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 Co-Chairs thank all of our observers for their diligent work in making scientifically useful measurements of our star's activity. Our goal is to make this Bulletin as informational as possible; if you have ideas for material you would like to see included, please email us at the address above. We are also looking for volunteers to write short (less than 500 words in length) articles related to solar observing or the sun in general. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 CCD SDO/HMI imaging skews the AAVSO R_a index values

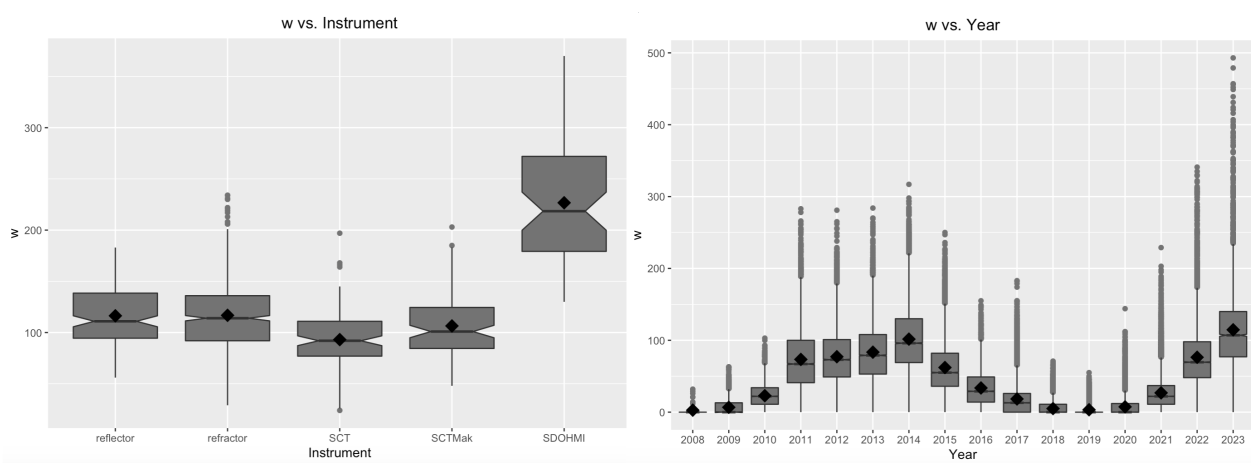

Figure 1: Using the SDO/HMI satellite images for counting groups and sunspots over-counts the AAVSO R_a values by almost 100 percent. The left panel shows the SDO/HMI vs. the other instruments and demonstrates how highly these SDO/HMI counts affect the current cycle 25 (raw Wolf number shown in right panel).

Over the past few years a few of our observers have been using CCD images from the SDO/HMI satellite to count sunspots. Historically (since 1944) the AAVSO has only counted groups and sunspots from under the Earth's atmosphere with small telescopes, during sunny days. Now with the SDO satellite it's possible to count groups and sunspots above the Earth's atmosphere every day of the month. Here we show how these CCD counts over-estimate the Wolf number over the last couple years.

"Although visual counting of spots may sound archaic in comparison with the many advanced modern solar data collected by ground-based observing networks and space missions (25-year old SOHO, SDO, Parker Probe, Solar Orbiter), they remain our sole link to the distant past. In order to put this detailed but mostly very recent solar knowledge in a temporal perspective, it must be attached to a long-term standard. We need to be able to answer one vital question: is the Sun, as we observe it today, equivalent and representative of the state of the Sun several centuries or millennia in the past and in the future? Therefore, today, we need to continue this heritage series in parallel with all other techniques, in order to calibrate the relation between various solar parameters (spectral irradiance, solar wind flux, global magnetic fields) and the sunspot number, and all of this over the whole range of possible activity regimes (See for example Svalgaard, 2017). This means that we must continue to observe the way we have for at least one or more solar cycles (Clette 2021)".

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

September 2023 (Figure 2): On the 21st there was an M8.7 flare recorded by Roberto Battaiola (A96).

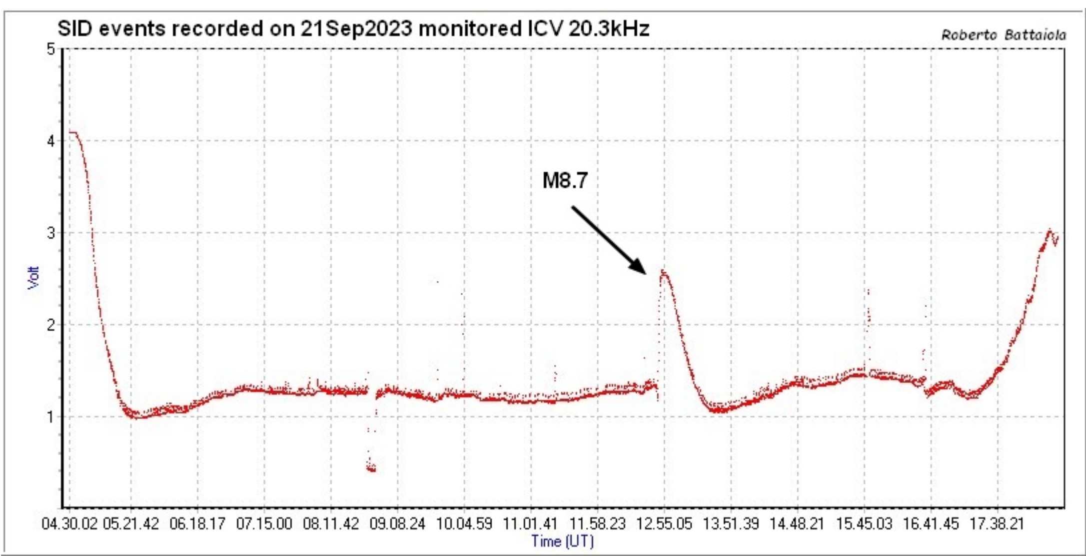

Figure 2: VLF recording from Roberto Battaiola, Milan, Italy.

2.2 SID Observers

In September 2023 we had 15 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202307 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
A Son	A112	DHO
L Loudet	A118	DHO GQD
J Godet	A119	GBZ GQD ICV
F Adamson	A122	NWC
J Karlovsky	A131	TBB
R Mrllak	A136	GQD NSY
S Aguirre	A138	NAA
G Silvis	A141	NAA NAU NLK
L Pina	A148	NAA NLK
J Wendler	A150	NAA
H Krumnow	A152	DHO FTA GBZ
J DeVries	A153	NLK
M Salo	A157	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.

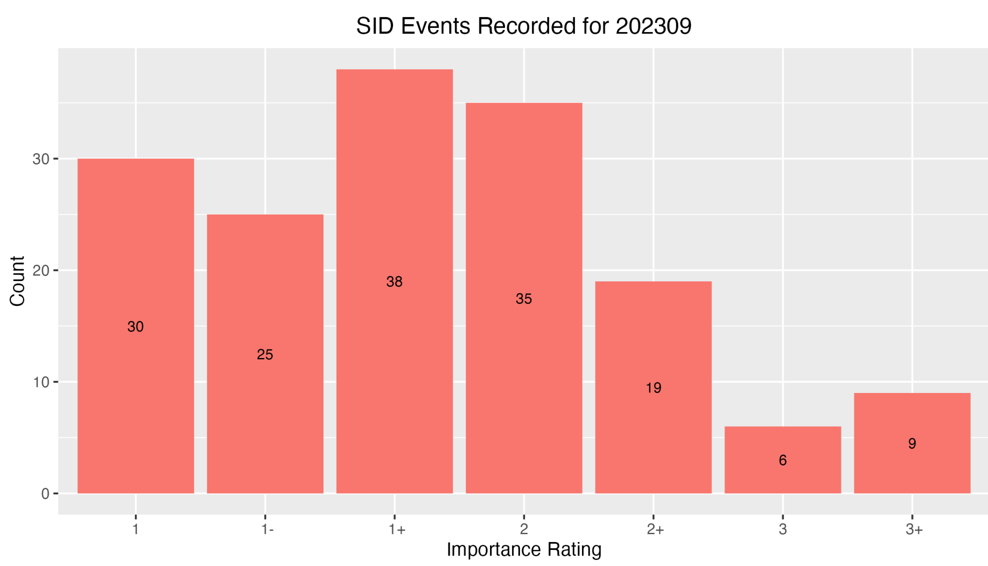

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In September 2023, there were 293 GOES-16 XRA flares: 256 C-class and 34 M-class and and 3 B-class flares. This is about the same as seen last month. (U.S. Dept. of Commerce–NOAA, 2022). (see Figure 4).

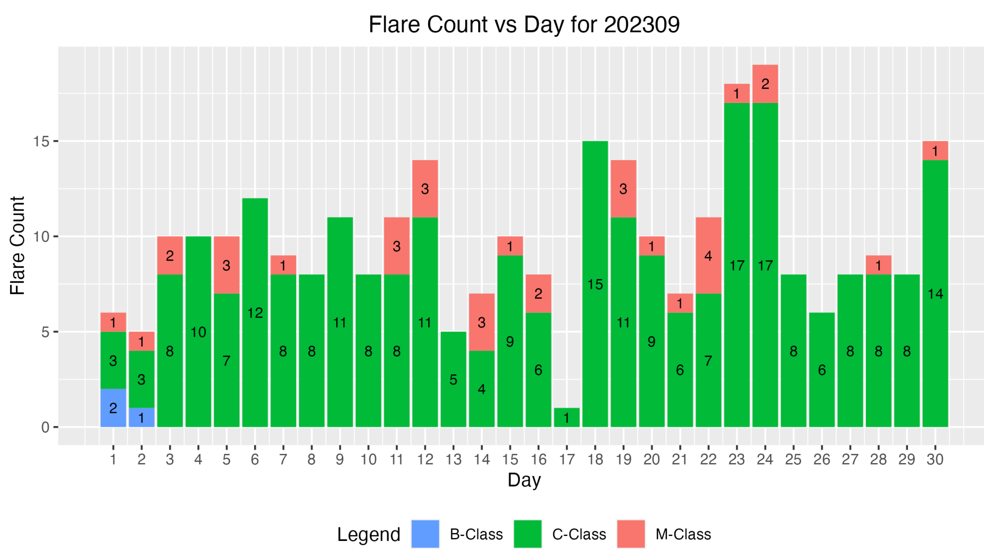

Figure 4: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 are then 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 September 2023. 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. As described on the first page, SDO/HMI data are not consistent with AAVSO protocols and are removed in the scrubbing process. All observers whose submissions qualify through this month's scrubbing process are represented in Figure 5.

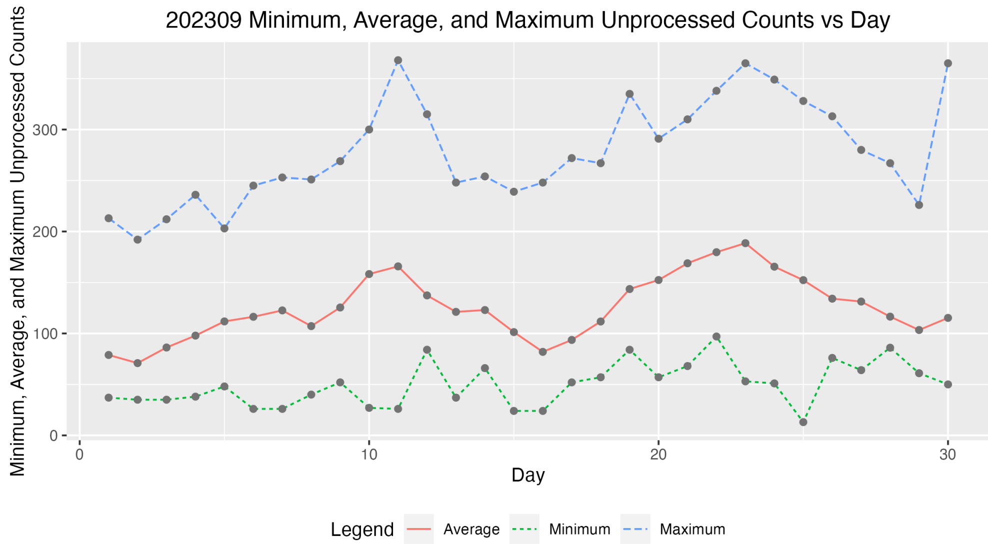

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

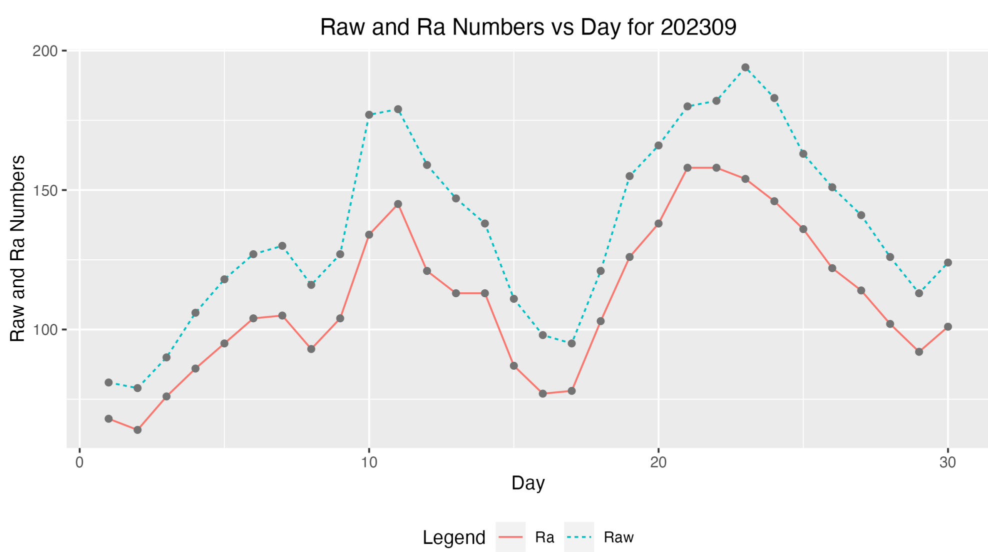

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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: 202309 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	42	81	68
2	40	79	64
3	41	90	76
4	40	106	86
5	39	118	95
6	43	127	104
7	42	130	105
8	43	116	93
9	39	127	104
10	41	177	134
11	40	179	145
12	33	159	121
13	30	147	113
14	37	138	113
15	32	111	87
16	38	98	77
17	37	95	78
18	38	121	103
19	45	155	126
20	38	166	138
21	35	180	158
22	45	182	158
23	40	194	154
24	43	183	146
25	39	163	136
26	40	151	122
27	36	141	114
28	34	126	102
29	36	113	92
30	41	124	101
Averages	38.9	135.9	110.4

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for September 2023, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (74), and total number of observations submitted (1167).

Table 3: 202309 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	21	Alexandre Amorim
AJV	15	J. Alonso
ARAG	30	Gema Araujo
ASA	4	Salvador Aguirre
ATE	5	Teofilo Arranz Heras
BATR	10	Roberto Battaiola
BKL	10	John A. Blackwell
BMF	14	Michael Boschat
BMIG	28	Michel Besson
BRAF	4	Raffaello Braga
BROB	25	Robert Brown
BXZ	23	Jose Alberto Berdejo
BZX	21	A. Gonzalo Vargas
CIOA	1	Ioannis Chouinavas
CKB	27	Brian Cudnik
CLDB	19	Laurent Cambon
CMAB	14	Maurizio Cervoni
CNT	21	Dean Chantiles
CVJ	9	Jose Carvajal
DARB	7	Aritra Das
DFR	9	Frank Dempsey
DJOB	10	Jorge del Rosario
DJSA	9	Jeff DeVries
DJVA	20	Jacques van Delft
DMIB	29	Michel Deconinck
DUBF	19	Franky Dubois
EHOA	23	Howard Eskildsen
ERB	6	Bob Eramia
FALB	19	Allen Frohardt
FERA	8	Eric Fabrigat
FLET	26	Tom Fleming
FTAA	9	Tadeusz Figiel
GIGA	29	Igor Grageda Mendez
HALB	20	Brian Halls
HKY	24	Kim Hay
HOWR	25	Rodney Howe
HSR	17	Serge Hoste
IEWA	22	Ernest W. Iverson

Continued

Table 3: 202309 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
ILUB	10	Luigi Iapichino
JGE	7	Gerardo Jimenez Lopez
JSI	5	Simon Jenner
KAND	27	Kandilli Observatory
KAPJ	12	John Kaplan
KNJS	26	James & Shirley Knight
KSOB	5	Souvik Karmokar
KTOC	14	Tom Karnuta
LKR	5	Kristine Larsen
LVY	25	David Levy
MARC	5	Arnaud Mengus
MARE	17	Enrico Mariani
MCE	19	Etsuiku Mochizuki
MJHA	23	John McCammon
MLL	10	Jay Miller
MMI	30	Michael Moeller
MSS	10	Sandy Mesics
MWMB	2	William McShan
MWU	20	Walter Maluf
ONJ	9	John O'Neill
PLUD	17	Ludovic Perbet
RARD	5	Arnav Ranjekar
RJV	17	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SJUA	14	Julian Simon Lopez-Villalta
SNE	2	Neil Simmons
SRIE	18	Rick St. Hilaire
TDE	24	David Teske
TNIA	15	Nick Tonkin
TPJB	2	Patrick Thibault
TST	20	Steven Toothman
URBP	28	Piotr Urbanski
VIDD	14	Dan Vidican
WGI	3	Guido Wollenhaupt
WND	20	Denis Wallian
WWM	25	William M. Wilson
Totals	1167	74

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.

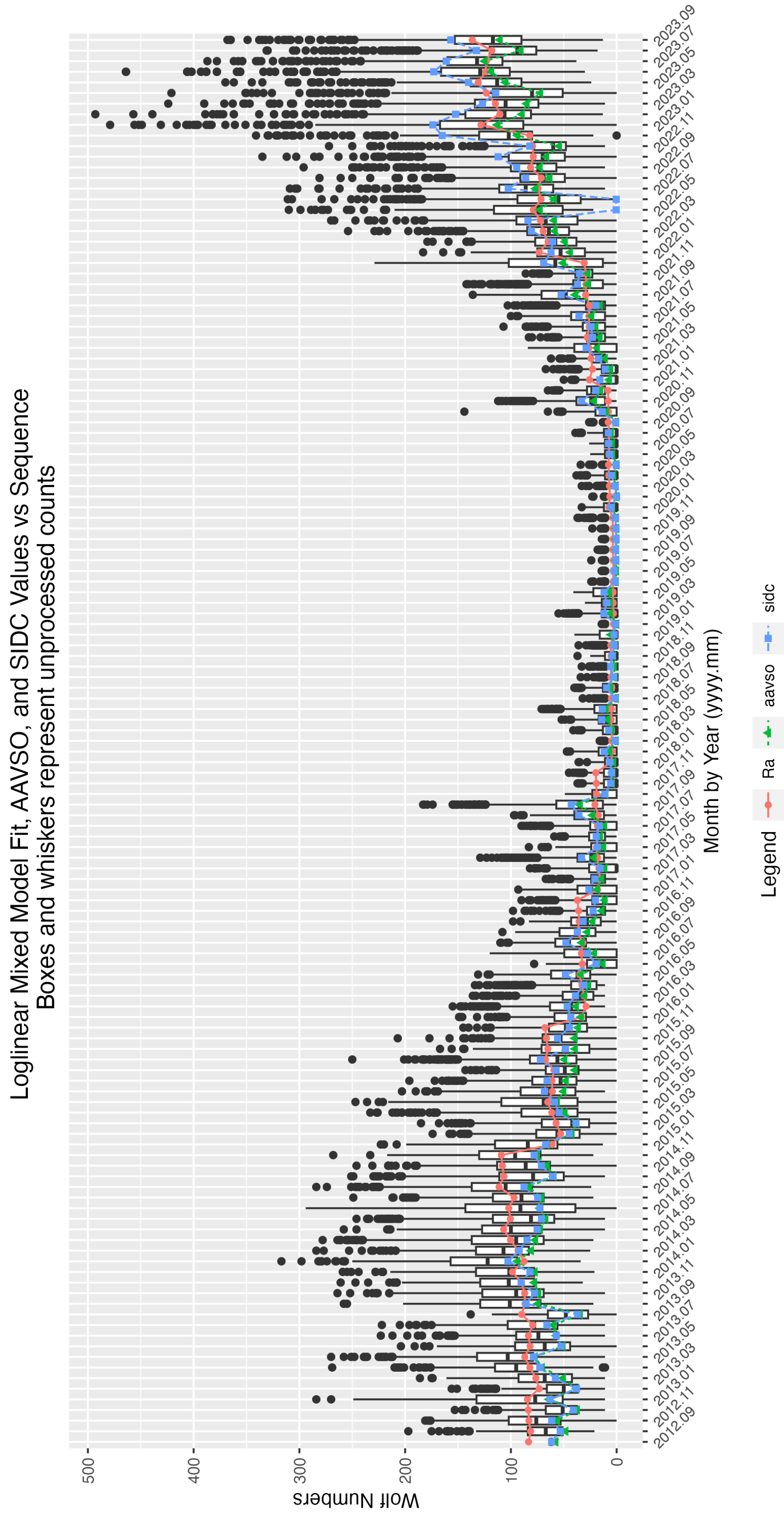

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

4.1 Antique telescope project

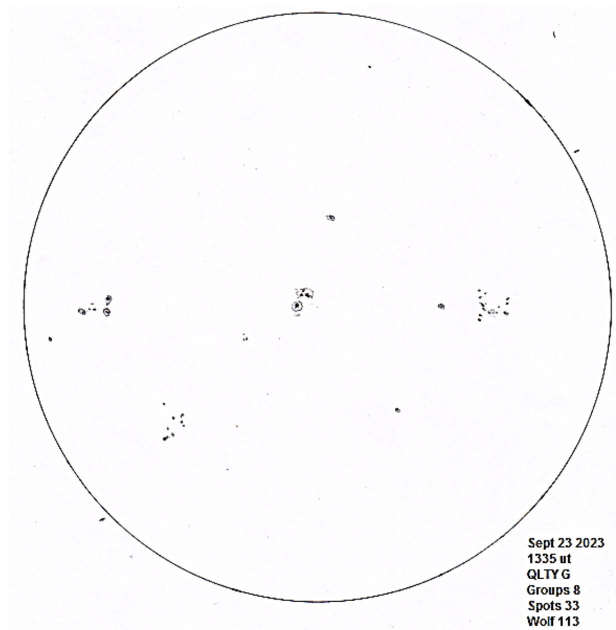

Figure 8: A recent replica of an antique telescope built by Gonzalo Vargas (BZX) (left), and a drawing for September 23 (right).

5 References

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

Clette, Fr'ed'eric (2021), The Sunspot Number: *Reconstructing the Past Solar Cycle for the Future.* [data set]. Space Research Today 210: 10-23. Royal Observatory of Belgium. `https://www.sidc.be/silso/datafiles`.

SDO — Data, *The Sun Now* `https://sdo.gsfc.nasa.gov/data/aiahmi/`

Svalgaard, L., [and Schatten, K. H.] (2017), *Sunspot Group Numbers Since 1900 and Implications for the Long-term Record of Solar Activity.* `https://www.researchgate.net/publication/316736457_Sunspot_Group_Numbers_Since_1900_and_Implications_for_the_Long-term_Record_of_Solar_Activity`