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 Use the AAVSO Group numbers back to 1947 to find the best solar cycle period

These are AAVSO data, daily group numbers back to 1947, then aggregated to monthly data. Then we find the Seasonal Period using Grant Foster's R routines for doing FFT (Foster, 2010). The following table shows the top periods from (R Statistical Software, 2010, TSA::periodogram()). The highest power period is 129 months, which is 10.8 years. The next closest period that matches this is 100, or 8.3 years. However, this is significantly lower power. From getting the solar cycle periods from the group number monthly data we can then find the best model to fit for the last 7 solar cycles.

Table 1: The highest power period is 129, which is 10.8 years.

period	power
129	7209.9068
100	591.5095
450	335.6277
64	185.4779
900	183.3674
180	181.0576

"A more refined treatment of the statistical behavior of this process is to approach it as a version of the *Analysis of Variance* (AoV). The AoV approach has not only been optimized to give the best statistical behavior, it has also been optimized to require the fewest numerical calculations." (Foster, 2010)

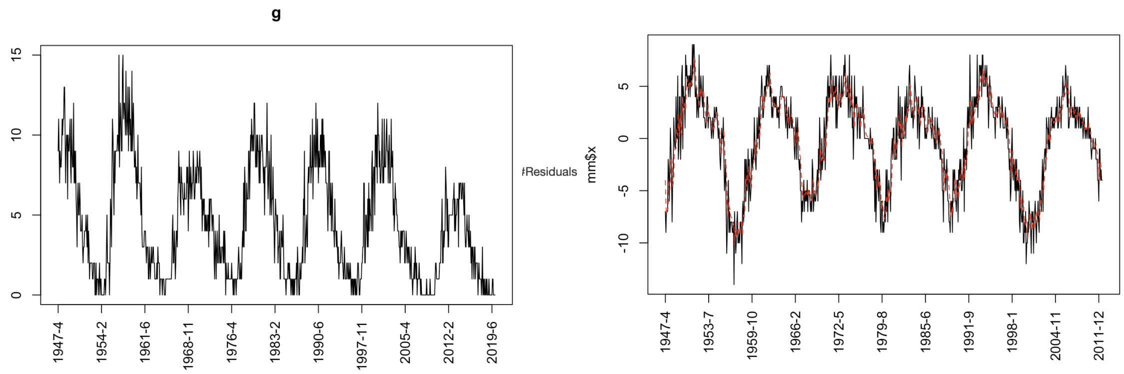

Figure 1: Fit an ARIMA model of the seasonally differenced group number with the seasonal component represented as a Fourier Series. The seasonal period is too long to use a seasonal ARIMA model. (AoV) Note: Variance = 11.81, which is significantly greater than the mean (4.47), which indicates that these data may be closer to a negative binomial distribution.

The R_a index data used by (Coban et al., 2021), and the comment being raised by (Peguero et al., 2023), assume an arbitrary 10 year cycle for AAVSO monthly R_a index, (data found from the 'NOAA monthly Ra numbers' data on the AAVSO Solar Section Web page: `https://www.aavso.org/solar`, and the SILSO ISN, (SIDC data, 2023). Perhaps the best model for comparing the Dalton Minimum described in these papers, might be better represented by a 10.8 year period rather than a 10 year period.

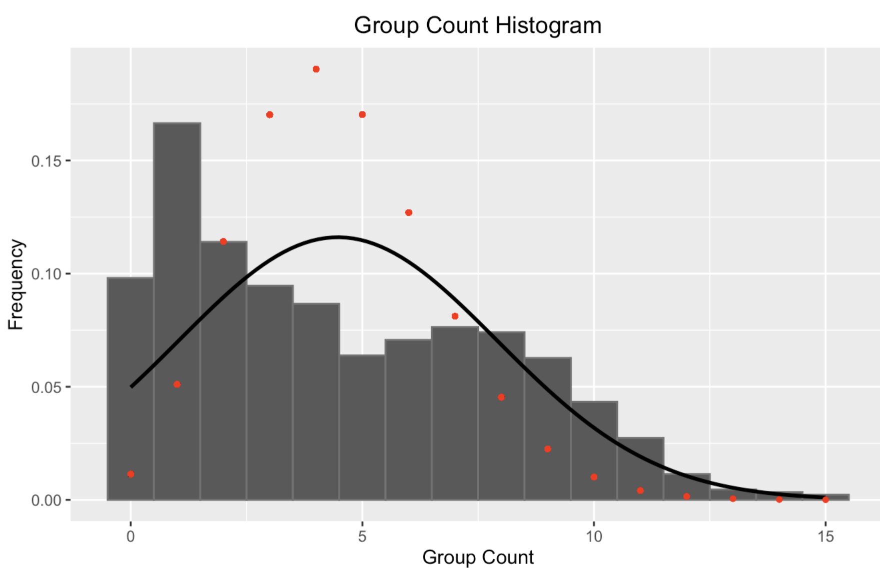

Figure 2: Poisson distribution with a long tail for the 10.8 year period

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

April 2023 (Figure 3): there were 2 M class and 12 C class flares on the 14th of April recorded here in Fort Collins, Colorado. (U.S. Dept. of Commerce–NOAA, 2022).

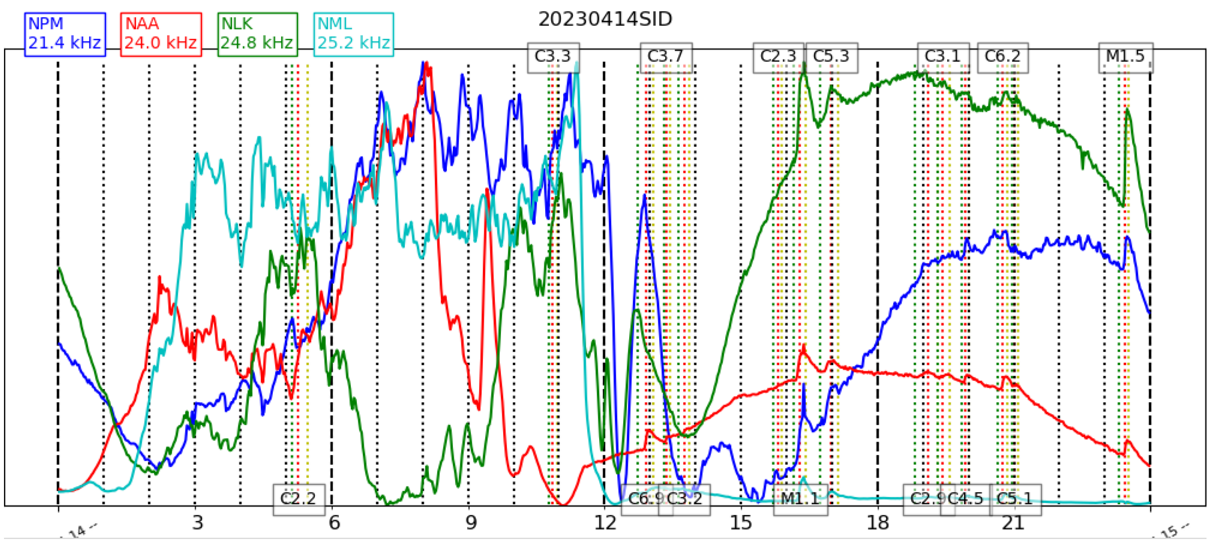

Figure 3: VLF recording from Fort Collins, Colorado for the 14th of April.

2.2 SID Observers

In April 2023 we had 14 AAVSO SID observers who submitted VLF data as listed in Table 2.

Table 2: 202304 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 Mrllak	A136	GQD NSY
S Aguirre	A138	NPM NAA
G Silvis	A141	NAA NML NLK
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 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.

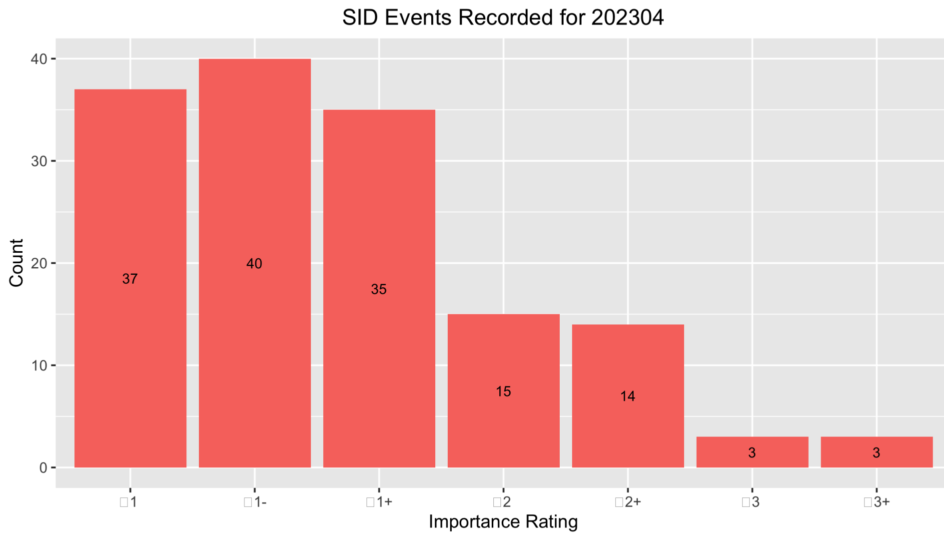

Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In April 2023, there were 247 GOES-16 XRA flares: 9 M Class, 228 C Class and 10 B Class. More flaring this month compared to last. (U.S. Dept. of CommerceNOAA, 2022). (see Figure 5).

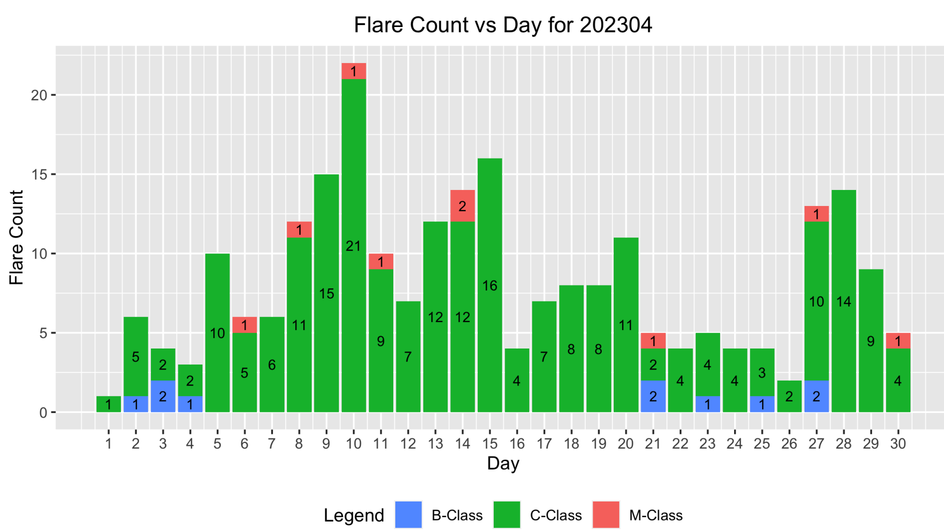

Figure 5: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 April 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. All observers whose submissions qualify through this month's scrubbing process are represented in Figure 6.

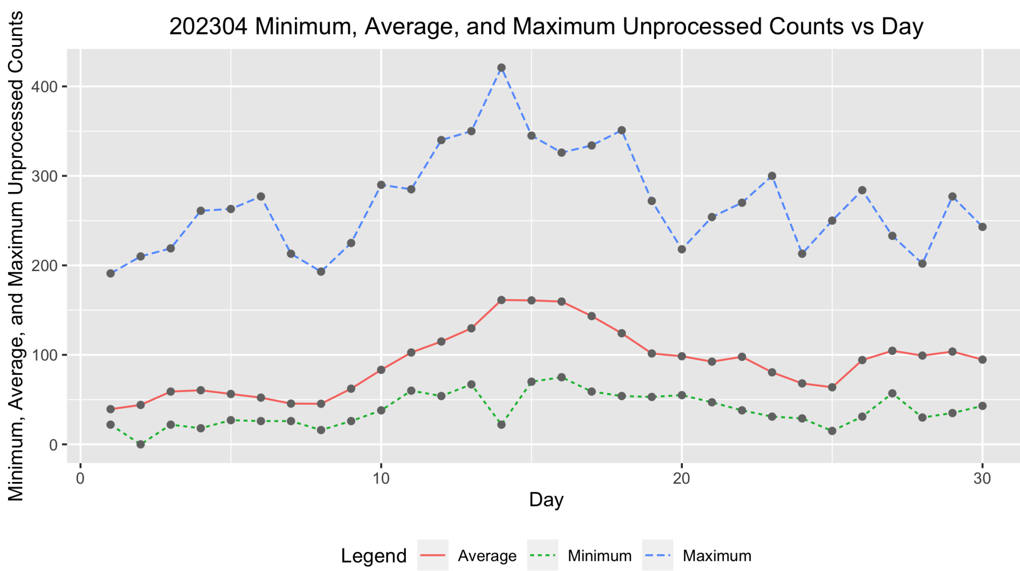

Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

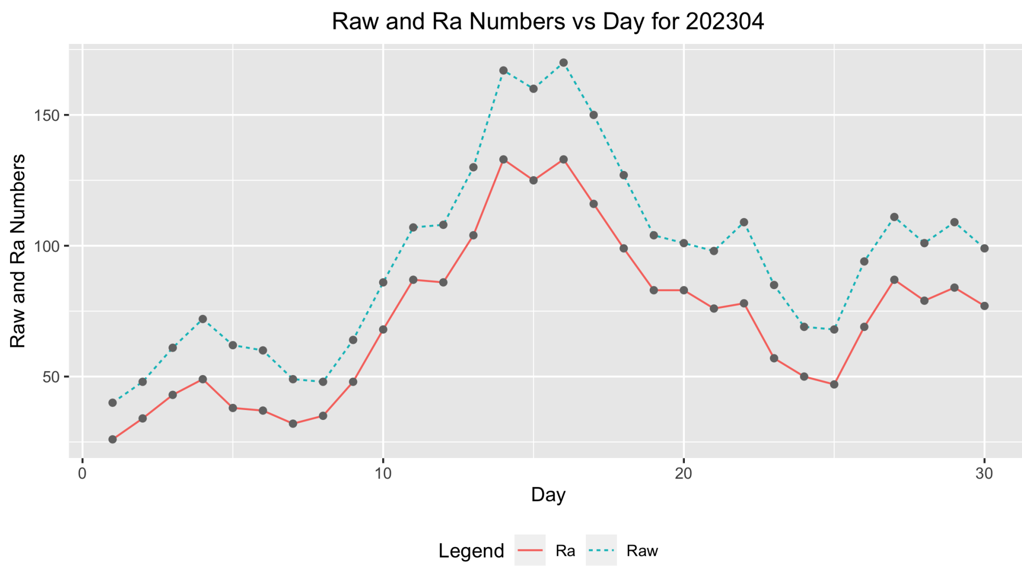

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 (`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 7, 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: 202304 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	34	40	26
2	36	48	34
3	35	61	43
4	35	72	49
5	29	62	38
6	31	60	37
7	29	49	32
8	36	48	35
9	38	64	48
10	42	86	68
11	35	107	87
12	32	108	86
13	38	130	104
14	34	167	133

Continued

Table 3: 202304 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	30	160	125
16	36	170	133
17	38	150	116
18	35	127	99
19	39	104	83
20	36	101	83
21	31	98	76
22	26	109	78
23	28	85	57
24	29	69	50
25	37	68	47
26	31	94	69
27	30	111	87
28	35	101	79
29	27	109	84
30	29	99	77
Averages	33.4	95.2	72.1

3.3 Sunspot Observers

Table 4 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for April 2023, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (62), and total number of observations submitted (1001).

Table 4: 202304 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	23	Alexandre Amorim
AJV	15	J. Alonso
ARAG	30	Gema Araujo
ASA	16	Salvador Aguirre
ATE	12	Teofilo Arranz Heras
BATR	10	Roberto Battaiola
BMF	22	Michael Boschat
BMIG	23	Michel Besson
BROB	28	Robert Brown
BXZ	17	Jose Alberto Berdejo
BZX	27	A. Gonzalo Vargas
CKB	23	Brian Cudnik
CMAB	11	Maurizio Cervoni
CNT	29	Dean Chantiles

Continued

Table 4: 202304 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CVJ	11	Jose Carvajal
DARB	24	Aritra Das
DELS	6	Susan Delaney
DFR	11	Frank Dempsey
DJOB	7	Jorge del Rosario
DJSA	11	Jeff DeVries
DMIB	20	Michel Deconinck
DUBF	26	Franky Dubois
EHOA	15	Howard Eskildsen
ERB	15	Bob Eramia
FERA	25	Eric Fabrigat
FLET	21	Tom Fleming
GIGA	27	Igor Grageda Mendez
HALB	11	Brian Halls
HKY	22	Kim Hay
HOWR	18	Rodney Howe
IEWA	15	Ernest W. Iverson
ILUB	3	Luigi Iapichino
JGE	5	Gerardo Jimenez Lopez
JSI	6	Simon Jenner
KAND	15	Kandilli Observatory
KAPJ	12	John Kaplan
KNJS	27	James & Shirley Knight
LKR	8	Kristine Larsen
LRRA	11	Robert Little
LVY	10	David Levy
MARC	6	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	20	Etsuiku Mochizuki
MJHA	26	John McCammon
MLL	10	Jay Miller
MMI	30	Michael Moeller
MSS	8	Sandy Mesics
MWU	18	Walter Maluf
ONJ	13	John O'Neill
PLUD	19	Ludovic Perbet
RJV	16	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SNE	6	Neil Simmons
SRIE	9	Rick St. Hilaire
TDE	25	David Teske
TNIA	4	Nick Tonkin
TPJB	3	Patrick Thibault

Continued

Table 4: 202304 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
TST	22	Steven Toothman
URBP	24	Piotr Urbanski
VIDD	12	Dan Vidican
WGI	1	Guido Wollenhaupt
WWM	18	William M. Wilson
Totals	1001	62

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 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 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.

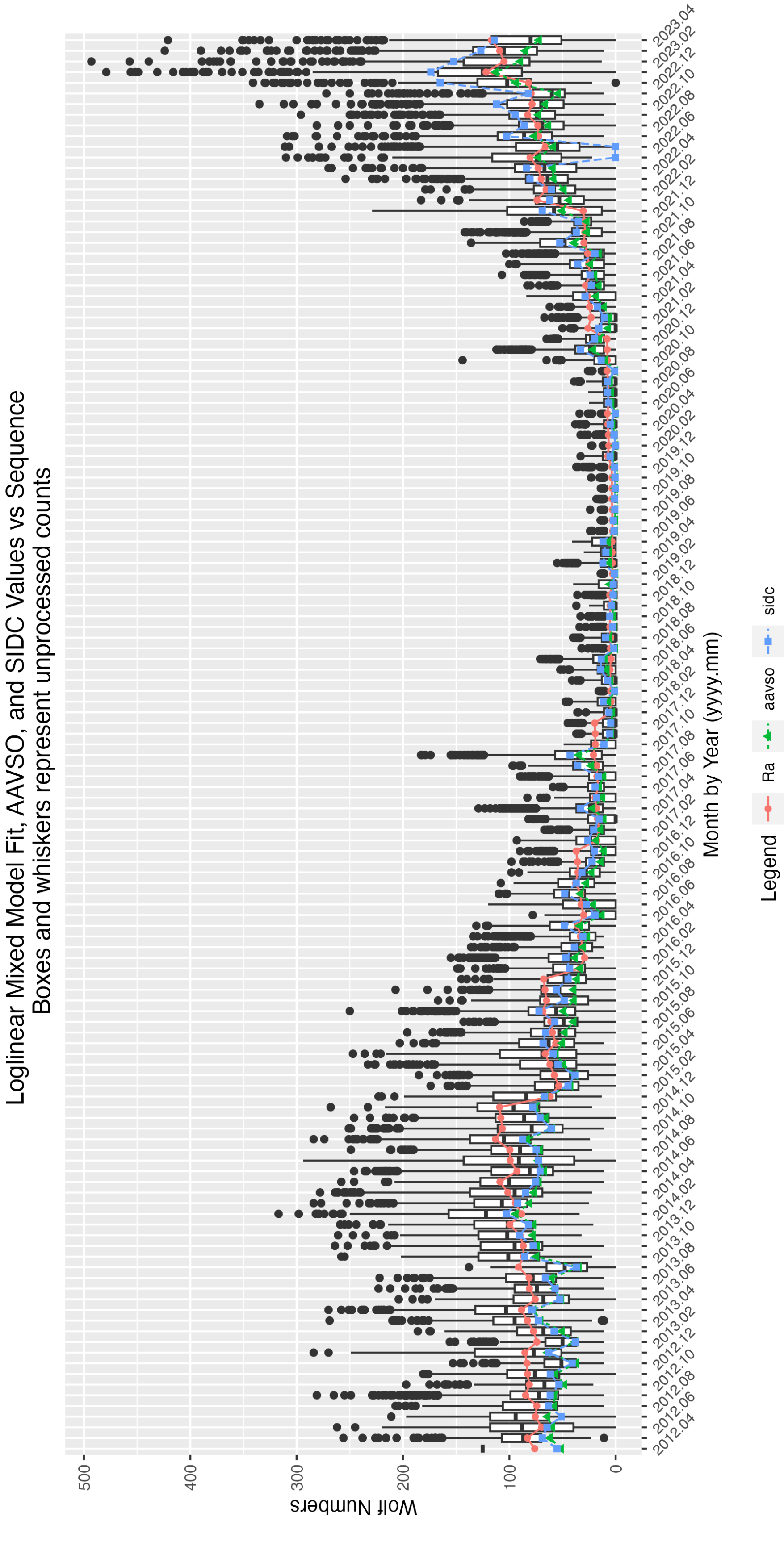

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

5 References

Coban G.C., et al. (2021), *Can Solar Cycle 25 Be a New Dalton Minimum?* https://www.researchgate.net/publication/355902321_Can_Solar_Cycle_25_Be_a_New_Dalton_Minimum.

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