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 Antique telescope project

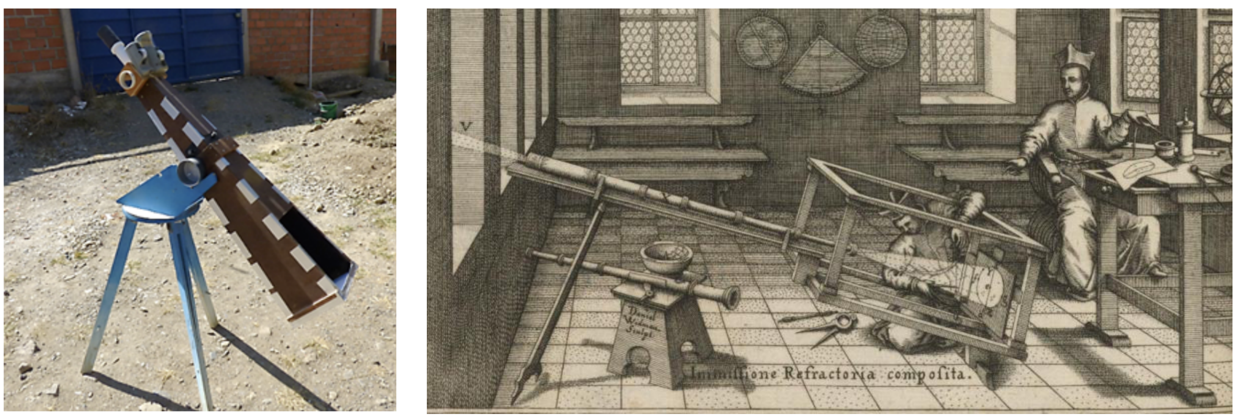

Figure 1: A recent replica of an ancient telescope built by Gonzalo Vargas (BZX) (left), and an observatory built by Christopher Scheiner (1630) (right).

For those who like to build telescopes, like observer Gonzalo Vargas (BZX), left panel, here is a project for duplicating antique telescopes from the past. These are small aperture telescopes that will be useful for collecting data for a project being sponsored by solar physicist Dr. Leif Svalgaard. "The novelty is that now I believe that this small instrument could be part of a program at Stanford University (USA), dedicated to a study and analysis of observations that began in ancient times (since the time of Galileo in 1610). The objective is to study or estimate in depth the quality of ancient observations with small refractors and compare with the observations that can be made today with instruments almost similar to those used in ancient times. This study project is very extensive and we hope to contribute with the information that is required. For sure, we will be commenting on everything related to this project and the progress it may have" (Leif Svalgaard, 2022). To contribute to this ongoing project, please visit `https: //www.aavso.org/solar-observing-project`.

Gonzalo Vargas (BZX) recorded the following data for December 2022 using his replica of an ancient refractor telescope. He explained his seeing (observations) and how he categorized what he viewed:

> "First I see the edge of the solar disk, if it is stable, the smallest sunspots are generally clearly observed, the granulation is also clearly seen and for me the seeing is E. If the sun's edge shows some vibration (generally when there are cirrus-type clouds) it indicates that there are currents in the atmosphere and I observe that the sunspots go from a good and clear image to another less clear one as if they were vibrating. Then my evaluation of the seeing is G. If I see the spots not very clearly, but I can count them at times, since the granulation is not very visible and the solar edge permanently shows vibration, my evaluation of seeing is F. If the solar limb or border is highly vibrating and I can't see granulation and solar sunspots are not clear, I cancel observations."(Personal communication, December 6, 2022)

Table 1: 202212 RG Telescope data

Day	TIME UT	SEE	G	S	Wolf
1	1255	G	3	5	35
4	1156	G	5	16	66
5	1215	F	5	26	76
8	1210	F	5	23	73
10	1310	F	7	26	96
12	2113	F	9	30	120
14	1310	F	8	38	118
15	1205	F	7	34	104
16	1230	F	7	33	103
17	1220	E	7	25	95
18	1320	F	7	33	103
20	1306	G	6	35	95
21	1312	F	6	19	79
22	1308	G	5	16	66
23	1250	G	6	14	74
24	1234	G	5	22	72
25	1302	F	5	19	69
26	1346	F	5	22	72
27	1305	G	5	22	72
31	1226	E	5	31	81
Averages			5.9	24.5	83.5

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

December 2022 (Figure 2): There were 6 M-Class flares during the daytime recorded in Milan, Italy where we can see a stream of SID Events during day time hours on the 14th of December.

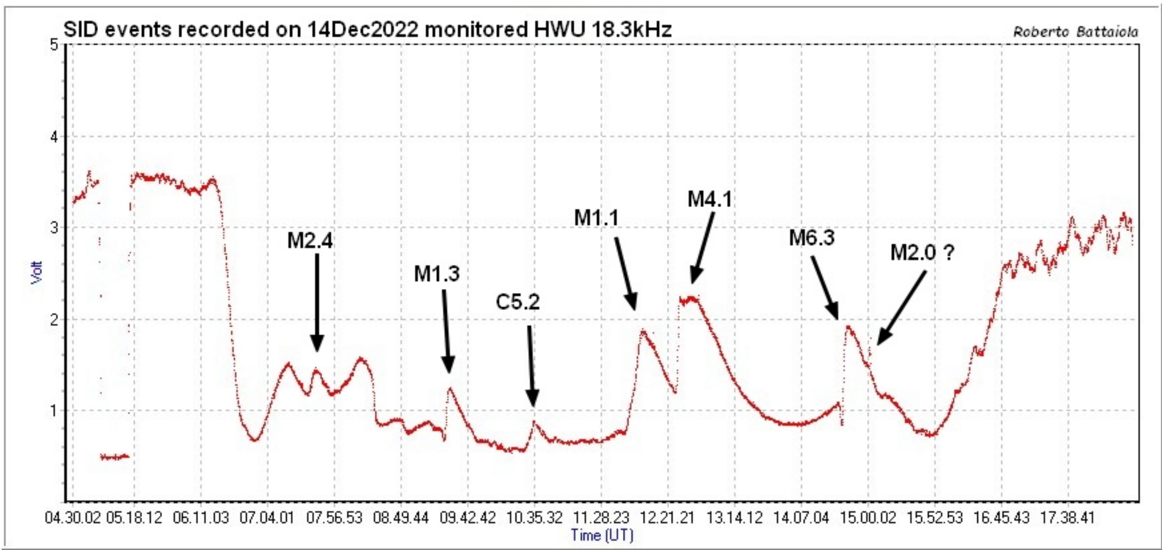

Figure 2: VLF recording from Milan, Italy by Roberto Battaiola.

2.2 SID Observers

In December 2022, 12 AAVSO SID observers submitted VLF data as listed in Table 2.

Table 2: 202211 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
F Adamson	A122	NWC
J Karlovsky	A131	DHO NAA TBB
R Mrllak	A136	GQD NSY
S Aguirre	A138	NPM NAA
K Menzies	A146	NAA
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 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.

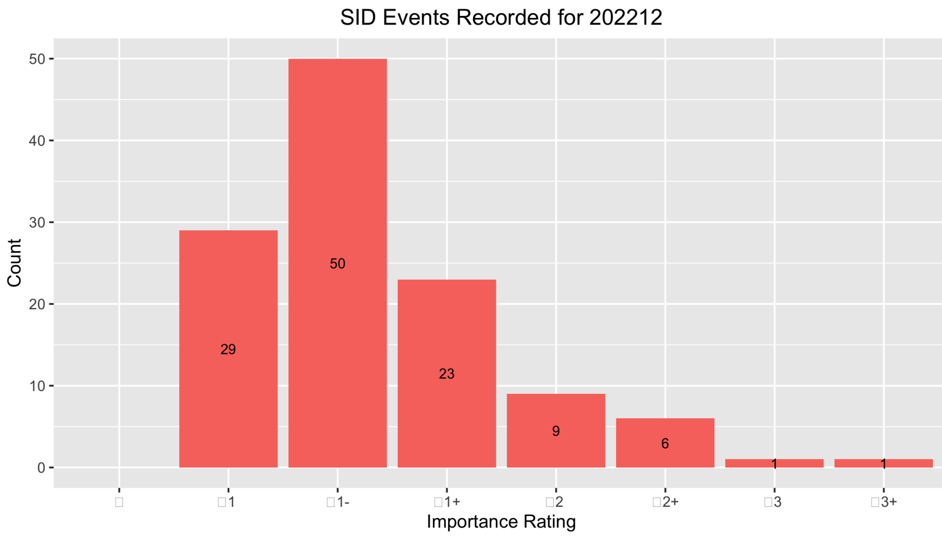

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In December 2022, there were 325 GOES-16 XRA flares, 39 M-class, 269 C-class, and 17 B-class flares (U.S. Dept. of Commerce–NOAA, 2022)(Figure 4).

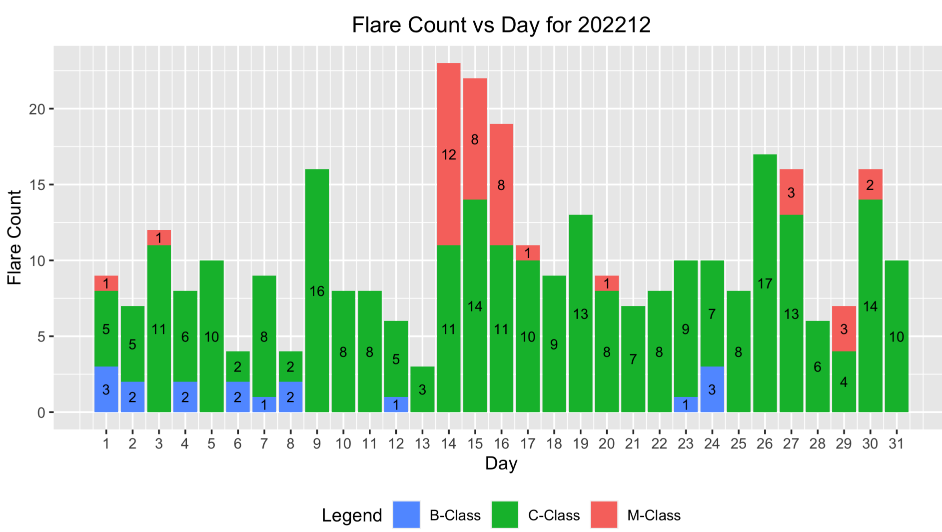

Figure 4: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 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 December 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 5.

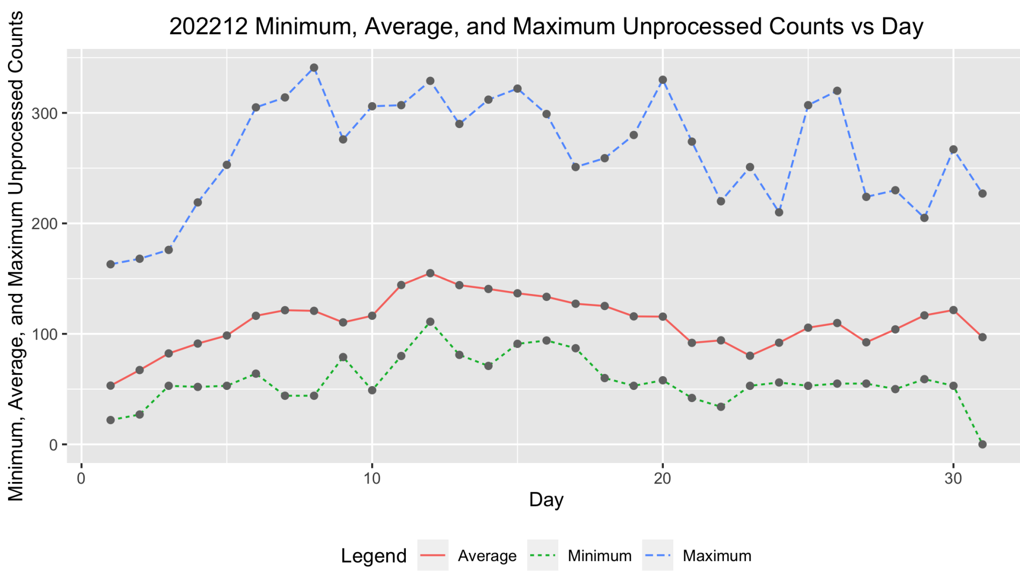

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

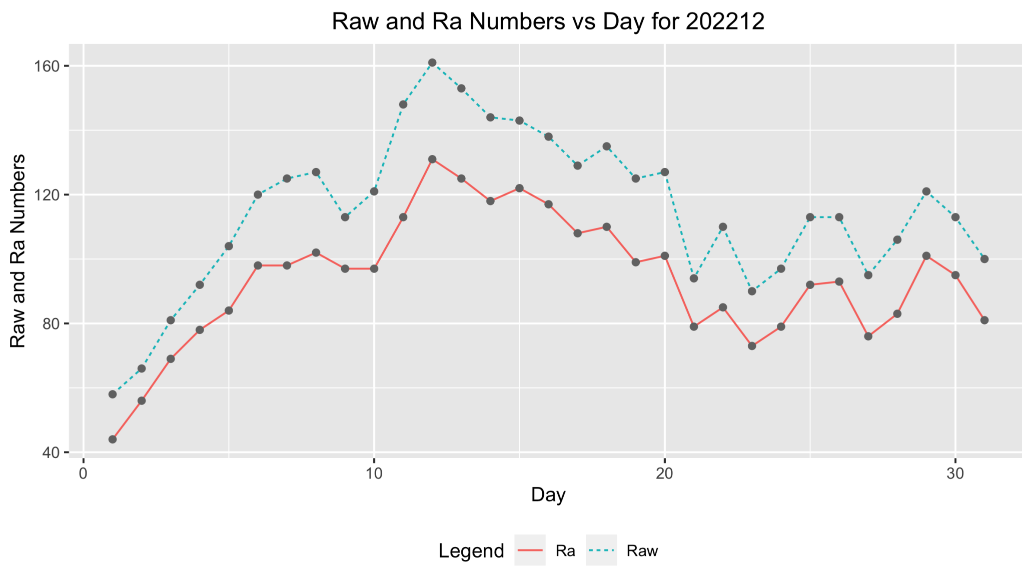

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202212 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	33	58	44
2	28	66	56
3	20	81	69
4	27	92	78
5	21	104	84
6	26	120	98
7	26	125	98
8	32	127	102
9	26	113	97
10	27	121	97
11	17	148	113
12	19	161	131
13	21	153	125
14	32	144	118

Continued

Table 3: 202212 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	27	143	122
16	28	138	117
17	33	129	108
18	33	135	110
19	18	125	99
20	25	127	101
21	34	94	79
22	22	110	85
23	30	90	73
24	25	97	79
25	36	113	92
26	35	113	93
27	30	95	76
28	29	106	83
29	23	121	101
30	22	113	95
31	24	100	81
Averages	26.7	114.9	93.7

3.3 Sunspot Observers

Table 4 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 2022, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (63), and total number of observations submitted (829).

Table 4: 202212 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	23	Alexandre Amorim
AJV	11	J. Alonso
ARAG	30	Gema Araujo
ASA	20	Salvador Aguirre
ATE	16	Teofilo Arranz Heras
BMF	10	Michael Boschat
BMIG	11	Michel Besson
BROB	14	Robert Brown
BXZ	18	Jose Alberto Berdejo
BZX	19	A. Gonzalo Vargas
CIOA	1	Ioannis Chouinavas
CKB	19	Brian Cudnik
CMAB	13	Maurizio Cervoni

Continued

Table 4: 202212 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CNT	19	Dean Chantiles
DARB	23	Aritra Das
DELS	11	Susan Delaney
DFR	3	Frank Dempsey
DJOB	9	Jorge del Rosario
DMIB	15	Michel Deconinck
DUBF	17	Franky Dubois
EGMA	12	Georgios Epitropou
EHOA	22	Howard Eskildsen
ERB	2	Bob Eramia
FERA	11	Eric Fabrigat
FLET	20	Tom Fleming
GIGA	24	Igor Grageda Mendez
HALB	5	Brian Halls
HKY	14	Kim Hay
HOWR	14	Rodney Howe
IEWA	13	Ernest W. Iverson
ILUB	6	Luigi Iapichino
JGE	6	Gerardo Jimenez Lopez
JSI	2	Simon Jenner
KAND	12	Kandilli Observatory
KAPJ	8	John Kaplan
KNJS	30	James & Shirley Knight
LEVM	9	Monty Leventhal
LKR	11	Kristine Larsen
LRRA	17	Robert Little
MARC	3	Arnaud Mengus
MARE	7	Enrico Mariani
MCE	25	Etsuiku Mochizuki
MJHA	29	John McCammon
MLL	12	Jay Miller
MMAY	31	Max Surlaroute
MMI	31	Michael Moeller
MSS	7	Sandy Mesics
MUDG	2	George Mudry
MWU	11	Walter Maluf
OAAA	9	Al Sadeem Astronomy Obs.
ONJ	7	John O'Neill
PLUD	3	Ludovic Perbet
RJV	13	Javier Ruiz Fernandez
SDOH	31	Solar Dynamics Obs - HMI
SNE	3	Neil Simmons
SRIE	17	Rick St. Hilaire

Continued

Table 4: 202212 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
TDE	18	David Teske
TNIA	1	Nick Tonkin
TPJB	1	Patrick Thibault
TST	8	Steven Toothman
URBP	4	Piotr Urbanski
VIDD	4	Dan Vidican
WWM	12	William M. Wilson
Totals	829	63

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.

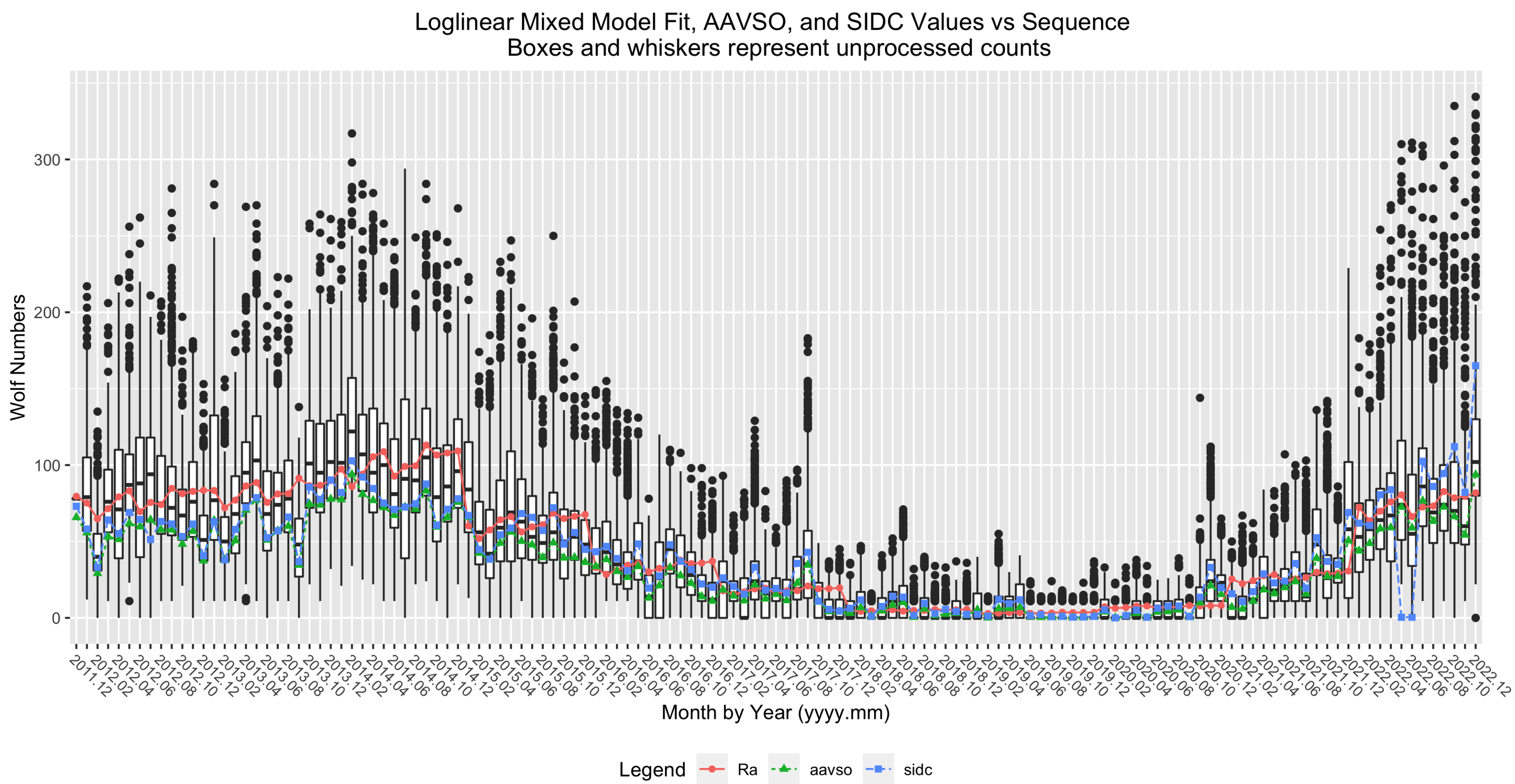

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

4.1 Observing Sunspots CHOICE course

With the increase in solar activity, now is a great time to learn more about counting sunspots and improving your skills by signing up for an online course being taught by AAVSO member and observer Raffaello Braga: Observing and Counting Sunspots - September 4 to September 30, 2023. To learn more about the course please visit:
`https://www.aavso.org/choice-course-descriptions#Sunspots`
To sign up go here: `https://www.aavso.org/choice-astronomy`

References

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Svalgaard, L. (2022, December). Sunspots with Ancient Telescopes. Leif Svalgaard's Research Page. http://svalgaard-redir.leif.org/research/Sunspots-with-Ancient-Telescopes.pdf

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