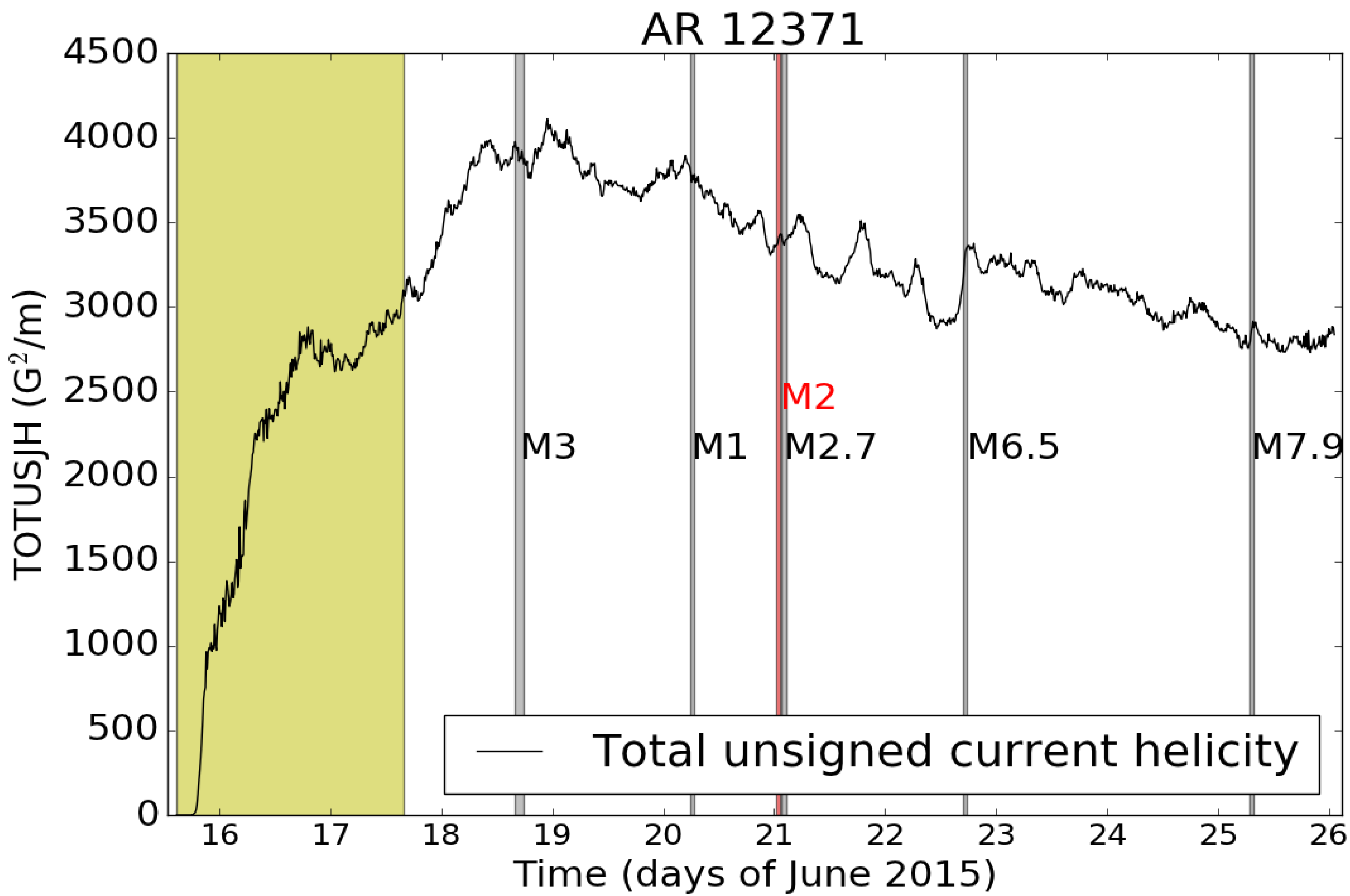


AR 12371
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
log(R)
M2
M2.7
R Schrijver
50%
80%
0:00
1:00
2:00
3:00
4:00
5:00
Time (hours of June 21 2015)

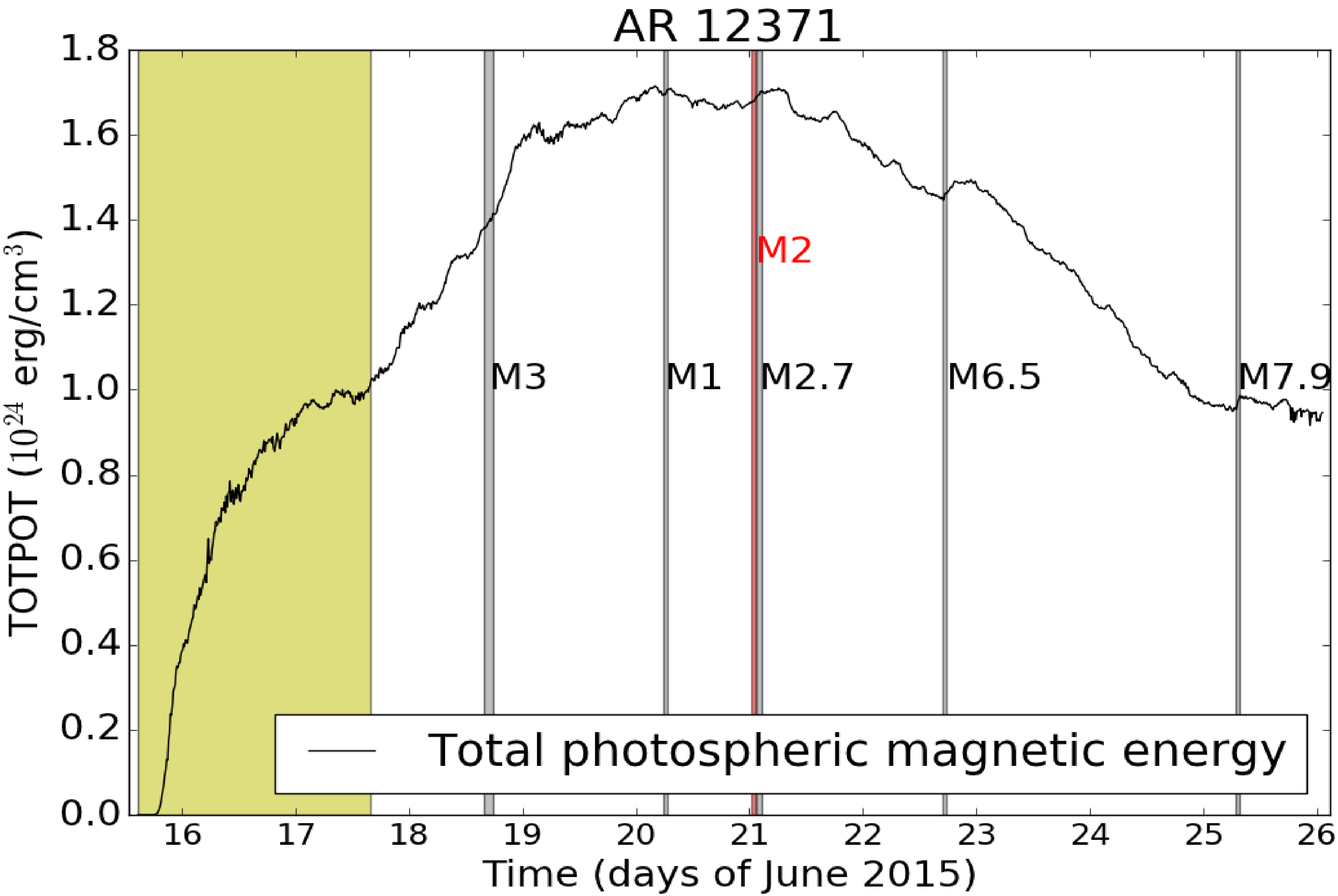
Total unsigned vertical current



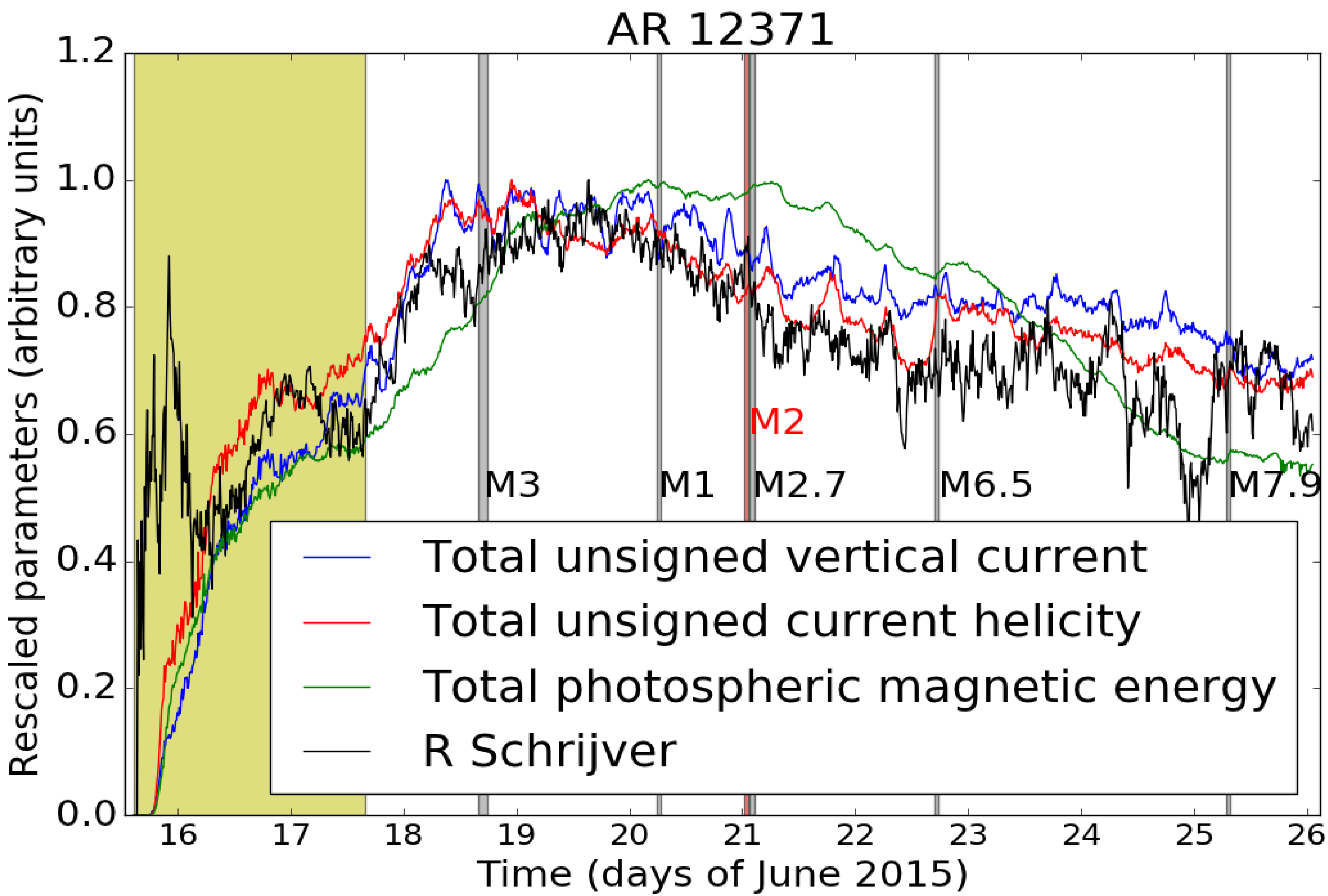
Total unsigned current helicity



Total photospheric magnetic energy



All proxies (rescaled)



Comments on 21 june event

- The probability of having an M flare, is high for the whole period.
- The log(r) values are based on HMI magnetograms, the occurrence rates of flares for a given log(R) value have been computed on MDI data. It is only indicative. A new calibration is necessary.
- The flare prediction is in good agreement with the observed sequence of 6 M-class flares.
- There is little or no evidence at all of a change of configuration of the magnetic field at photospheric level associated to the flare.