Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

Rodney Howe, Kristine Larsen, Co-Chairs
c/o AAVSO, 185 Alewife Brook Parkway,
Cambridge, MA 02138 USA

Web: https://www.aavso.org/solar-bulletin
Email: solar@aavso.org

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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 Year end reports and Shapley's method with k-factors

Max Surlaroute's (MMAY) year end report:

GLOBAL DATA SUNSPOTS FOR 2024 BY MONTH											
MONTH	NUMBER OF DAYS	OBSERVERS AAVSO SOLAR SECTION						OBSERVERS INTERNATIONAL GROUP			
		TOTAL OBS	Mean / Day	Raw	Mean / Day	Ra	Mean / Day	TOTAL OBS	Mean / Day	Rint	Mean / Day
1	31	735	23,7	4299	138,7	85	2,7	890	28,7	3905	126,0
2	29	881	30,4	3326	114,7	2749	94,8	806	27,8	3566	123,0
3	31	918	29,6	3195	103,1	2630	84,8	1071	34,5	3215	103,7
4	30	968	32,3	3953	131,8	3212	107,1	1094	36,5	4109	137,0
5	31	1091	35,2	4462	143,9	3737	120,5	1215	39,2	5335	172,1
6	30	1086	36,2	4090	136,3	3743	124,8	1186	39,5	4923	164,1
7	31	1135	36,6	5225	168,5	4549	146,7	1044	33,7	6093	196,5
8	31	1152	37,2	5697	183,8	4909	158,4	1110	35,8	6681	215,5
9	30	956	31,9	3949	131,6	3298	109,9	911	30,4	4241	141,4
10	31	978	31,5	4521	145,8	3849	124,2	893	28,8	5158	166,4
11	30	750	25,0	4203	140,1	3418	113,9	681	22,7	4574	152,5
12	31	663	21,4	4352	140,4	3736	120,5	572	18,5	4790	154,5
Total 2024	**366**	***11313***	***30,9***	***51272***	***140,1***	***39915***	***109,1***	***11473***	***31,3***	***56590***	***154,6***
Mean		**942,8**	**30,9**	**4272,7**	**140,1**	**3326,3**	**109,1**	**956,1**	**31,3**	**4715,8**	**154,6**
Standard Deviation		**3122,4**	**4,9**	**14158,5**	**20,6**	**10934,3**	**19,7**	**3170,9**	**6,6**	**15610,0**	**29,6**

Important Notes : For a given month, the same observer can be counted as many times as there are days in the month.

Sources : For Ra and Raw, Solar Bulletin, AAVSO Solar Section. [https://www.aavso.org/solar-bulletin]
For Rint, SILSO Web site, Daily total sunspot number (1/1/1818 - now). [https://www.sidc.be/silso/INFO/sndtotcsv.php]

Figure 1: Evolution of the number of observers for AAVSO vs. SILSO's international ISN.

"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.

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

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.
"It is important to note 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." (Dr. Jamie Riggs, 2017)

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
HOWR	423	1.171	0.917
HSR	240	0.0	0.538

Continued

Table 1: 202502 K factor of observations by observer.

Observer Code	Number of observations	old K	new K
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

February 2025 (Figure 2): there was one X.2 class, 4 M class, and 7 C class flares on the 23rd. (U.S. Dept. of Commerce–NOAA, 2022).

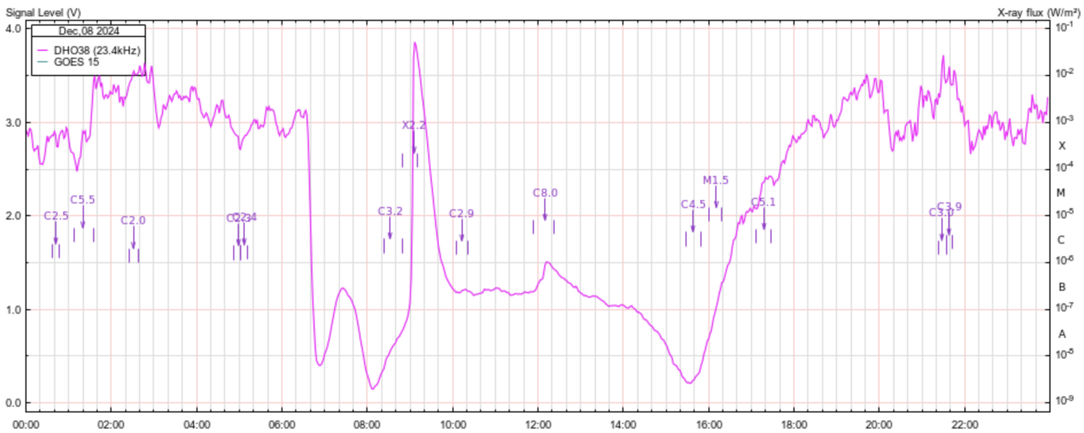

Figure 2: VLF recording from Lionel Loudet (A118) from France.

2.2 SID Observers

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

Table 2: 202502 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	DHO GBZ GQD
J Karlovsky	A131	DHO
R Mrllak	A136	GQD NSY
S Aguirre	A138	NLK
G Silvis	A141	HWU NAU NLK
L Pina	A148	NAA NML
J Wendler	A150	NAA
J DeVries	A153	NLK

Figure 3 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.

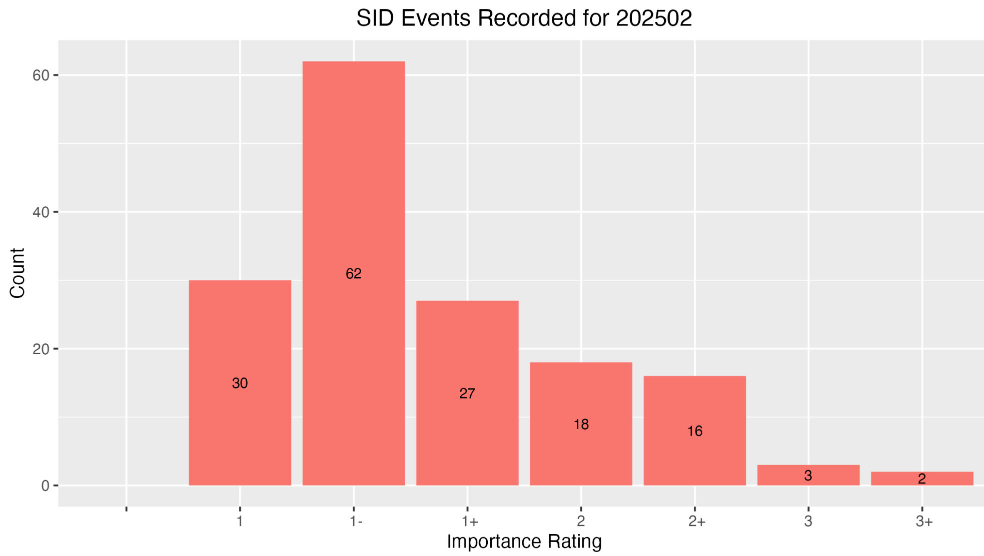

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In February 2025, there were 295 GOES-16 XRA flares for Feb 2025: one X -class, 49 M-class, and 245 C-class, a little more flaring than last month. (U.S. Dept. of Commerce–NOAA, 2024). (see Figure 4).

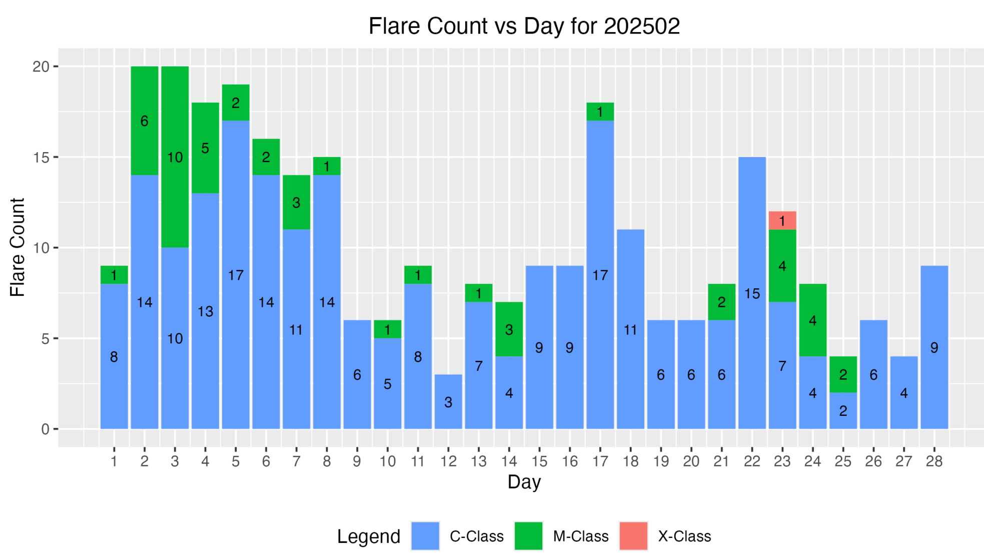

Figure 4: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2024).

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 February 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 5.

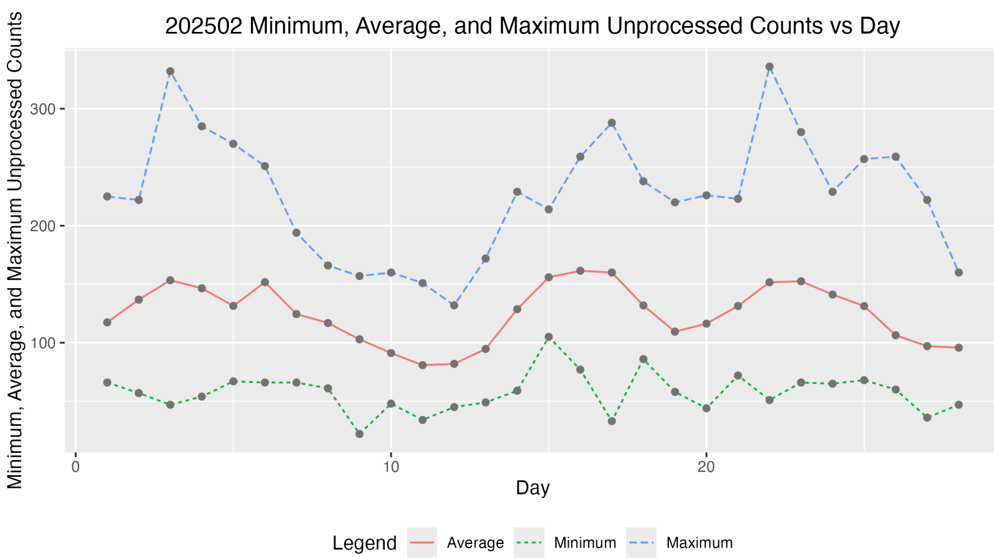

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

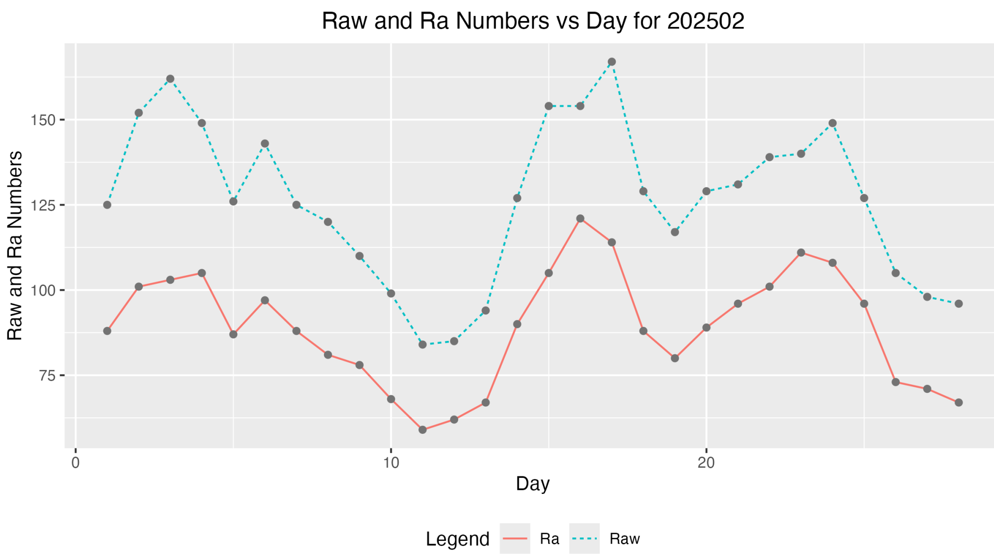

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 6, 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: 202502 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	28	125	88
2	27	152	101
3	29	162	103
4	26	149	105
5	30	126	87
6	27	143	97
7	22	125	88
8	25	120	81
9	25	110	78
10	23	99	68
11	19	84	59
12	20	85	62
13	27	94	67
14	31	127	90
15	24	154	105

Continued

Table 3: 202502 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	33	154	121
17	32	167	114
18	23	129	88
19	23	117	80
20	27	129	89
21	26	131	96
22	29	139	101
23	31	140	111
24	24	149	108
25	28	127	96
26	36	105	73
27	25	98	71
28	31	96	67
Averages	26.8	126.3	89.1

3.3 Sunspot Observers

Table 4 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for February 2025, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (59), and total number of observations submitted (751).

Table 4: 202502 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	21	Alexandre Amorim
AJV	11	J. Alonso
ARAG	28	Gema Araujo
ASA	3	Salvador Aguirre
BATR	1	Roberto Battaiola
BMIG	19	Michel Besson
BTB	3	Thomas Bretl
BVZ	9	Jesus E. Blanco
BXZ	21	Jose Alberto Berdejo
BZX	16	A. Gonzalo Vargas
CKB	18	Brian Cudnik
CLDB	14	Laurent Cambon
CMAB	6	Maurizio Cervoni
CNT	25	Dean Chantiles
DARB	21	Aritra Das
DGIA	8	Giuseppe di Tommasco
DJOB	16	Jorge del Rosario

Continued

Table 4: 202502 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DJSA	6	Jeff DeVries
DJVA	25	Jacques van Delft
DMIB	7	Michel Deconinck
DUBF	18	Franky Dubois
EHOA	5	Howard Eskildsen
FERA	9	Eric Fabrigat
FJOF	6	Joe Fazio
FLET	17	Tom Fleming
HALB	3	Brian Halls
HKY	15	Kim Hay
HOWR	21	Rodney Howe
HSR	10	Serge Hoste
IEWA	11	Ernest W. Iverson
ILUB	5	Luigi Iapichino
JGE	2	Gerardo Jimenez Lopez
KAMB	28	Amoli Kakkar
KAND	10	Kandilli Observatory
KAPJ	7	John Kaplan
KNJS	27	James & Shirley Knight
KTOC	16	Tom Karnuta
LKR	4	Kristine Larsen
LRRA	11	Robert Little
MARC	4	Arnaud Mengus
MARE	10	Enrico Mariani
MCE	26	Etsuiku Mochizuki
MJHA	25	John McCammon
MLL	4	Jay Miller
MMI	28	Michael Moeller
MUDG	1	George Mudry
MWMB	11	William McShan
MWU	23	Walter Maluf
NMID	6	Milena Niemczyk
PLUD	13	Ludovic Perbet
RJV	12	Javier Ruiz Fernandez
SNE	5	Neil Simmons
SQN	5	Lance Shaw
SRIE	6	Rick St. Hilaire
TDE	16	David Teske
TPJB	3	Patrick Thibault
TST	15	Steven Toothman
URBP	24	Piotr Urbanski
VIDD	11	Dan Vidican

Continued

Table 4: 202502 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
Totals	751	59

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 7 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.

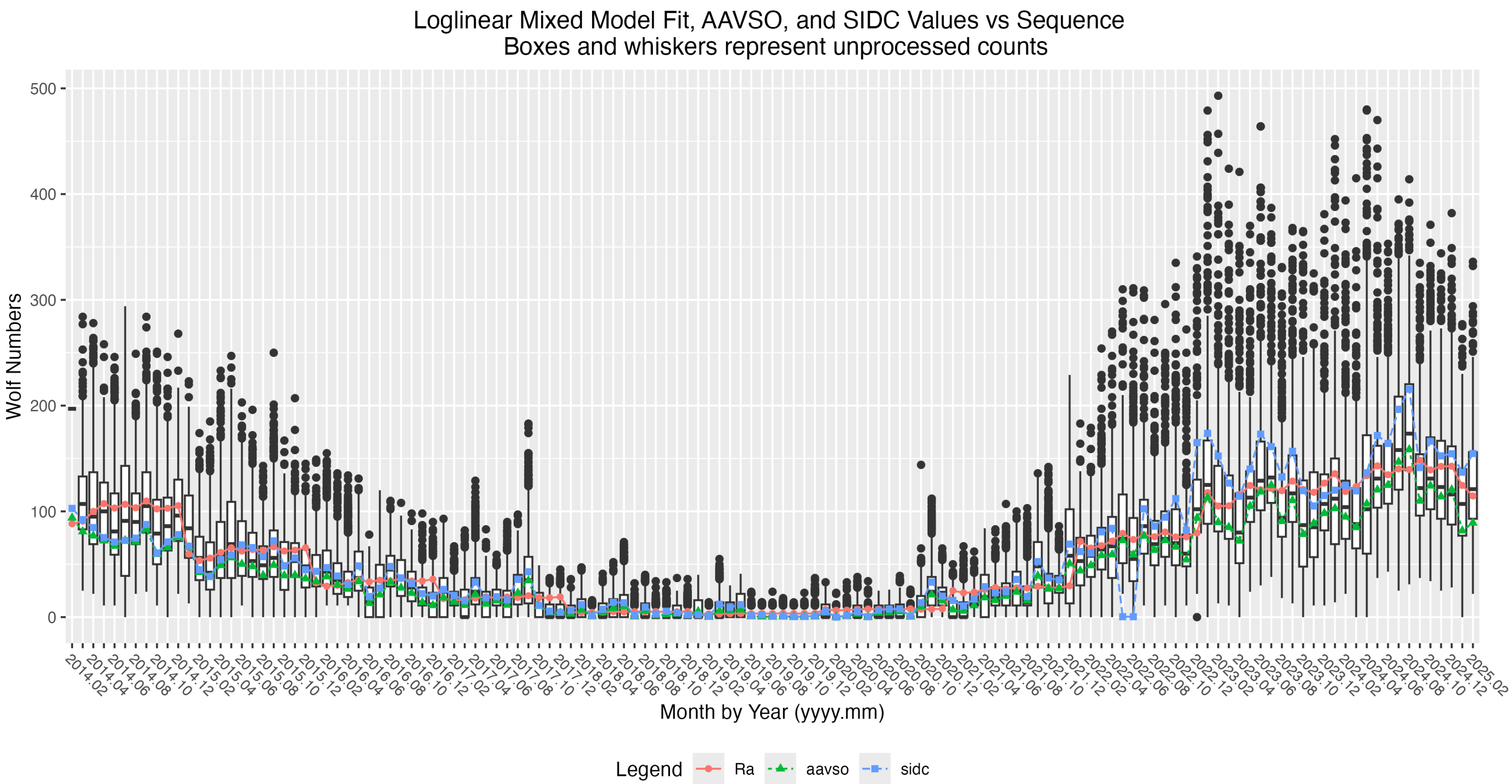

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

5 Antique telescope project

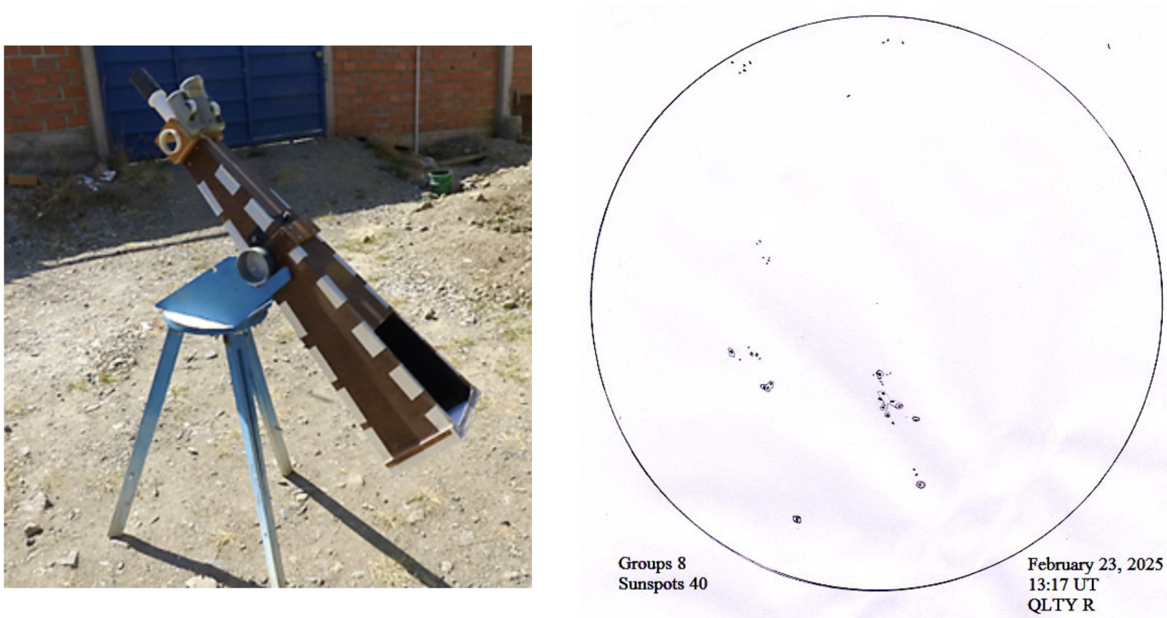

Figure 8: A recent replica of an antique telescope built by Gonzalo Vargas (BZX) in Cochabamba, Bolivia (left), and a drawing for the 23rd of February with an X class flare (right).

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.

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