Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

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The Solar Bulletin of the AAVSO is a summary of each month's solar activity recorded by visual solar observers' counts of group and sunspots, and the VLF radio recordings of SID Events in the ionosphere. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Compare the GOES-16 XRA flares with AAVSO R_a index

Each month we can compare GOES-16 XRA flares to the AAVSO R_a index. The AAVSO R_a index is using the Shapley method with k-factors to be compared to GOES-16 XRA flare production from the NOAA data. With various group and sunspot classification schemes, these GOES-16 XRA data can be compared to visual observations. See the Reference section for details.

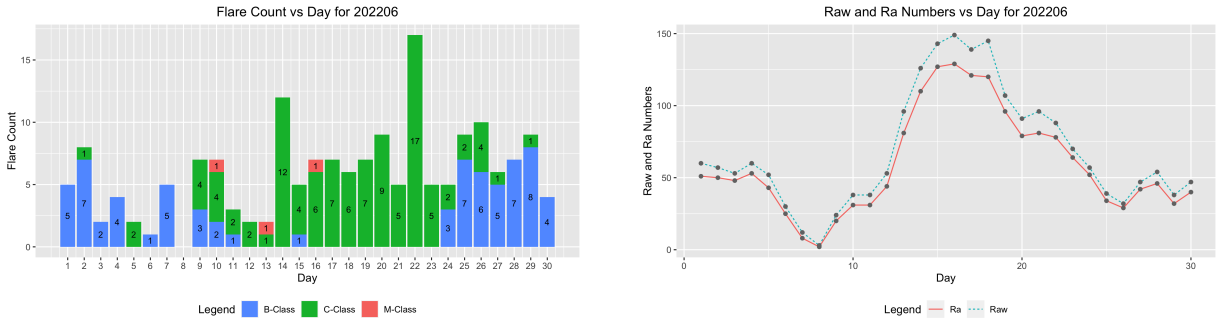

Figure 1: How do the GOES-16 XRA (NOAA, 2022) Solar flares match to AAVSO observers data and the AAVSO R_a index? The GOES-16 XRA flares have 4 categories: B-, C-, M-, X-class flares on a log scale. The AAVSO R_a can be compared with a one-day visual count of the groups and sunspots from an image submitted by Arnaud Mengus (below).

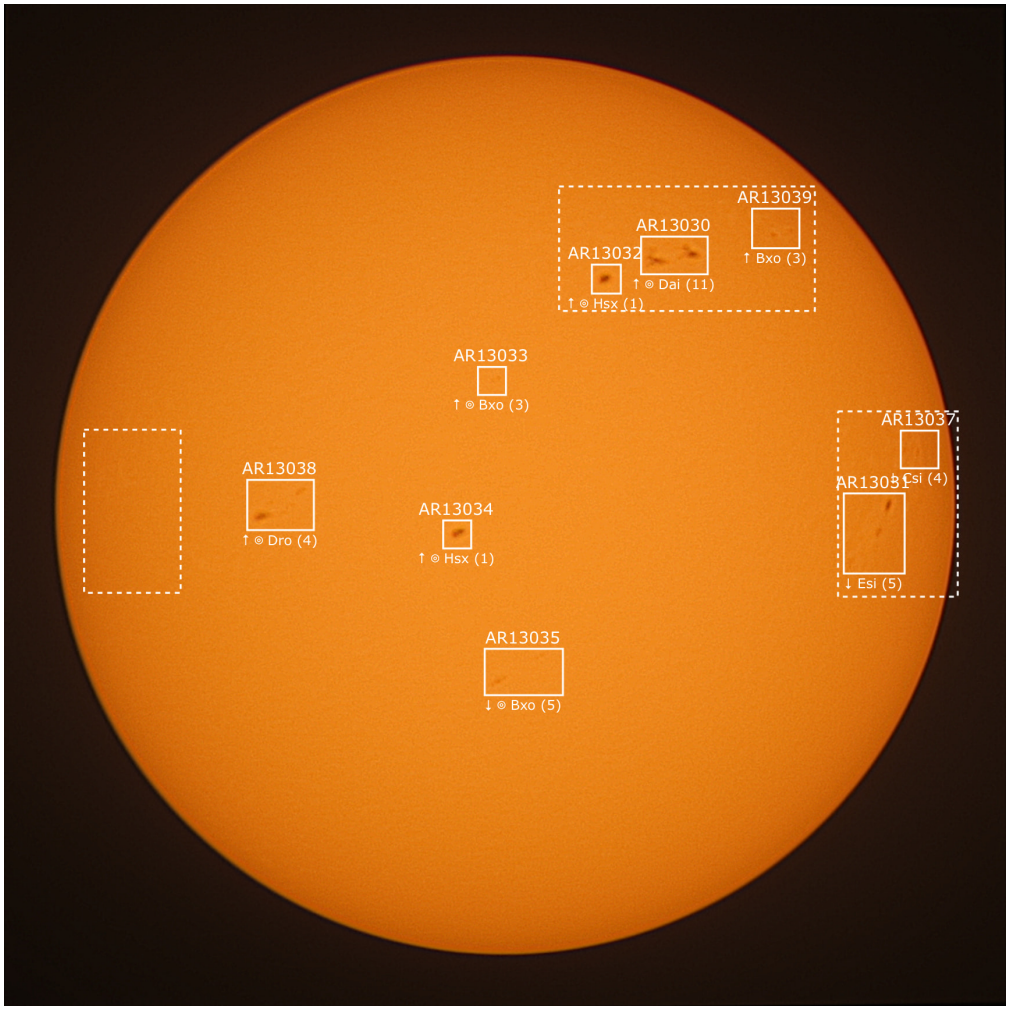

Figure 2: Here is an image by Arnaud Mengus as sent to French Solar report GFOES June 2022. "Arnaud Mengus sends us a nice photo of 18/6. I wish you a beautiful summer, Francois." If you look on the GOES-16 XRA plot, the above graph of data for the 18th of June, you can see only 6 C-class XRA flares for that day. Now compare those numbers with how many groups of sunspots Arnaud has imaged and outlined. And for the same day, the AAVSO observers also record a peak high number for the R_a index. It does not seem the GOES-16 XRA flaring compares well with the daily group and sunspot counts.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

June 2022 (Figure 3) The 14th of June was the most active day recorded here in Fort Collins, Colorado, with 3 SID Events.

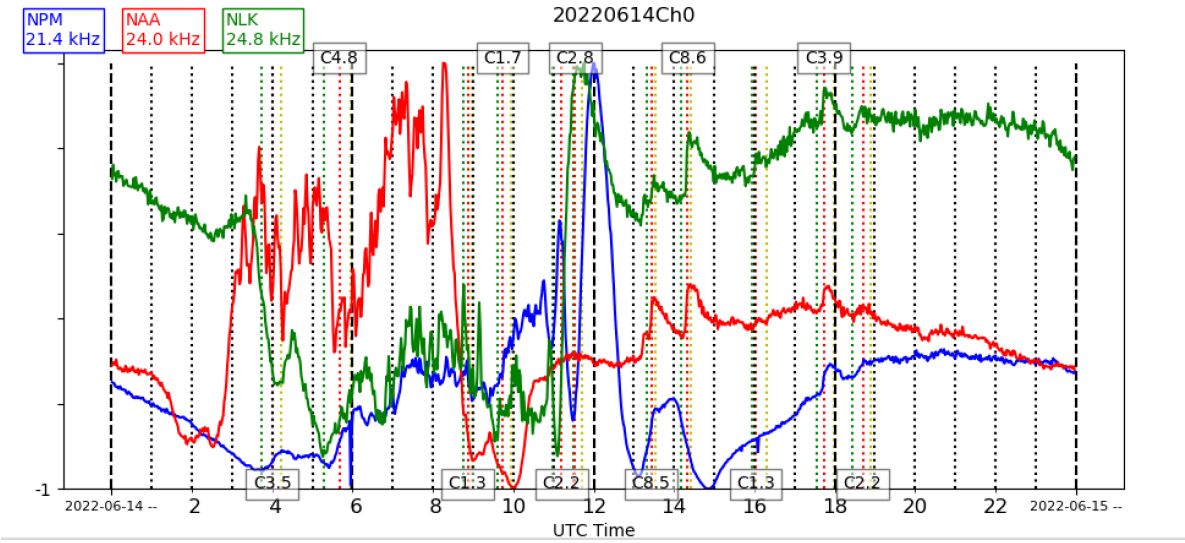

Figure 3: VLF recording on the 14th of June.

2.2 SID Observers

In June 2022, 15 AAVSO SID observers submitted VLF data as listed in Table 1.

Table 1: 202206 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD ICV
F Adamson	A122	NWC
J Karlovsky	A131	DHO NAA TBB
R Green	A134	NWC
R Mrllak	A136	GQD NSY
S Aguirre	A138	NPM NAA
G Silvis	A141	NAA NML NLK
L Pina	A148	NAA NLK NML
J Wendler	A150	NAA
H Krumnow	A152	FTA GBZ HWU
J DeVries	A153	NLK
R Mazur	A155	NLK NML

Figure 4 depicts the importance rating of the solar events. The duration in minutes are -1: LT 19, 1: 19-25, 1+: 26-32, 2: 33-45, 2+: 46-85, 3: 86-125, and 3+: GT 125.

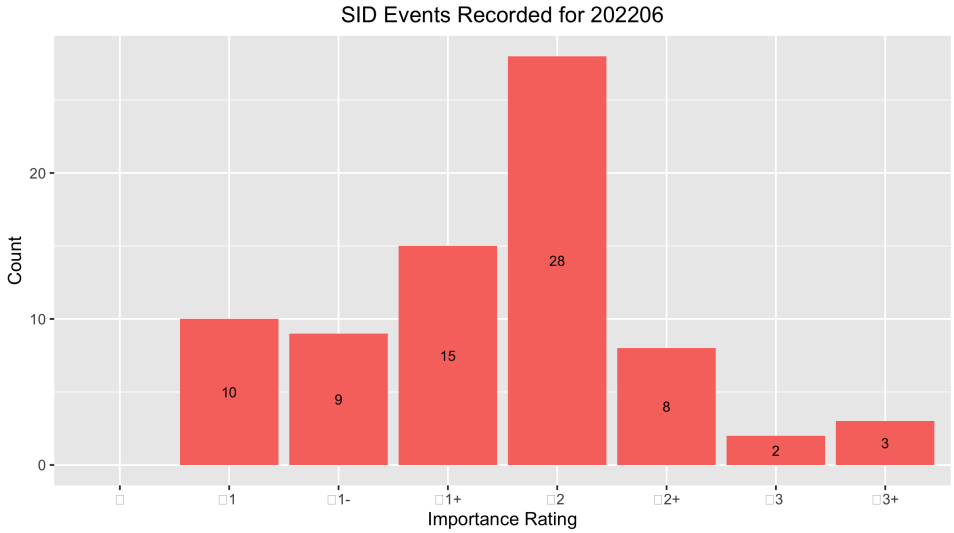

Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In June 2022, there were 178 GOES-16 XRA flares: 3 M-class, 104 C-class, and 71 B-class flares. Far less flaring this month compared to last (Figure 5).

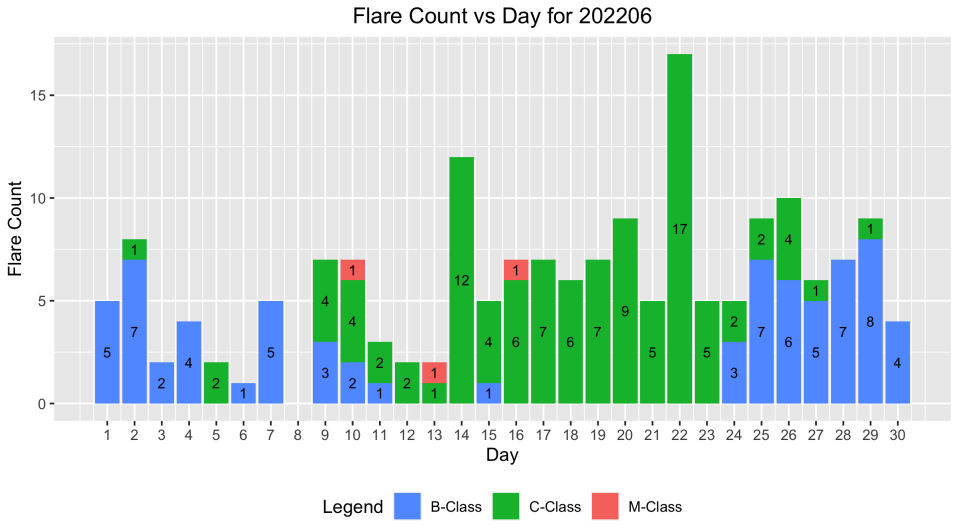

Figure 5: GOES-16 XRA (NOAA, 2022) flares.

3 Relative Sunspot Numbers (R_a)

Reporting monthly sunspot numbers consists of submitting an individual observer's daily counts for a specific month to the AAVSO Solar Section. These data are maintained in a Structured Query Language (SQL) database. The monthly data then are extracted for analysis. This section is the portion of the analysis concerned with both the raw and daily average counts for a particular month. Scrubbing and filtering the data assure error-free data are used to determine the monthly sunspot numbers.

3.1 Raw Sunspot Counts

The raw daily sunspot counts consist of submitted counts from all observers who provided data in June 2022. These counts are reported by the day of the month. The reported raw daily average counts have been checked for errors and inconsistencies, and no known errors are present. All observers whose submissions qualify through this month's scrubbing process are represented in Figure 6.

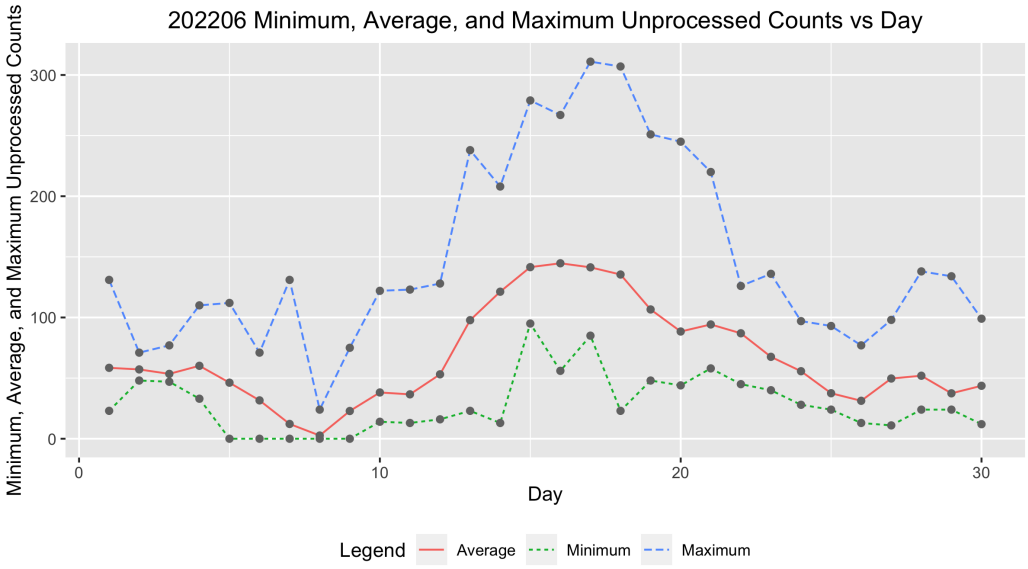

Figure 6: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

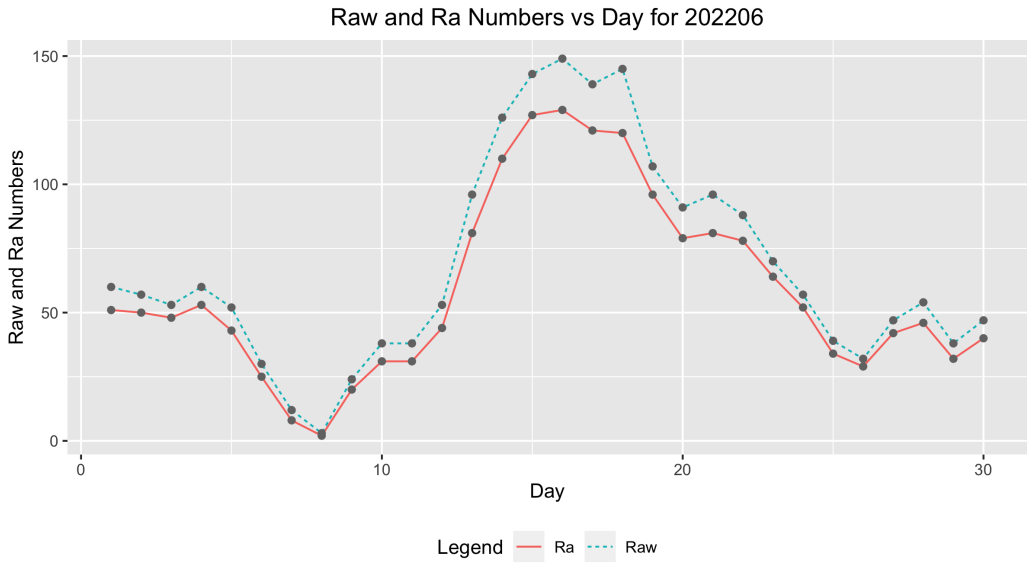

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

3.2 American Relative Sunspot Numbers

The relative sunspot numbers, R_a, contain the sunspot numbers after the submitted data are scrubbed and modeled by Shapley's method with k-factors (`https://adsabs.harvard.edu/full/1949PASP...61...13S`). The Shapley method is a statistical model that agglomerates variation due to random effects, such as observer group selection, and fixed effects, such as seeing condition. The raw Wolf averages and calculated R_a are seen in Figure 7, and Table 2 shows the Day of the observation (column 1), the Number of Observers recording that day (column 2), the Raw Wolf number (column 3), and the Shapley Correction (R_a) (column 4).

Table 2: 202206 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	42	60	51
2	43	57	50
3	47	53	48
4	47	60	53
5	43	52	43
6	40	30	25
7	39	12	8
8	41	3	2
9	50	24	20
10	45	38	31
11	43	38	31
12	45	53	44
13	49	96	81
14	46	126	110

Continued

Table 2: 202206 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	48	143	127
16	45	149	129
17	48	139	121
18	43	145	120
19	52	107	96
20	42	91	79
21	40	96	81
22	38	88	78
23	38	70	64
24	38	57	52
25	40	39	34
26	45	32	29
27	47	47	42
28	50	54	46
29	49	38	32
30	47	47	40
Averages	44.3	68.1	58.9

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for June 2022, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (72), and total number of observations submitted (1330).

Table 3: 202206 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	15	Alexandre Amorim
AJV	21	J. Alonso
ARAG	30	Gema Araujo
ASA	21	Salvador Aguirre
ATE	28	Teofilo Arranz Heras
BATR	10	Roberto Battaiola
BKL	15	John A. Blackwell
BMF	24	Michael Boschat
BMIG	30	Michel Besson
BROB	24	Robert Brown
BXZ	29	Jose Alberto Berdejo
BZX	25	A. Gonzalo Vargas
CANG	12	Andrew Corkill
CIOA	8	Ioannis Chouinavas

Continued

Table 3: 202206 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CKB	18	Brian Cudnik
CMOD	6	Mois Carlo
CNT	22	Dean Chantiles
CVJ	13	Jose Carvajal
DARB	17	Aritra Das
DFR	13	Frank Dempsey
DJOB	6	Jorge del Rosario
DUBF	27	Franky Dubois
EHOA	27	Howard Eskildsen
ERB	17	Bob Eramia
FERA	27	Eric Fabrigat
FLET	30	Tom Fleming
GIGA	27	Igor Grageda Mendez
HALB	16	Brian Halls
HKY	23	Kim Hay
HOWR	22	Rodney Howe
HRUT	27	Timothy Hrutkay
IEWA	26	Ernest W. Iverson
ILUB	6	Luigi Iapichino
JDAC	3	David Jackson
JGE	2	Gerardo Jimenez Lopez
JSI	4	Simon Jenner
KAMB	30	Amoli Kakkar
KAND	26	Kandilli Observatory
KAPJ	26	John Kaplan
KNJS	27	James & Shirley Knight
KZAD	9	Zachary Knoles
LKR	16	Kristine Larsen
LRRA	19	Robert Little
MARC	6	Arnaud Mengus
MARE	11	Enrico Mariani
MCE	16	Etsuiku Mochizuki
MJAF	28	Juan Antonio Moreno Quesada
MJHA	29	John McCammon
MLL	16	Jay Miller
MMAE	9	Aaron McNeely
MMAY	30	Max Surlaroute
MMI	25	Michael Moeller
MSS	7	Sandy Mesics
MUDG	9	George Mudry
MWU	17	Walter Maluf
OAAA	24	Al Sadeem Astronomy Obs.
ONJ	22	John O'Neill

Continued

Table 3: 202206 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
PLUD	19	Ludovic Perbet
RJUB	6	Justus Randolph
RJV	18	Javier Ruiz Fernandez
SDOH	25	Solar Dynamics Obs - HMI
SNE	12	Neil Simmons
SQN	4	Lance Shaw
SRIE	25	Rick St. Hilaire
TDE	30	David Teske
TPJB	4	Patrick Thibault
TST	18	Steven Toothman
URBP	26	Piotr Urbanski
VIDD	21	Dan Vidican
WGI	5	Guido Wollenhaupt
WND	16	Denis Wallian
WWM	28	William M. Wilson
Totals	1330	72

3.4 Generalized Linear Model of Sunspot Numbers

Dr. Jamie Riggs, Solar System Science Section Head, International Astrostatistics Association, maintains a relative sunspot number (R_a) model containing the sunspot numbers after the submitted data are scrubbed and modeled by a Generalized Linear Mixed Model (GLMM), which is a different model method from the Shapley method of calculating R_a in Section 3 above. The GLMM is a statistical model that accounts for variation due to random effects and fixed effects. For the GLMM R_a model, random effects include the AAVSO observer, as these observers are a selection from all possible observers, and the fixed effects include seeing conditions at one of four possible levels. For more details: *A Generalized Linear Mixed Model for Enumerated Sunspots* (see 'GLMM06' in the sunspot counts research page at http://www.spesi.org/?page_id=65).

Figure 8 shows the monthly GLMM R_a numbers for a rolling eleven-year (132-month) window beginning within the 24th solar cycle and ending with last month's sunspot numbers. The solid cyan curve that connects the red *X*'s is the GLMM model R_a estimates of excellent seeing conditions, which in part explains why these R_a estimates often are higher than the Shapley R_a values. The dotted black curves on either side of the cyan curve depict a 99% confidence band about the GLMM estimates. The green dotted curve connecting the green triangles is the Shapley method R_a numbers. The dashed blue curve connecting the blue *O*'s is the SILSO values for the monthly sunspot numbers. The box plot represents the InterQuartile Range (IQR), which depicts from the 25^{th} through the 75^{th} quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25^{th} quartile, and 1.5 times the IQR above the 75^{th} quartile. The black dots below and above the whiskers traditionally are considered outliers, but with GLMM modeling, they are observations that are accounted for by the GLMM model.

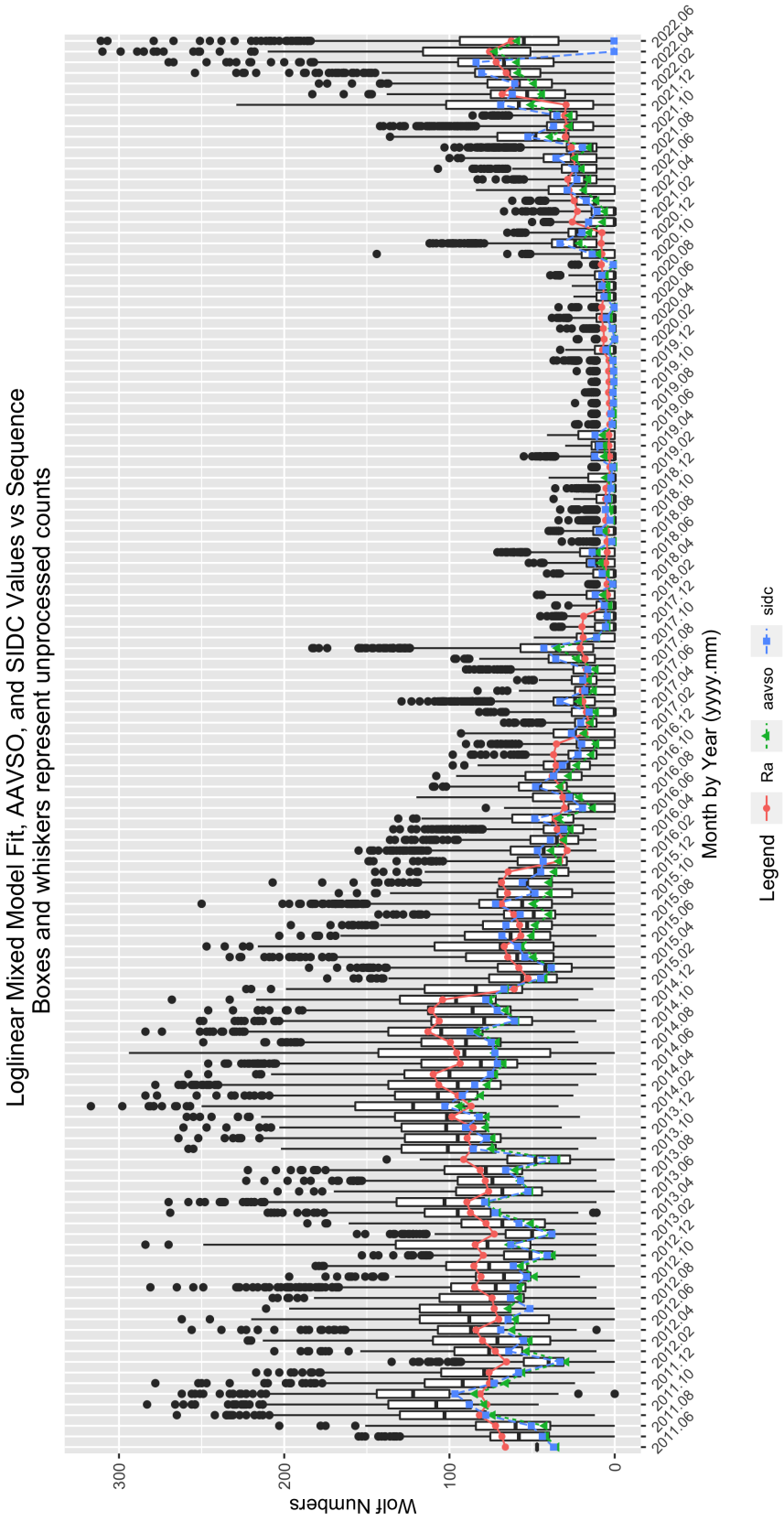

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

- Sunspot Reports: Kim Hay solar@aavso.org
- SID Solar Flare Reports: Rodney Howe ahowe@frii.com

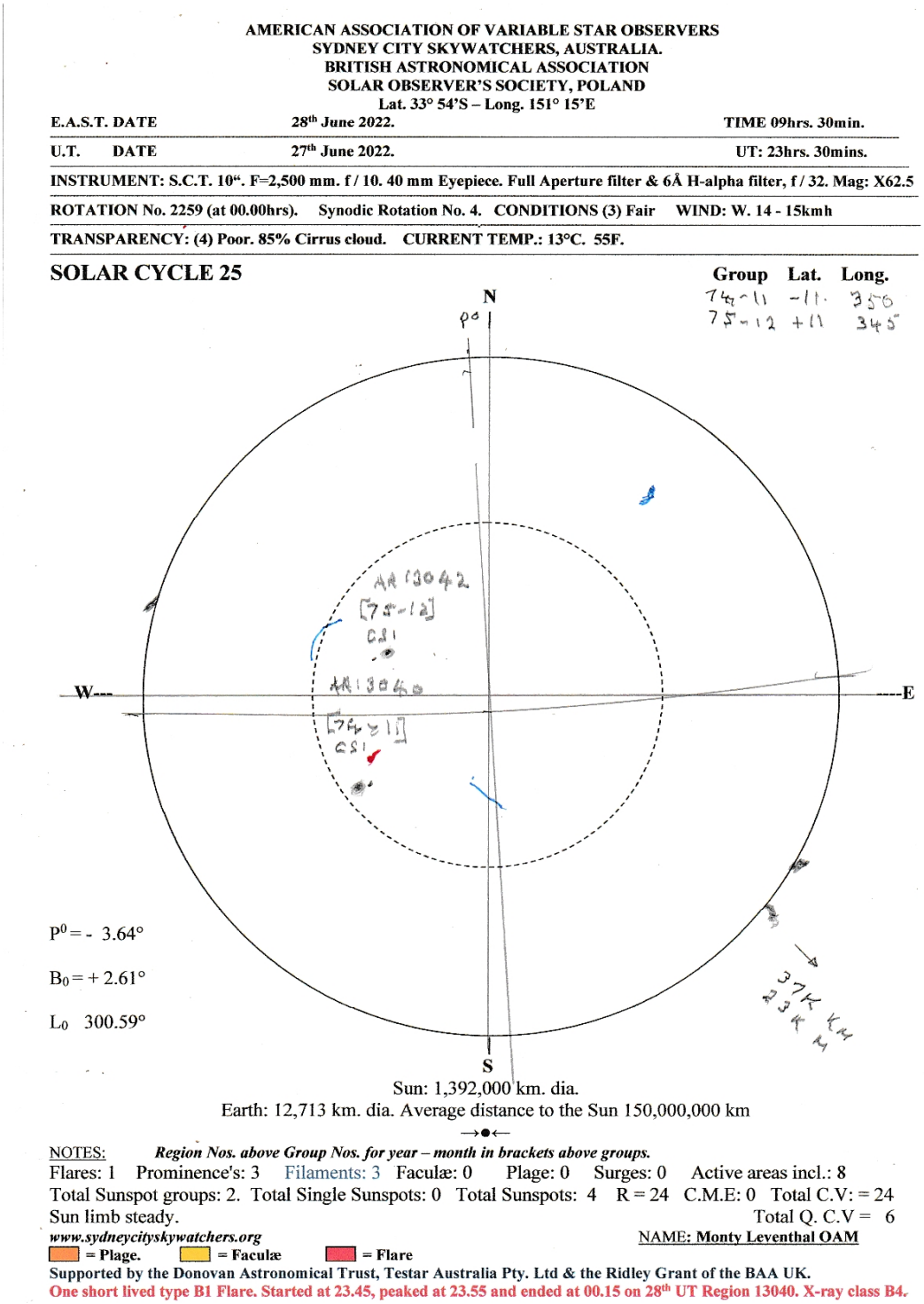

Figure 9: Monty Leventhal (OAM) drew this solar disk on the BAA form for the 27th of June.

5 References

S. Eren, et al., 2016, Flare-production potential associated with different sunspot groups (http: //academic.oup.com/mnras/article/465/1/68/2417463?login=false).

SILSO, World Data Center - Sunspot Number and Long-term Solar Observations, Royal Observatory of Belgium, on-line Sunspot Number catalogue: (https://www.sidc.be/silso/datafiles).

U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center, 2022, GOES-16 XRA data, (ftp://ftp.swpc.noaa.gov/pub/indices/events/).