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 Sunspot Forecast for the 100 year Gleissberg cycle

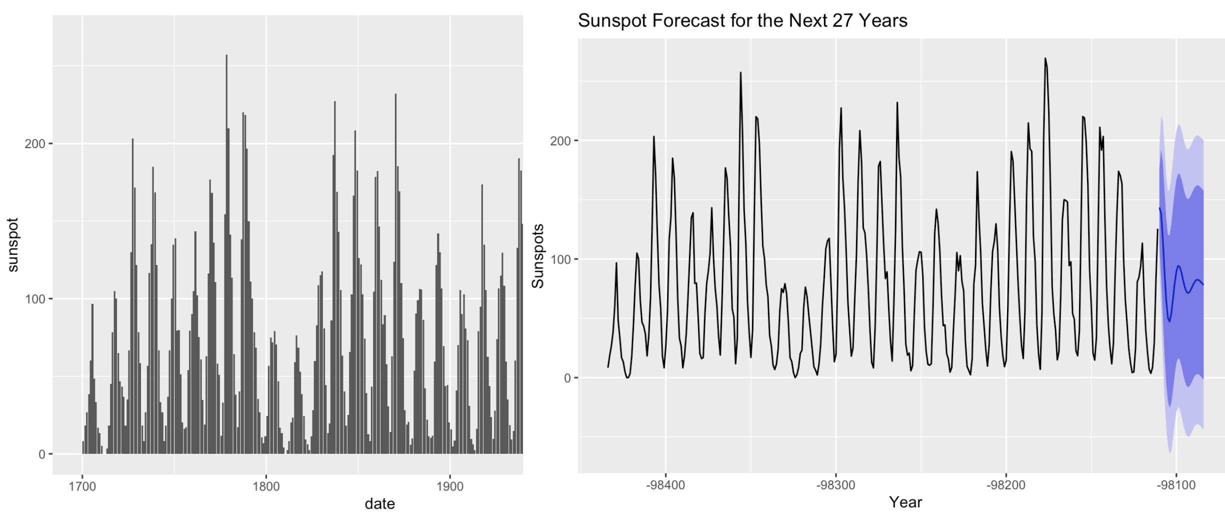

Figure 1: 300 years of solar cycles, left panel; (SIDC, World Data Center), a Yearly Sunspot Forecast: 2024 - 2050, right panel,

"The Gleissberg cycle, first identified in 1862, strengthens and weakens the 11-year cycle over the course of a century (shown in yellow). One paper posits that the Gleissberg pattern is caused by a slow swaying of the sun's magnetic pole. The Suess-DeVries cycle (green) lasts about 200 years, whereas the Hallstatt cycle (blue) runs on the order of 2,400 years. Still, the sun can also be erratic, making it tricky for physicists to predict future sunspots, says Alexei Pevtsov, an astronomer at the National Solar Observatory in Boulder, Colo.: There's an element of randomness. "
(`https://www.scientificamerican.com/article/the-sunspot-cycle-is-more-intricate-than-previously-thought/`)

(`https://www.sciencedirect.com/science/article/abs/pii/S1384107608000511`)

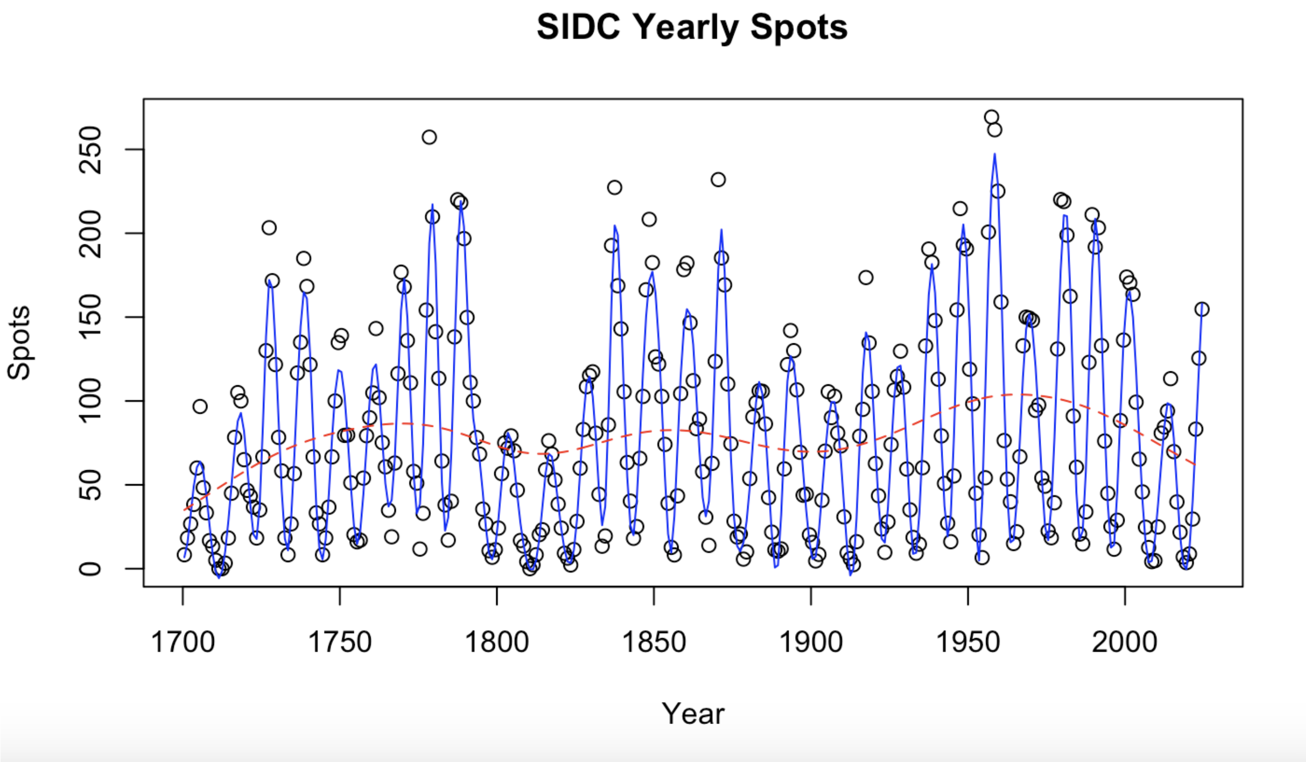

Figure 2: A spline fit (red line) showing the Gleissberg dips for an approximate 100 year cycle. SIDC, World Data Center. The forecast for the next 27 years would represent the future two or three low cycles in the overall Gleissberg cycle. Note the the blue outline of the forecast for scale, see Figure 1.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

December 2025 (Figure 3): there was an X1.1 class, and 5 M-class, 13 C-class flares on the 8th of December; a C5.2 and a M1.0 show a nice SID with a "shark's tail" lasting about 2 hours. This VLF scan was recorded in southern France by Lionel Laudet (A118) (U.S. Dept. of Commerce–NOAA, 2022).

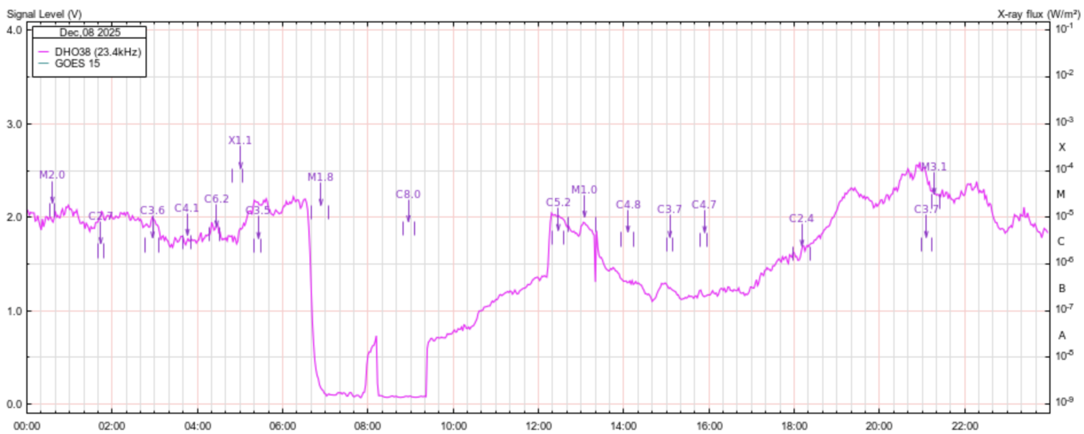

Figure 3: VLF recording from southern France, for December 8, 2025.

2.2 SID Observers

In December 2025 we had 12 AAVSO SID observers who submitted VLF data, as listed in Table 1.

Table 1: 202512 VLF Observers

Observer	Code	Stations
R Battaiola	A96	ICV
L Loudet	A118	DHO GBZ
J Godet	A119	DHO GBZ GQD
J Karlovsky	A131	DHO
R Mrllak	A136	NSY
S Aguirre	A138	NPM
G Silvis	A141	NAU NPM NLK
L Pina	A148	NAA NML
J Wendler	A150	NAA
H Krumnow	A152	DHO GBZ HWU
J DeVries	A153	NLK
M Cervoni	A154	DHO ICV

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.

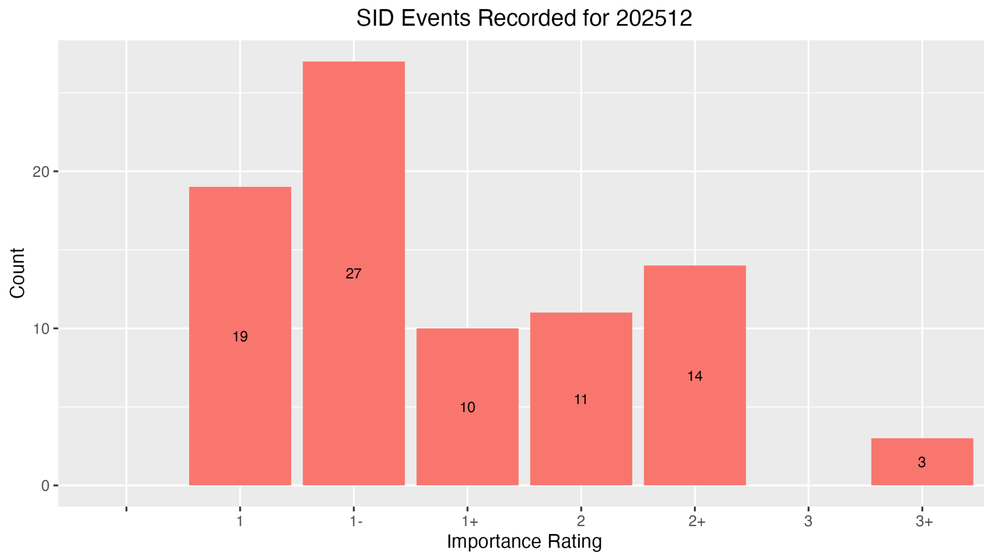

Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In December 2025, There were 316 GOES-16 XRA flares: 2 X-class, 29, M-class, 270 C-class, and 15 B-class flares, about the same as last month. (U.S. Dept. of Commerce–NOAA, 2022). (see Figure 5).

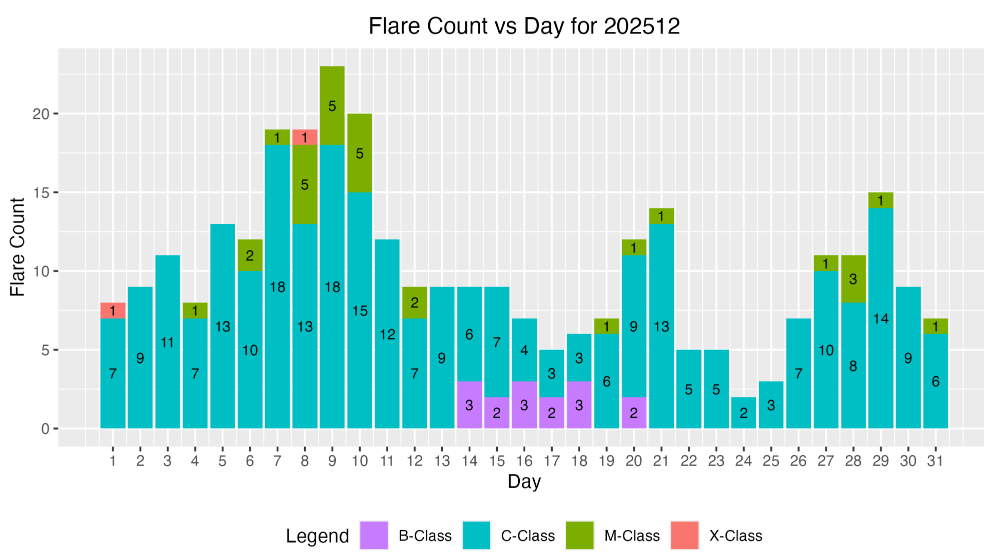

Figure 5: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 December 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 6.

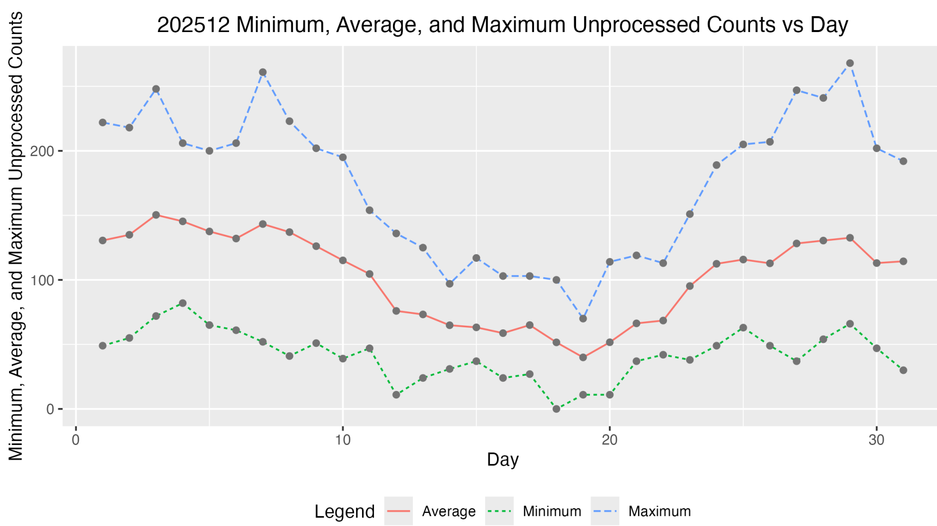

Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

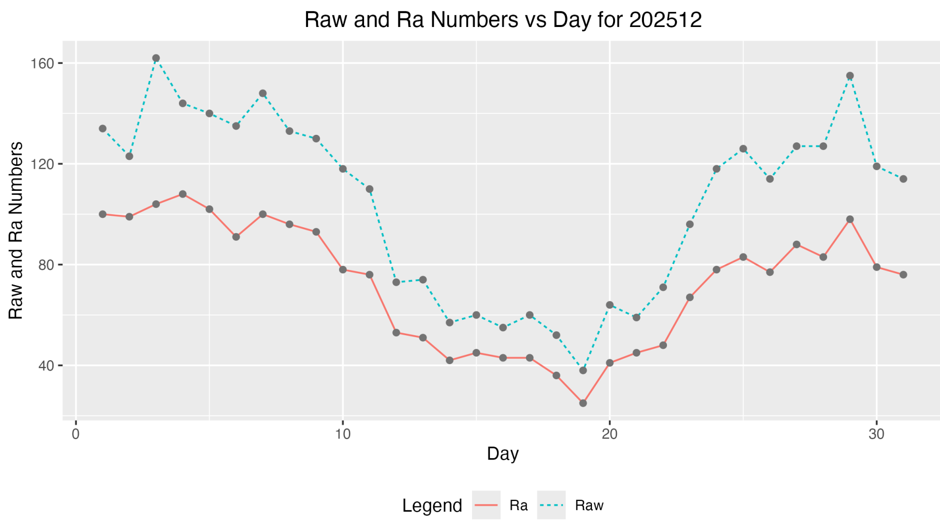

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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: 202512 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	20	134	100
2	19	123	99
3	19	162	104
4	22	144	108
5	22	140	102
6	21	135	91
7	21	148	100
8	31	133	96
9	23	130	93
10	23	118	78
11	22	110	76
12	25	73	53
13	25	74	51
14	22	57	42
15	23	60	45
16	19	55	43

Continued

Table 2: 202512 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
17	19	60	43
18	22	52	36
19	20	38	25
20	21	64	41
21	19	59	45
22	18	71	48
23	17	96	67
24	23	118	78
25	18	126	83
26	19	114	77
27	22	127	88
28	25	127	83
29	22	155	98
30	24	119	79
31	22	114	76
Averages	21.5	104.4	72.5

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 2025, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (54), and total number of observations submitted (668).

Table 3: 202512 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	25	Alexandre Amorim
AJV	3	J. Alonso
ARAG	27	Gema Araujo
ASA	1	Salvador Aguirre
BATR	6	Roberto Battaiola
BMIG	11	Michel Besson
BTB	2	Thomas Bretl
BVZ	9	Jesus E. Blanco
BXZ	16	Jose Alberto Berdejo
CKB	17	Brian Cudnik
CMAB	3	Maurizio Cervoni
CNT	18	Dean Chantiles
CPAD	6	Panagiotis Chatzistamatiou
DARB	27	Aritra Das
DELS	1	Susan Delaney

Continued

Table 3: 202512 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DGIA	6	Giuseppe di Tommasco
DIL	16	Bill Dillon
DJOB	10	Jorge del Rosario
DJSA	2	Jeff DeVries
DJVA	29	Jacques van Delft
DMIB	15	Michel Deconinck
DUBF	15	Franky Dubois
EHOA	3	Howard Eskildsen
FALB	12	Allen Frohardt
FERA	8	Eric Fabrigat
GCNA	1	Candido Gomez
GIGA	18	Igor Grageda Mendez
HKY	11	Kim Hay
HOWR	15	Rodney Howe
ILUB	3	Luigi Iapichino
JGE	2	Gerardo Jimenez Lopez
KAMB	31	Amoli Kakkar
KAND	15	Kandilli Observatory
KAPJ	9	John Kaplan
KNJS	29	James & Shirley Knight
KTOC	15	Tom Karnuta
LKR	4	Kristine Larsen
LLEC	26	Leroy Leonard
LRRA	7	Robert Little
MARC	2	Arnaud Mengus
MARE	11	Enrico Mariani
MJHA	27	John McCammon
MMI	31	Michael Moeller
MUDG	5	George Mudry
MWU	17	Walter Maluf
PLUD	13	Ludovic Perbet
RJV	8	Javier Ruiz Fernandez
SDOH	31	Solar Dynamics Obs - HMI
SNE	1	Neil Simmons
SRIE	7	Rick St. Hilaire
TDE	19	David Teske
TST	7	Steven Toothman
URBP	11	Piotr Urbanski
WGI	4	Guido Wollenhaupt
Totals	668	54

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.

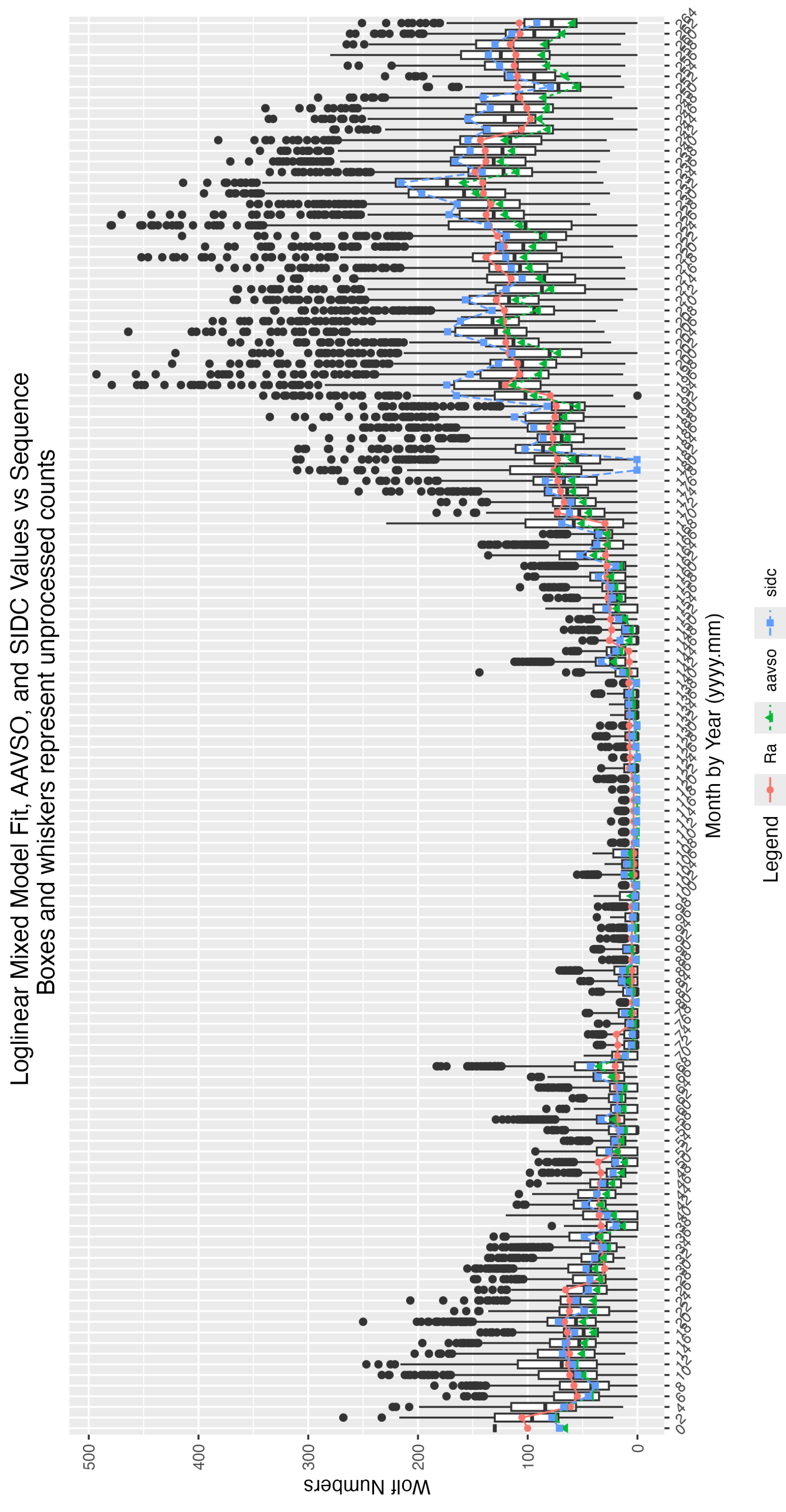

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

5 References

SIDC, World Data Center - Sunspot Number and Long-term Solar Observations. (2022). *Sunspot number catalog, 1850-2022* [data set]. Royal Observatory of Belgium. (`https://www.sidc.be/silso/datafiles`)

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/`)