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 very low frequency (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 Calibrate sunspot observations and Shapley's method with k-factors

The AAVSO aggregates data from dozens of individuals, each of whom brings not only different equipment and observing conditions, but disparate experience in solar observing. In order to turn the individual data points into scientifically useful information, we need to calibrate the observations. There are several aspects to this calibration, including the following: .

1. Percent of repeatability and reproducibility
   This is a representation of the amount of variation related to the observing system for repeatability and reproducibility.

2. Stability
   The total variation in the counts obtained with an observing system of all observers' counts is compared to a single observer's counts through time.

3. Linearity
   The differences in the bias values need to be determined through the expected operating range of the observing system from sunspot counts representing solar minima through sunspot counts representing solar maxima.

4. Percent of tolerance
   This is the percentage of the sunspot count tolerance related to the measurement system for repeatability and reproducibility. Shapley (1949) gives one set of criteria to define allowable tolerance.

Dr. Jamie Riggs (2017) describes the Shapley method as a statistical model that agglomerates variation due to random effects, such as observer group selection, and fixed effects, such as seeing condition. The calculations are shown below:

$$\begin{aligned} \mu &= e^{\beta_0}\, e^{\beta_1 x_1}\, e^{\beta_2 x_2} \\ &= e^{\beta_0+\beta_1 x_1+\beta_2 x_2} \\ \Rightarrow \log\mu &= \beta_1 x_1 + \beta_2 x_2. \end{aligned} \tag{1}$$

"where μ is the expected value of the Wolf number as generated by the model predictor variables x_1 = observer, say, and x_2 = observing method such as projection or direct filtering. The model estimation process calculates the values of β_0 (the model intercept), β_1, and β_2, estimated by likelihood methods, which connect the expected value of the Wolf number to the example's observer and corresponding observation method."

Dr. Riggs further notes that "The Wolf number (R_a) data are not transformed as $\log(R_a)$, rather the expected value of the Wolf number as given by a multiplication of exponential functions is transformed to yield the log of the mean as an additive relationship using the natural log link function as an example." The AAVSO uses the Shapley method and calculates a k-factor for all observers who have at least 100 observations submitted to our database. The k-factors are periodically recalculated. For example, see the changes in k-factors listed in Table 1.

Table 1: 202502 K factor of observations by observer.

Observer Code	Number of observations	old K	new K
AAX	408	0.76	0.632
AJV	339	0.915	0.951
ARAG	620	0.593	0.439
BATR	106	0.806	0.676
BKL	151	1.001	0.715
BMF	176	0.842	1.081
BMIG	450	0.782	0.553
BROB	234	0.848	0.669
BTB	151	0.0	0.772
BXZ	455	0.96	0.8
BZX	443	0.927	0.91
CKB	500	0.755	0.595
CLDB	286	0.0	0.635
CMAB	154	0.0	0.651
CNT	529	0.908	0.728
DARB	400	1.134	0.898
DFR	104	0.966	0.891
DGIA	153	0.0	0.631
DJOB	242	0.804	0.696
DJSA	124	0.0	0.984
DJVA	429	0.0	0.816
DMIB	363	0.805	0.68
DUBF	424	0.742	0.654
EHOA	312	0.875	0.65
ERB	139	1.433	1.4
FALB	116	0.0	2.555
FERA	360	1.203	0.761
FLET	439	0.804	0.598
GIGA	507	1.212	0.756
HALB	259	0.826	0.636
HKY	400	1.136	0.791

Continued

Table 1: 202502 K factor of observations by observer.

Observer Code	Number of observations	old K	new K
HOWR	423	1.171	0.917
HSR	240	0.0	0.538
IEWA	363	1.01	1.083
JGE	104	0.799	0.623
KAND	479	0.825	0.698
KAPJ	240	1.316	1.371
KNJS	524	0.863	0.739
KTOC	204	0.0	0.495
LKR	191	1.073	1.048
LRRA	274	1.238	0.929
LVY	545	0.0	0.768
MARE	280	0.858	0.573
MCE	366	0.79	0.893
MJAF	202	0.646	0.604
MJHA	559	1.232	1.199
MLL	161	1.106	0.637
MMI	606	0.393	0.304
MWMB	161	0.0	0.685
MWU	430	0.862	0.632
NMID	134	0.0	0.639
ONJ	147	1.113	0.804
PLUD	331	0.76	0.547
RJV	309	0.693	0.45
SDOH	606	0.479	0.45
SNE	122	0.956	0.903
SQN	261	0.976	0.628
SRIE	298	0.865	0.592
TDE	446	0.774	0.689
TST	407	1.387	0.901
URBP	460	0.849	0.677
VIDD	269	1.367	0.883
WND	125	0.557	0.459
WWM	293	0.832	0.823
Totals	20333	0.7473	0.7716

The old k - factor average of 0.7473 was calculated during the start of cycle 25 (2023 through 2025) and there are 0 k - factors for some observers. The new k - factor average of 0.7716 shows how from the start of this cycle 25 with new observers the k - factor average should be closer to 1, the optimum for calculating the (R_a) index. There have to be at least 100 observations with the current telescope before the k - factor is calculated.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

November 2025 (Figure 1): There were one X1.2-class, one M-class, 15 C-class flares on the 10th. (U.S. Dept. of Commerce–NOAA, 2022).

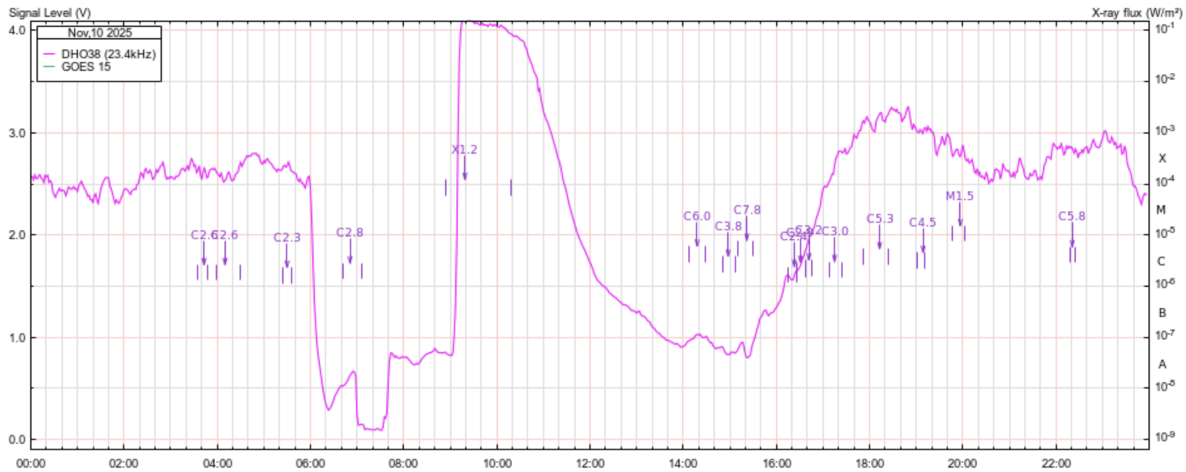

Figure 1: VLF recording from Lionel Loudet (A118) from France.

2.2 SID Observers

In November 2025 we had 11 AAVSO SID observers who submitted VLF data as listed in Table 2.

Table 2: 202511 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
L Loudet	A118	DHO
J Godet	A119	DHO GBZ GQD
J Karlovsky	A131	DHO
R Mrllak	A136	NSY
S Aguirre	A138	NLK
G Silvis	A141	NAA NPM NLK
L Pina	A148	NAA NML
H Krumnow	A152	DHO GBZ
J DeVries	A153	NLK
M Cervoni	A154	DHO ICV

Figure 2 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.

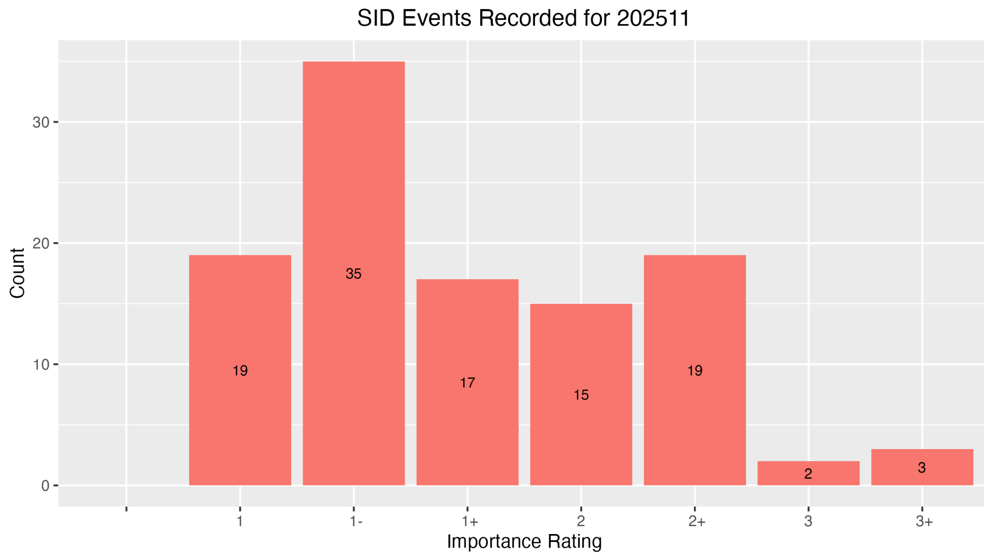

Figure 2: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In November 2025, there were 373 GOES-16 XRA flares for Nov 2025: 6 X-class, 25 M-class, 317 C-class, and 25 B-class, far more flaring than last month. (U.S. Dept. of Commerce–NOAA, 2024). (see Figure 3).

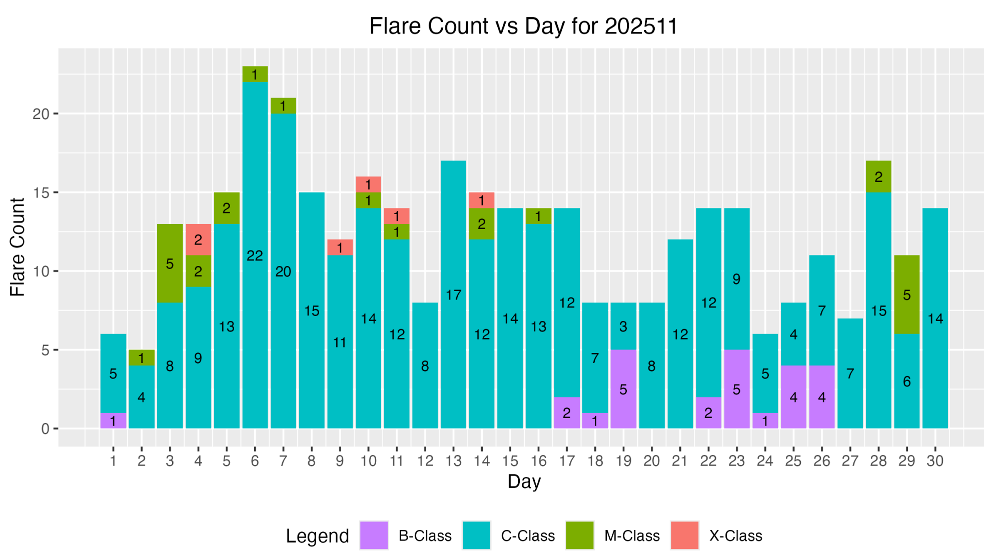

Figure 3: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2024).

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 November 2025. 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 4.

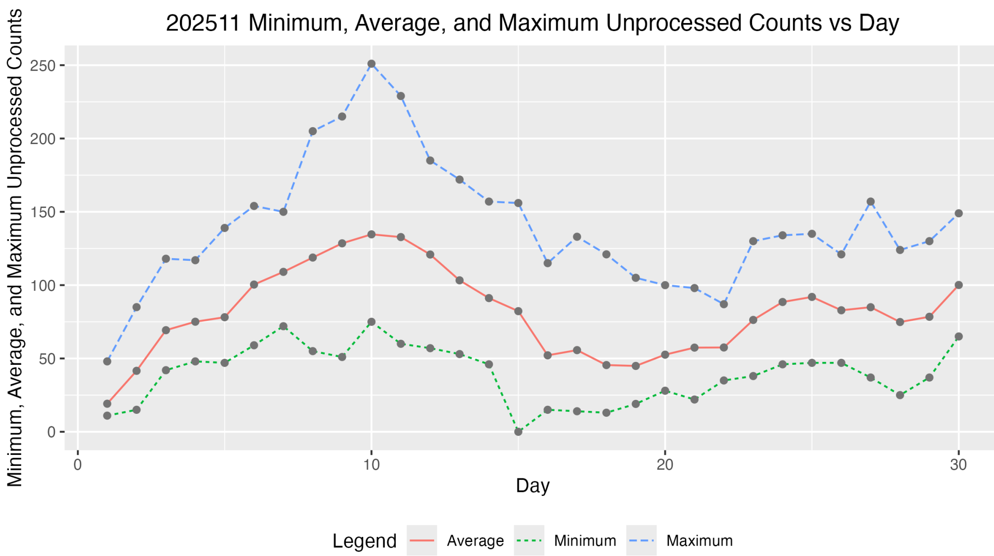

Figure 4: Raw Wolf number average, minimum and maximum by day of the month for all observers.

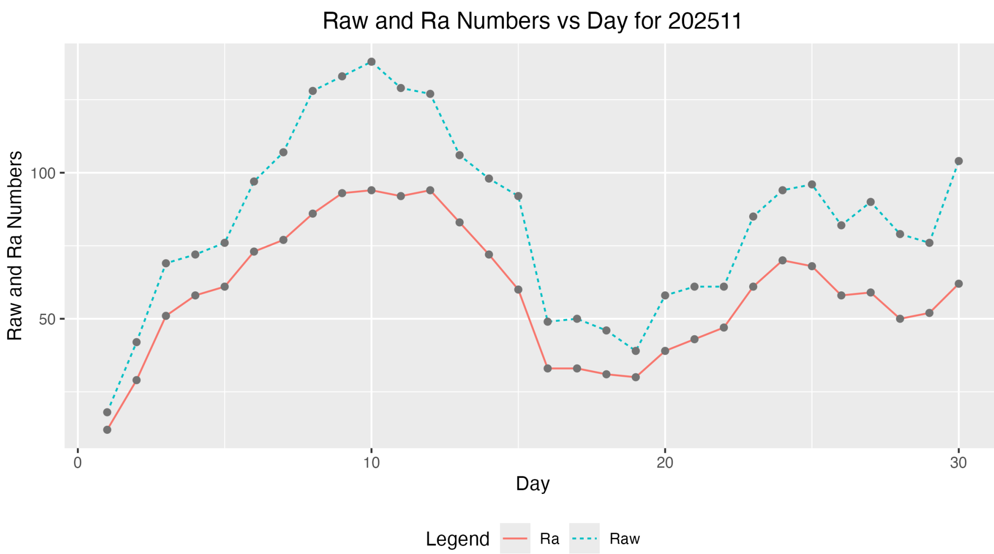

Figure 5: Raw Wolf average and R_a numbers by day of the month for all observers.

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 (`http://iopscience.iop.org/article/10.1086/126109/pdf`). 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 5, and Table 3 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 3: 202511 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	23	18	12
2	28	42	29
3	32	69	51
4	37	72	58
5	24	76	61
6	30	97	73
7	21	107	77
8	27	128	86
9	27	133	93
10	25	138	94
11	27	129	92
12	26	127	94
13	25	106	83
14	24	98	72
15	19	92	60

Continued

Table 3: 202511 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	22	49	33
17	19	50	33
18	26	46	31
19	22	39	30
20	29	58	39
21	23	61	43
22	31	61	47
23	22	85	61
24	24	94	70
25	27	96	68
26	21	82	58
27	22	90	59
28	27	79	50
29	23	76	52
30	18	104	62
Averages	25	83.4	59

3.3 Sunspot Observers

Table 4 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for November 2025, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (56), and total number of observations submitted (751).

Table 4: 202511 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	21	Alexandre Amorim
AJV	8	J. Alonso
ARAG	29	Gema Araujo
ASA	2	Salvador Aguirre
BATR	5	Roberto Battaiola
BMIG	19	Michel Besson
BTB	8	Thomas Bretl
BVZ	16	Jesus E. Blanco
BXZ	25	Jose Alberto Berdejo
BZX	13	A. Gonzalo Vargas
CKB	26	Brian Cudnik
CMAB	3	Maurizio Cervoni
CNT	13	Dean Chantiles
CPAD	2	Panagiotis Chatzistamatiou
CWD	1	David Cowall

Continued

Table 4: 202511 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DARB	30	Aritra Das
DELS	4	Susan Delaney
DFR	6	Frank Dempsey
DGIA	4	Giuseppe di Tommasco
DJOB	10	Jorge del Rosario
DJSA	6	Jeff DeVries
DJVA	27	Jacques van Delft
DMIB	18	Michel Deconinck
DUBF	22	Franky Dubois
EHOA	10	Howard Eskildsen
FALB	18	Allen Frohardt
FERA	10	Eric Fabrigat
GIGA	24	Igor Grageda Mendez
HKY	9	Kim Hay
HOWR	14	Rodney Howe
ILUB	2	Luigi Iapichino
JGE	1	Gerardo Jimenez Lopez
JSI	4	Simon Jenner
KAMB	27	Amoli Kakkar
KAND	24	Kandilli Observatory
KAPJ	14	John Kaplan
KNJS	28	James & Shirley Knight
KTOC	12	Tom Karnuta
LKR	5	Kristine Larsen
LRRA	6	Robert Little
MARC	1	Arnaud Mengus
MARE	10	Enrico Mariani
MJHA	27	John McCammon
MMI	30	Michael Moeller
MUDG	5	George Mudry
MWMB	8	William McShan
MWU	20	Walter Maluf
PLUD	18	Ludovic Perbet
RJV	9	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SNE	7	Neil Simmons
SRIE	3	Rick St. Hilaire
TDE	20	David Teske
TPJB	5	Patrick Thibault
TST	13	Steven Toothman
URBP	19	Piotr Urbanski
Totals	751	56

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. More details on GLMM are available in the paper, *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 6 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 tan box plots for each month are the actual observations submitted by the AAVSO observers. The heavy solid lines approximately midway in the boxes represent the count medians. 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.

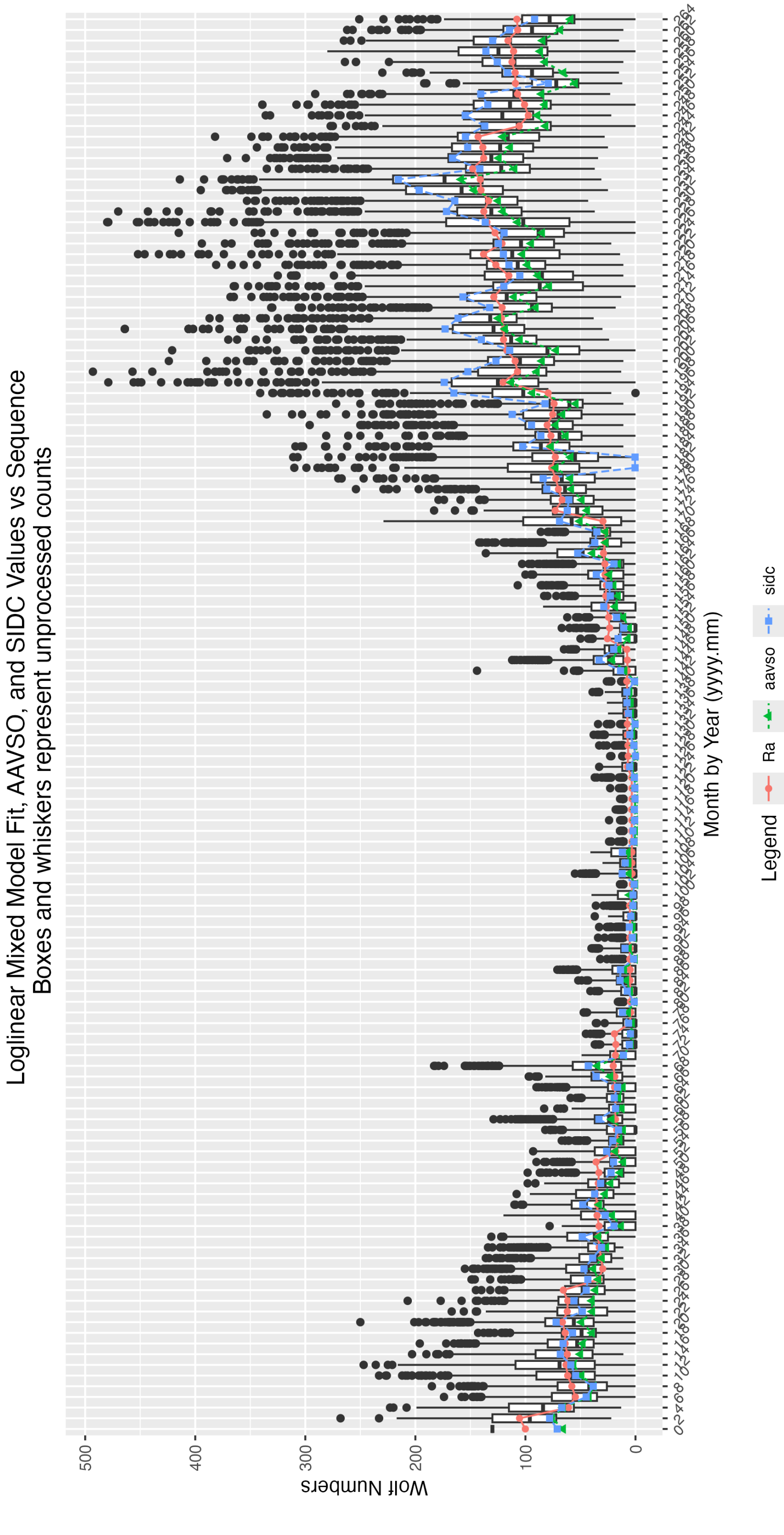

Figure 6: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

- Sunspot Reports: Kim Hay solar@aavso.org
- SID Solar Flare Reports: Rodney Howe rhowe137@icloud.com

5 Antique telescope project

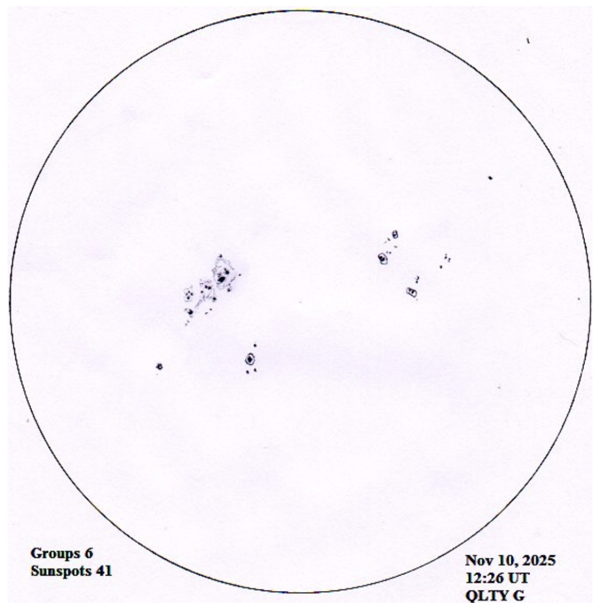

Figure 7: A recent replica of an antique telescope built by Gonzalo Vargas (BZX) in Cochabamba, Bolivia (left), and a drawing for the 10th of November with an X class flare (right).

6 References

Dr. Jamie Riggs (2017), Solar System Science Section Head, International Astrostatistics (using R Statistical Software (2023), TSA Libraries: (`https://cran.r-project.org`)

The longest running AAVSO (R_a) index can be seen on the LASP site: (`https://lasp.colorado.edu/lisird/data/american_relative_sunspot_number_daily`) extracted from the NOAA compilations of 70 years of submitted Solar Bulletins.

Shapley, (1949), method with k-factors (`http://iopscience.iop.org/article/10.1086/126109/pdf`).

U.S. Dept. of Commerce–NOAA, Space Weather Prediction Center (2024). *GOES-16 XRA data.* `ftp://ftp.swpc.noaa.gov/pub/indices/events/`