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 Sunspot Counts from Fourteen Carrington Rotations in 2021

This graph was made by Max Surlaroute (MMAY) using his AAVSO data. It shows the distribution of his sunspot observations according to latitude and longitude during the 14 Carrington rotations of 2021.

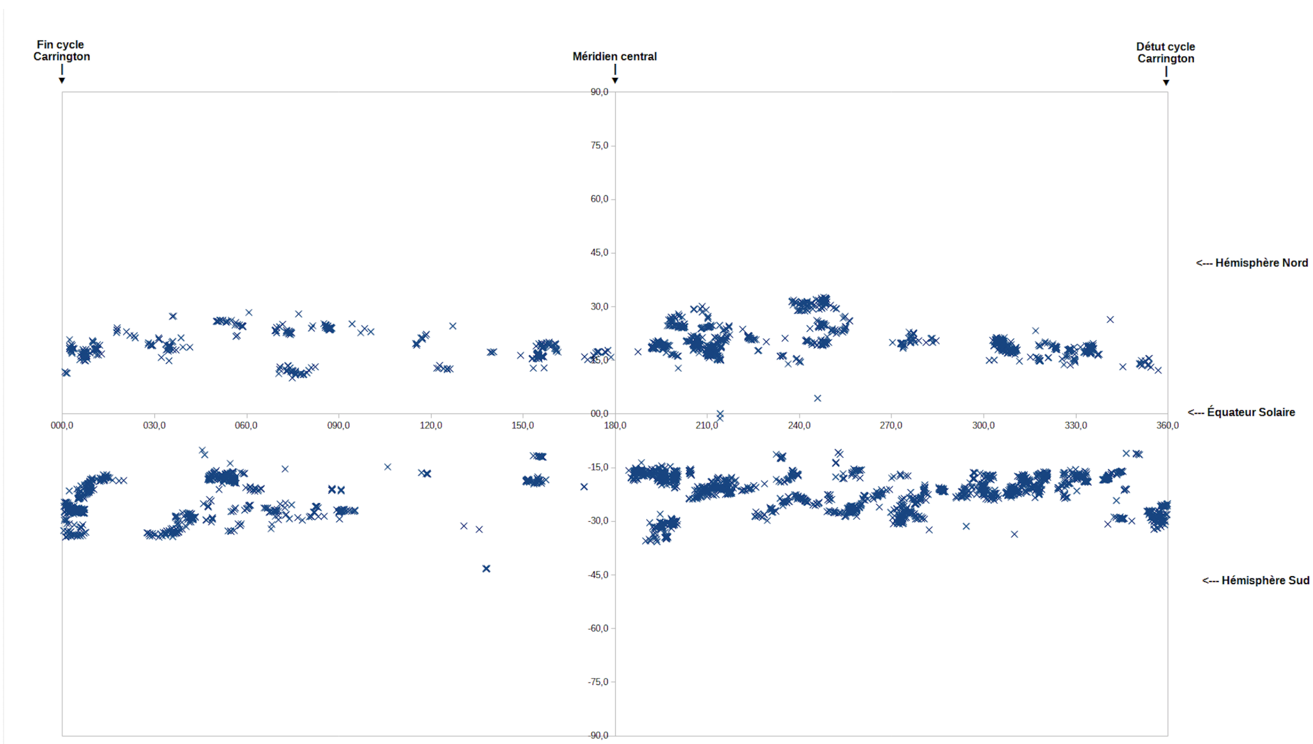

Figure 1: Cumulative sunspot counts for North and South Hemispheres for each Carrington Rotation of 27.25 days for all of 2021. More information on Carrington Rotations can be found here: `https://solarscience.msfc.nasa.gov/greenwch.shtml`.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

February 2022 (Figure 2) Roberto Battaiola (A96) recorded an inverted M1.4 SID Event on the 12th of February from Milan, Italy.

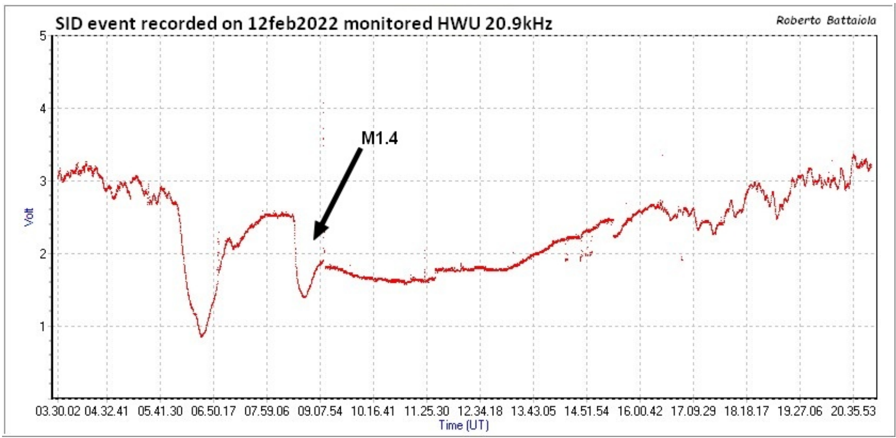

Figure 2: VLF recording on the 12th of February.

2.2 SID Observers

In February 2022, 17 AAVSO SID observers submitted VLF data as listed in Table 1.

Table 1: 202202 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD ICV
B Terrill	A120	NWC
F Adamson	A122	NWC
G Perry	A126	DHO
J Karlovsky	A131	DHO TBB
R Green	A134	NWC
R Mrllak	A136	GQD
S Aguirre	A138	NPM
K Menzies	A146	NAA
J Wendler	A150	NAA
H Krumnow	A152	DHO GBZ
J DeVries	A153	NLK
R Mazur	A155	NAA 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.

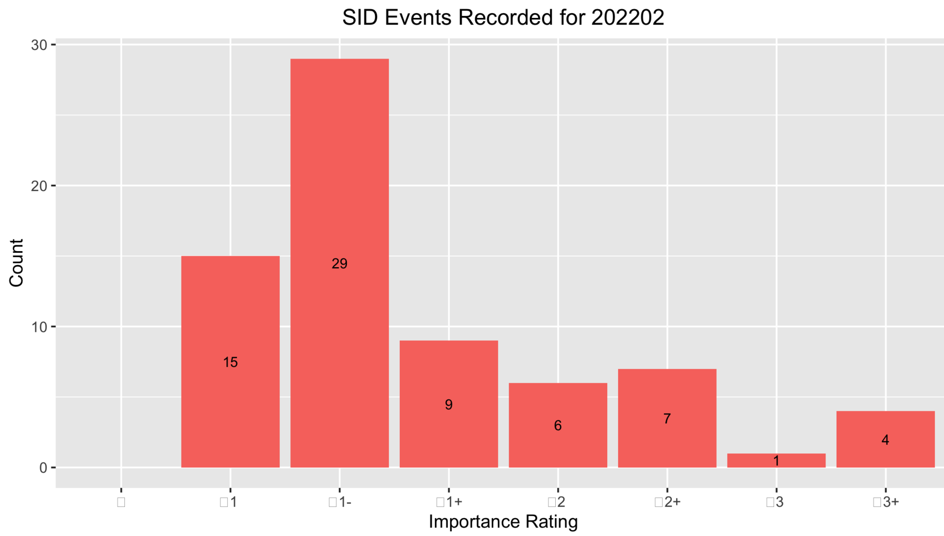

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In February 2022, there were 208 GOES-16 XRA flares: 3 M-Class, 102 C-Class, and 103 B-Class flares. Less flaring this month compared to last (see Figure 4).

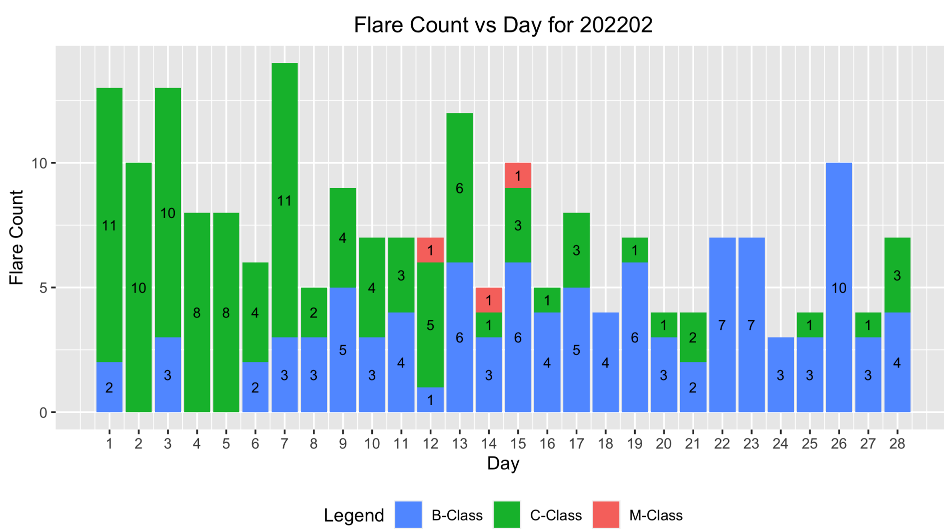

Figure 4: GOES-16 XRA flares.

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 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.

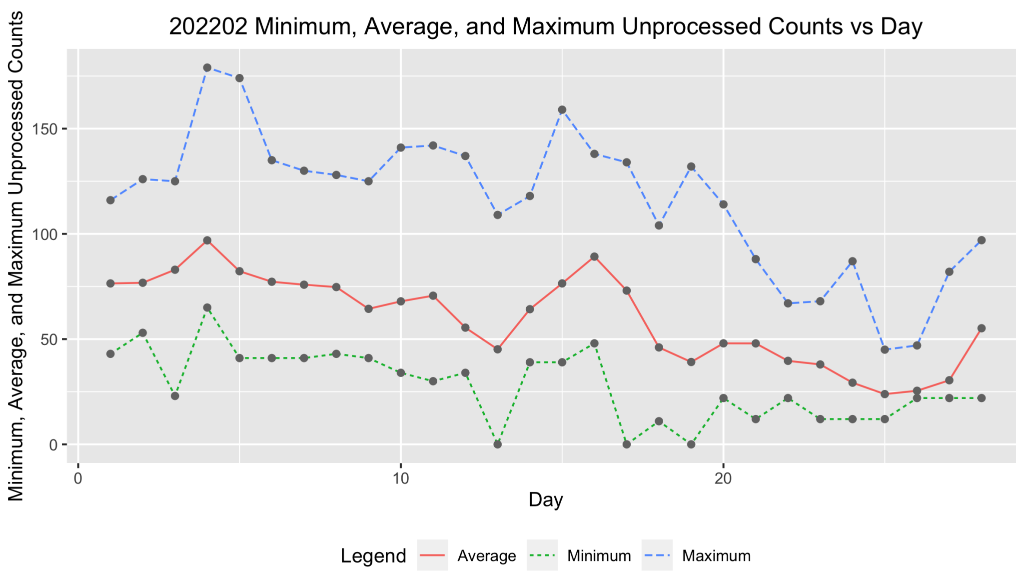

Figure 5: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

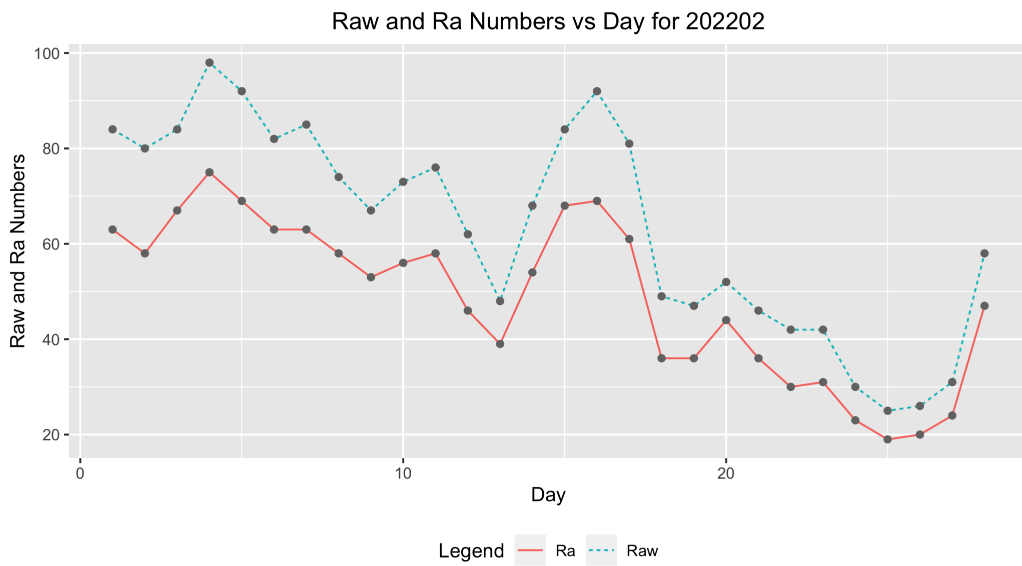

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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: 202202 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	35	84	63
2	30	80	58
3	29	84	67
4	25	98	75
5	50	92	69
6	43	82	63
7	35	85	63
8	41	74	58
9	49	67	53
10	39	73	56
11	44	76	58
12	39	62	46
13	38	48	39
14	37	68	54

Continued

Table 2: 202202 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	45	84	68
16	29	92	69
17	36	81	61
18	35	49	36
19	40	47	36
20	42	52	44
21	31	46	36
22	31	42	30
23	33	42	31
24	33	30	23
25	33	25	19
26	41	26	20
27	44	31	24
28	42	58	47
Averages	37.5	63.5	48.8

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for February 2022, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (71), and total number of observations submitted (1049).

Table 3: 202202 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	25	Alexandre Amorim
AJV	23	J. Alonso
ARAG	28	Gema Araujo
ASA	17	Salvador Aguirre
ATE	27	Teofilo Arranz Heras
BATR	8	Roberto Battaiola
BMF	19	Michael Boschat
BMIG	22	Michel Besson
BRAF	1	Raffaello Braga
BROB	26	Robert Brown
BXZ	26	Jose Alberto Berdejo
BZX	21	A. Gonzalo Vargas
CIOA	11	Ioannis Chouinavas
CKB	16	Brian Cudnik
CMOD	2	Mois Carlo
CNT	28	Dean Chantiles

Continued

Table 3: 202202 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CPAD	6	Panagiotis Chatzistamatiou
CVJ	10	Jose Carvajal
DARB	14	Aritra Das
DFR	11	Frank Dempsey
DJOB	11	Jorge del Rosario
DMIB	25	Michel Deconinck
DROB	1	Bob Dudley
DUBF	20	Franky Dubois
EHOA	19	Howard Eskildsen
ERB	10	Bob Eramia
FERA	17	Eric Fabrigat
FTAA	7	Tadeusz Figiel
GIGA	23	Igor Grageda Mendez
HALB	7	Brian Halls
HKY	11	Kim Hay
HMQ	8	Mark Harris
HOWR	18	Rodney Howe
HRUT	16	Timothy Hrutkay
IEWA	16	Ernest W. Iverson
ILUB	4	Luigi Iapichino
JDAC	5	David Jackson
JGE	5	Gerardo Jimenez Lopez
JSI	4	Simon Jenner
KAND	9	Kandilli Observatory
KAPJ	11	John Kaplan
KNJS	28	James & Shirley Knight
LKR	10	Kristine Larsen
LRRA	22	Robert Little
MARC	3	Arnaud Mengus
MARE	4	Enrico Mariani
MCE	23	Etsuiku Mochizuki
MJAF	26	Juan Antonio Moreno Quesada
MJHA	26	John McCammon
MLL	9	Jay Miller
MMAY	28	Max Surlaroute
MMI	28	Michael Moeller
MSS	7	Sandy Mesics
MUDG	2	George Mudry
MWU	18	Walter Maluf
OAAA	24	Al Sadeem Astronomy Obs.
ONJ	5	John O'Neill
PEKT	8	Riza Pektas
PLUD	19	Ludovic Perbet

Continued

Table 3: 202202 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
RJV	18	Javier Ruiz Fernandez
SATH	11	Andries Son
SDOH	28	Solar Dynamics Obs - HMI
SNE	1	Neil Simmons
SQN	20	Lance Shaw
SRIE	19	Rick St. Hilaire
TDE	20	David Teske
TPJB	5	Patrick Thibault
TST	13	Steven Toothman
URBP	14	Piotr Urbanski
VIDD	9	Dan Vidican
WWM	13	William M. Wilson
Totals	1049	71

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. For more details, *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 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.

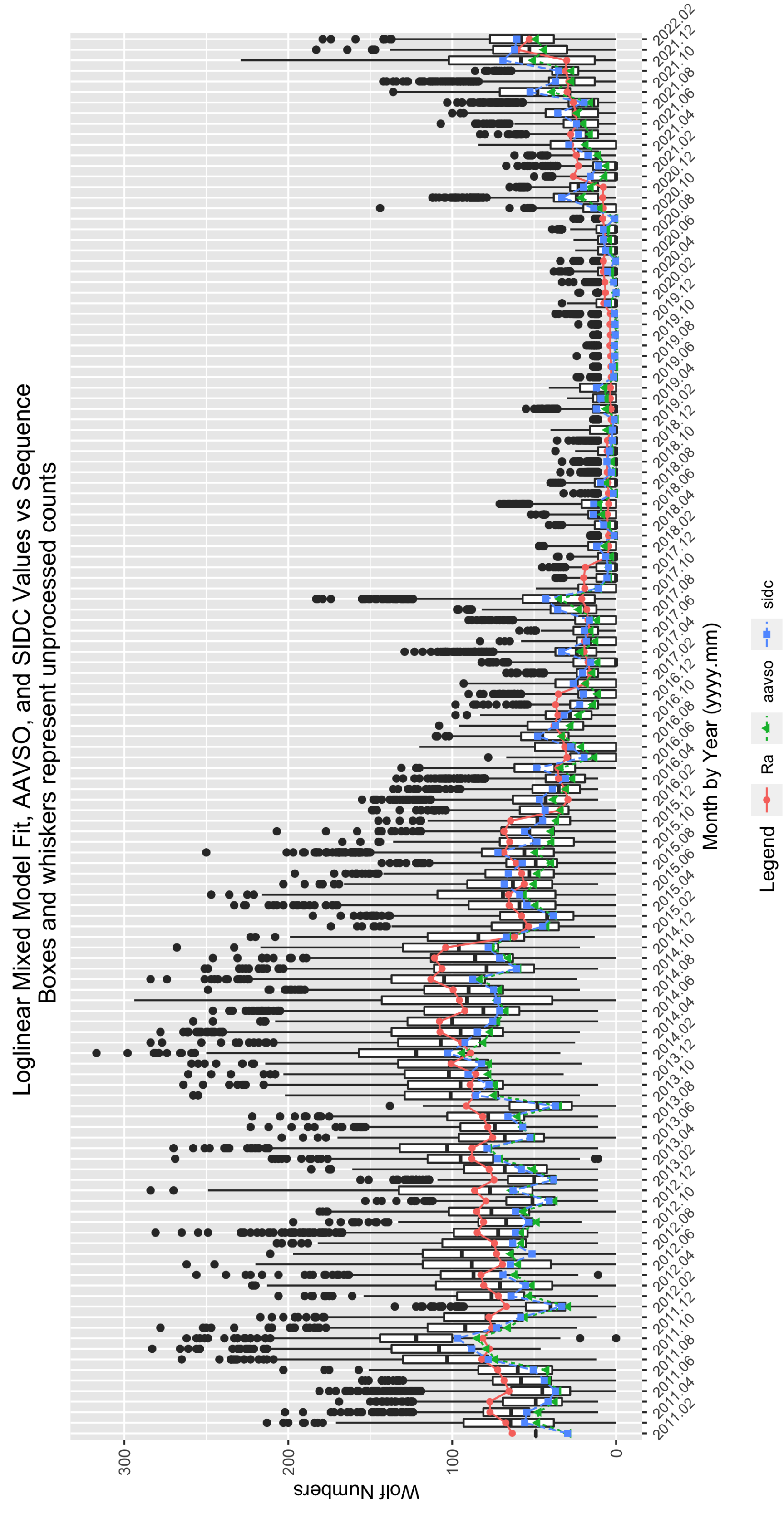

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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