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 Zero group number days for the last 4 cycles of solar minimums

Table 1: Cycle start and cycle peak amplitude dates, with the number of days when groups were seen and the total number of groups counted for those days.

Cycle No.	Start	Peak	days	No. groups:
21	197603	197912	1365	1177
22	198609	198911	1155	923
23	199608	200111	1915	1654
24	200812	201404	1855	1595

Table 2: Cycle start and cycle end dates, with the number of days when groups were seen and the number of days for which no groups were counted.

Cycle No.	Start	End	days	zero group days:
21	197603	198609	3830	985
22	198609	199608	3620	845
23	199608	200812	4500	1322
24	200812	202003	4110	1781

Looking back through the AAVSO group number data during the last 4 solar minimums gives an indication that the zero group days during solar minimum days (calculated as fractional zero days) have increased for each of the last 4 cycles.

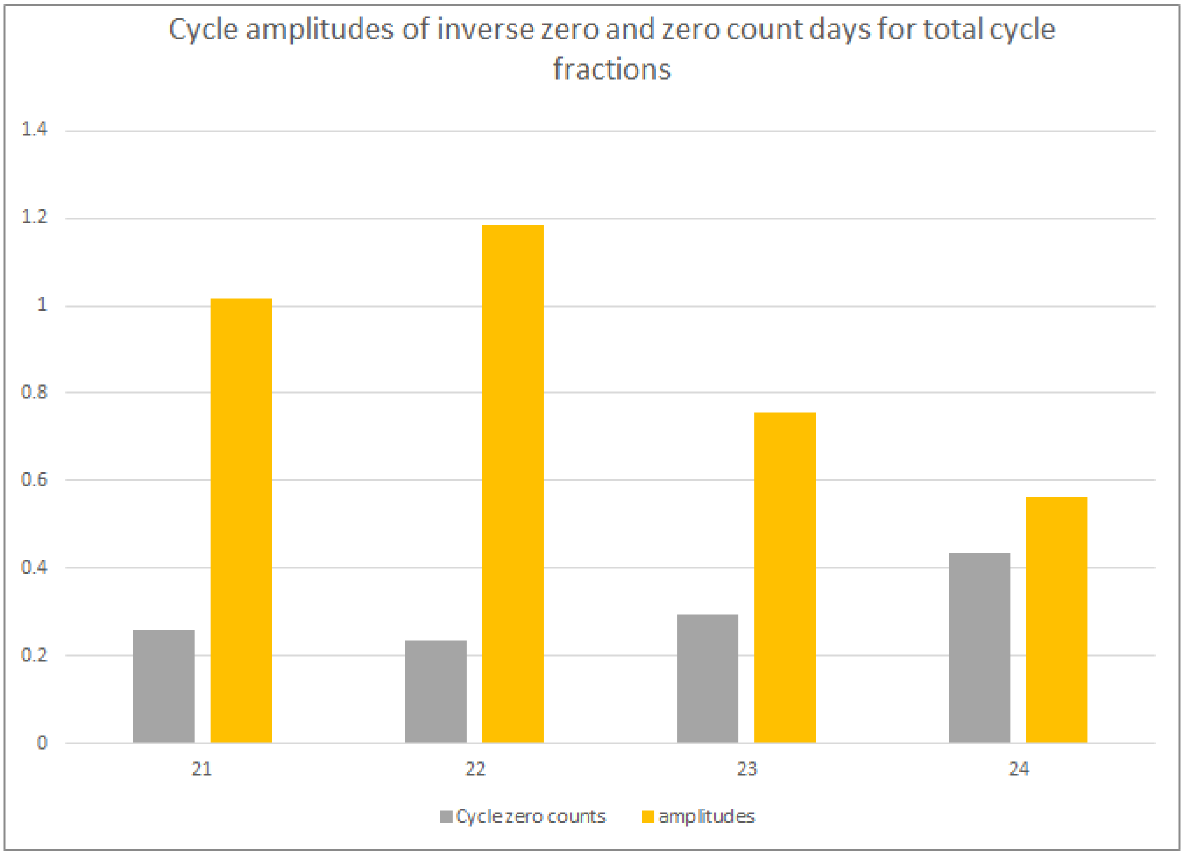

Figure 1: Graph shows how the fractional increase of zero group days during the last 4 solar minimums (grey bars) indicates recent lengthening of solar minimums in solar cycles. The Yellow bars show the solar cycle relative group counts have decreased (the y-axis is the same scale as the fractional zero days).

Table 3: Cycle zero group count days and inverse fractional amplitudes

Cycle No.	Fractional Zero Days	Inverse Amplitudes
21	0.257180157	1.015228426
22	0.233425414	1.183431953
23	0.293777778	0.756429652
24	0.433333333	0.561482313

See the Reference section for details:

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

April 2022 (Figure 2) The plot was created by Holger Krumnow (A152) Frankfurt, Germany using Super-SID Software with the embedded plotter. Day: 30th April 2022, Transmitter Frequency: HWU 21,750kHz, Transmitter Location: Rosnay France.

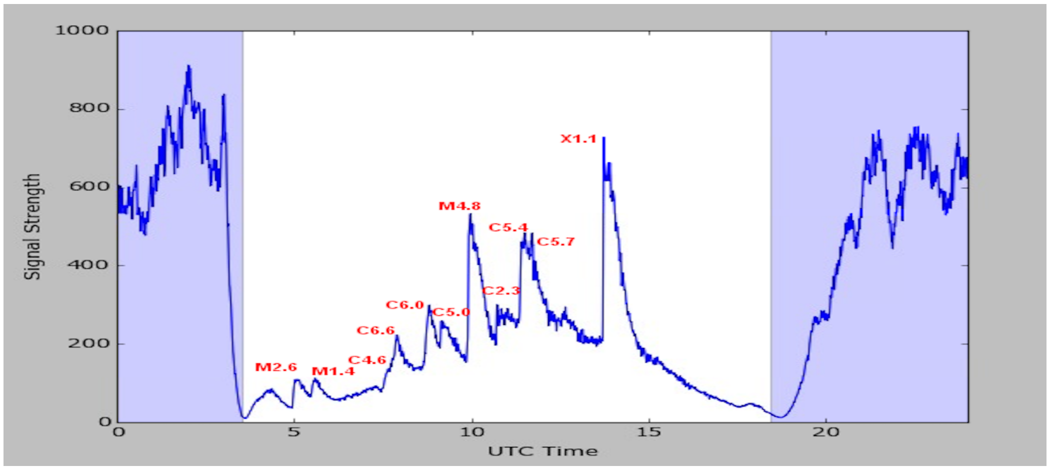

Figure 2: VLF recording on the 30th of April.

2.2 SID Observers

In April 2022 we had 17 AAVSO SID observers who submitted VLF data as listed in Table 4.

Table 4: 202204 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO GQD
J Godet	A119	GBZ GQD ICV
F Adamson	A122	NWC
G Perry	A126	DHO
J Karlovsky	A131	DHO NAA TBB
R Green	A134	NWC
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 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.

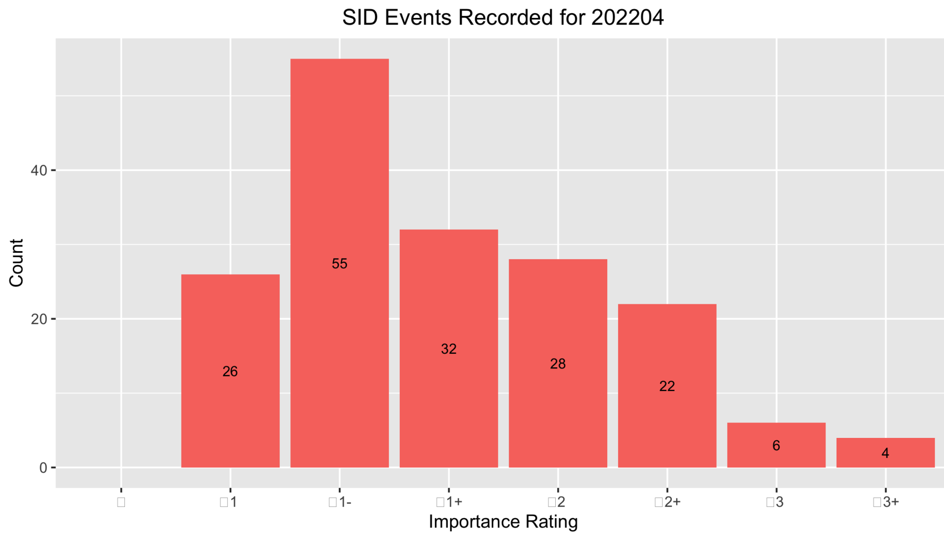

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In April 2022, there were 249 GOES-16 XRA flares; 3 X class, 30 M class, 193 C class and 23 B class flares, about the same flaring this month compared to last. (see Figure 4).

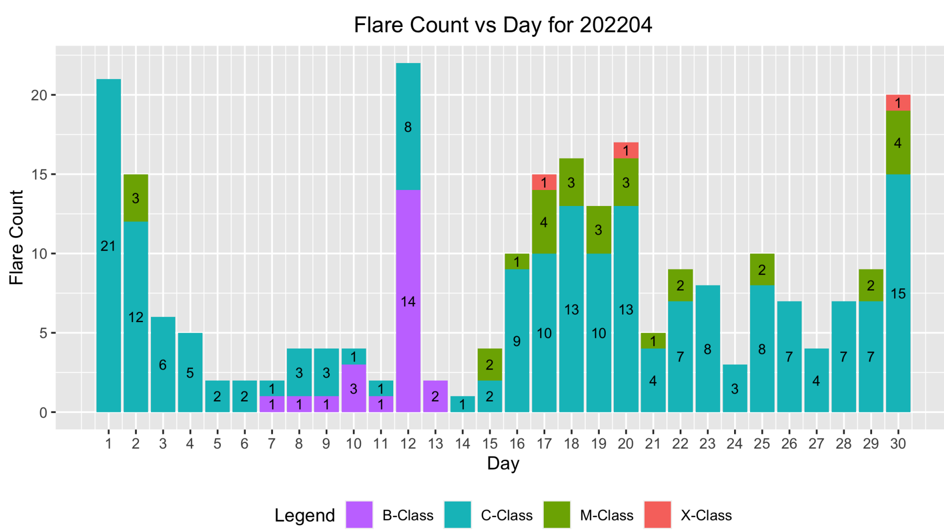

Figure 4: GOES-16 XRA flares.

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 April 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.

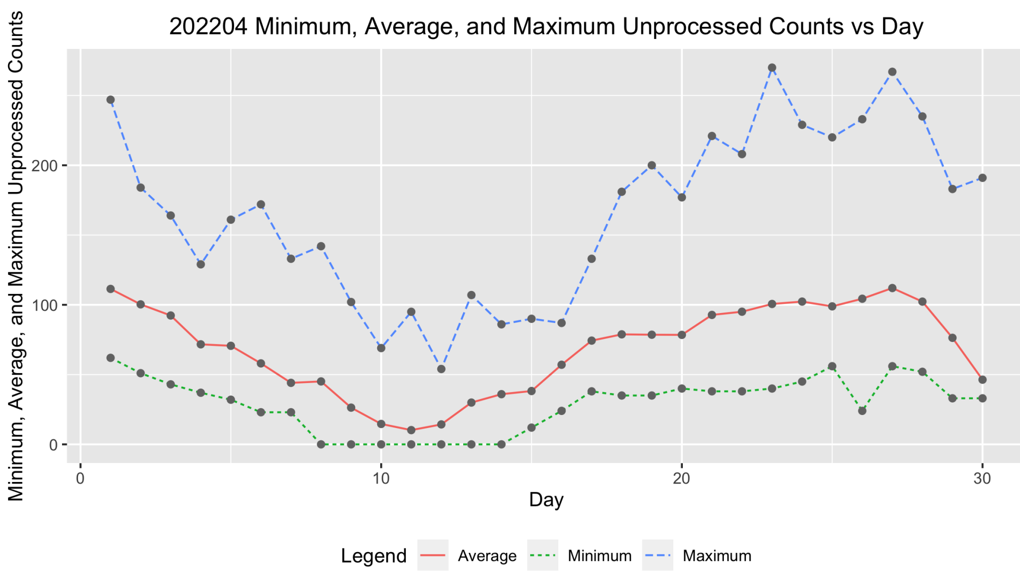

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

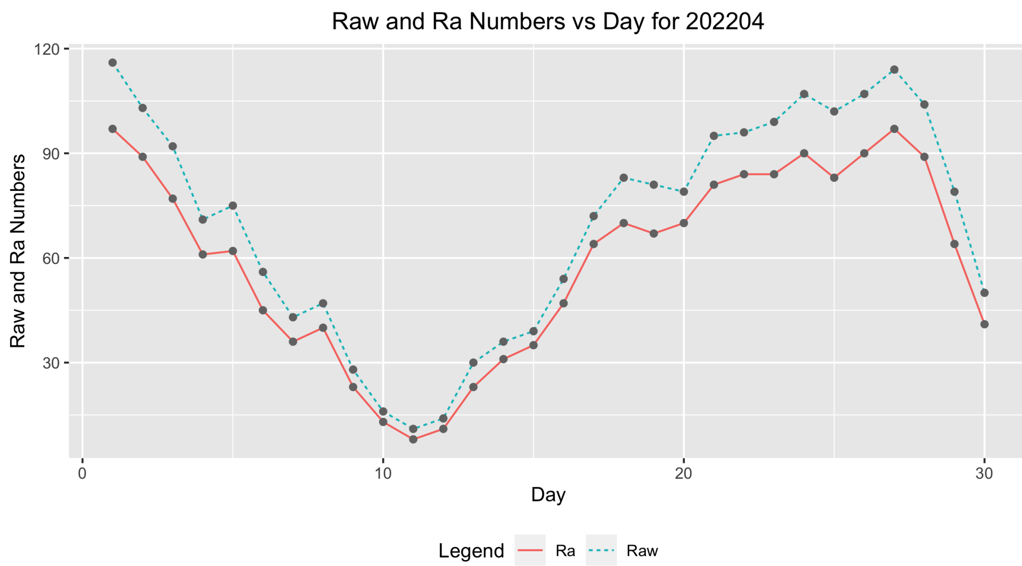

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 (`https://adsabs.harvard.edu/full/1949PASP...61...13S`). 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 5 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 5: 202204 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	36	116	97
2	43	103	89
3	38	92	77
4	34	71	61
5	38	75	62
6	38	56	45
7	38	43	36
8	41	47	40
9	47	28	23
10	47	16	13
11	43	11	8
12	41	14	11
13	41	30	23
14	45	36	31

Continued

Table 5: 202204 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	46	39	35
16	45	54	47
17	47	72	64
18	42	83	70
19	42	81	67
20	46	79	70
21	38	95	81
22	36	96	84
23	36	99	84
24	51	107	90
25	37	102	83
26	41	107	90
27	45	114	97
28	48	104	89
29	47	79	64
30	41	50	41
Averages	41.9	70	59.1

3.3 Sunspot Observers

Table 6 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for April 2022, 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 (1258).

Table 6: 202204 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	14	Alexandre Amorim
AJV	22	J. Alonso
ARAG	29	Gema Araujo
ASA	19	Salvador Aguirre
ATE	27	Teofilo Arranz Heras
BATR	12	Roberto Battaiola
BKL	11	John A. Blackwell
BMF	20	Michael Boschat
BMIG	23	Michel Besson
BROB	24	Robert Brown
BXZ	22	Jose Alberto Berdejo
BZX	29	A. Gonzalo Vargas
CANG	1	Andrew Corkill
CIOA	9	Ioannis Chouinavas

Continued

Table 6: 202204 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CKB	26	Brian Cudnik
CMOD	4	Moise Carlo
CNT	30	Dean Chantiles
CVJ	5	Jose Carvajal
DARB	19	Aritra Das
DFR	9	Frank Dempsey
DJOB	17	Jorge del Rosario
DMIB	28	Michel Deconinck
DUBF	23	Franky Dubois
EHOA	21	Howard Eskildsen
ERB	21	Bob Eramia
FDAE	3	David Fox
FERA	21	Eric Fabrigat
FLET	21	Tom Fleming
GIGA	26	Igor Grageda Mendez
HALB	17	Brian Halls
HKY	21	Kim Hay
HMQ	4	Mark Harris
HOWR	20	Rodney Howe
HRUT	23	Timothy Hrutkay
IEWA	22	Ernest W. Iverson
ILUB	9	Luigi Iapichino
JDAC	6	David Jackson
JGE	5	Gerardo Jimenez Lopez
JSI	4	Simon Jenner
KAMB	30	Amoli Kakkar
KAND	17	Kandilli Observatory
KAPJ	12	John Kaplan
KNJS	30	James & Shirley Knight
KZAD	10	Zachary Knoles
LEVM	13	Monty Leventhal
LKR	10	Kristine Larsen
LRRA	21	Robert Little
MARE	16	Enrico Mariani
MCE	20	Etsuiku Mochizuki
MJAF	25	Juan Antonio Moreno Quesada
MJHA	29	John McCammon
MLL	10	Jay Miller
MMAY	30	Max Surlaroute
MMI	30	Michael Moeller
MSS	7	Sandy Mesics
MUDG	6	George Mudry
MWU	25	Walter Maluf

Continued

Table 6: 202204 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
OAAA	20	Al Sadeem Astronomy Obs.
ONJ	18	John O'Neill
PEKT	4	Riza Pektas
PLUD	23	Ludovic Perbet
RJV	18	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SNE	3	Neil Simmons
SQN	5	Lance Shaw
SRIE	20	Rick St. Hilaire
TDE	28	David Teske
TPJB	2	Patrick Thibault
TST	15	Steven Toothman
URBP	23	Piotr Urbanski
VIDD	17	Dan Vidican
WGI	2	Guido Wollenhaupt
WTIC	1	Timothy Weaver
WWM	21	William M. Wilson
Totals	1258	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. 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.

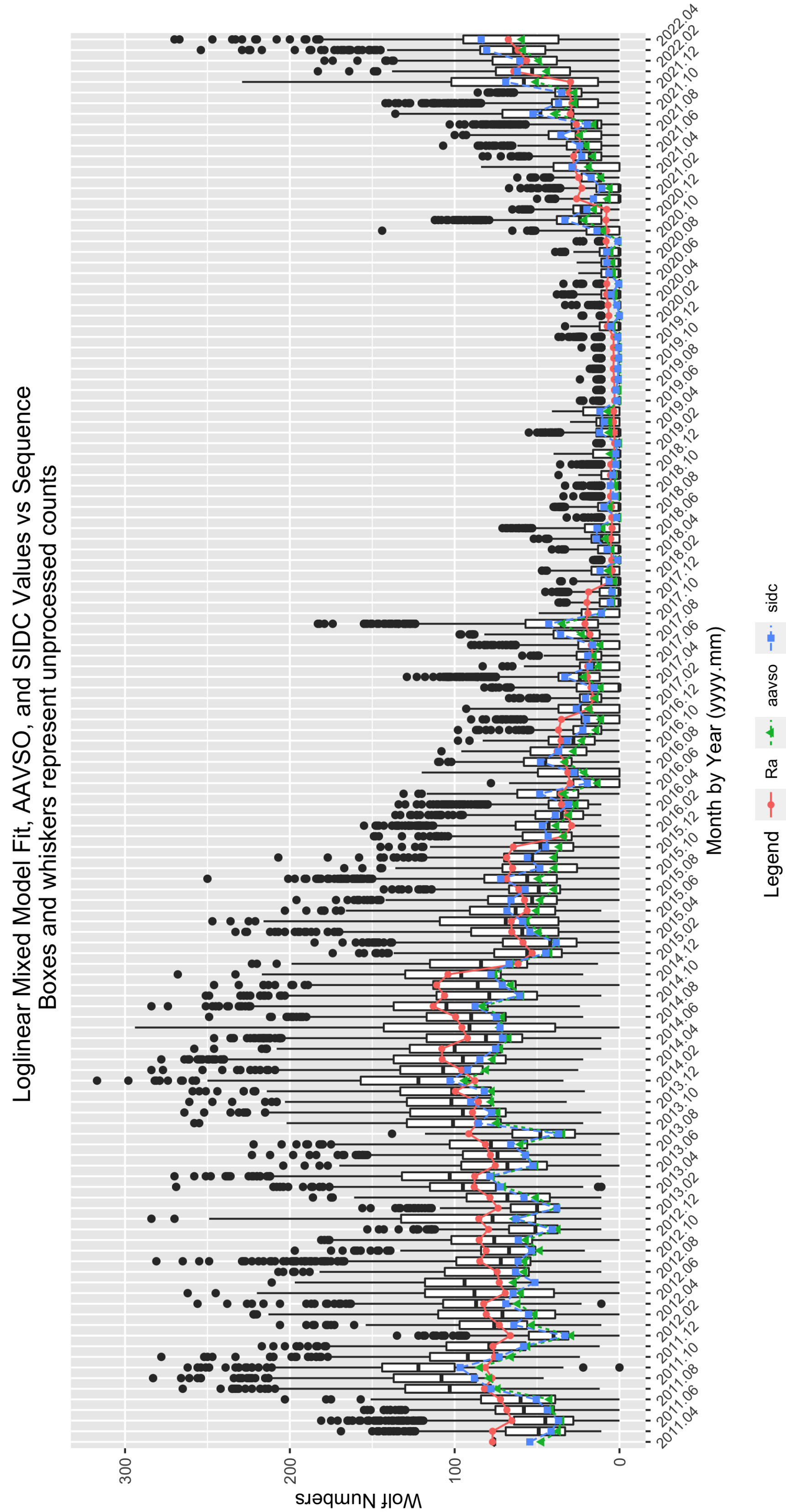

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

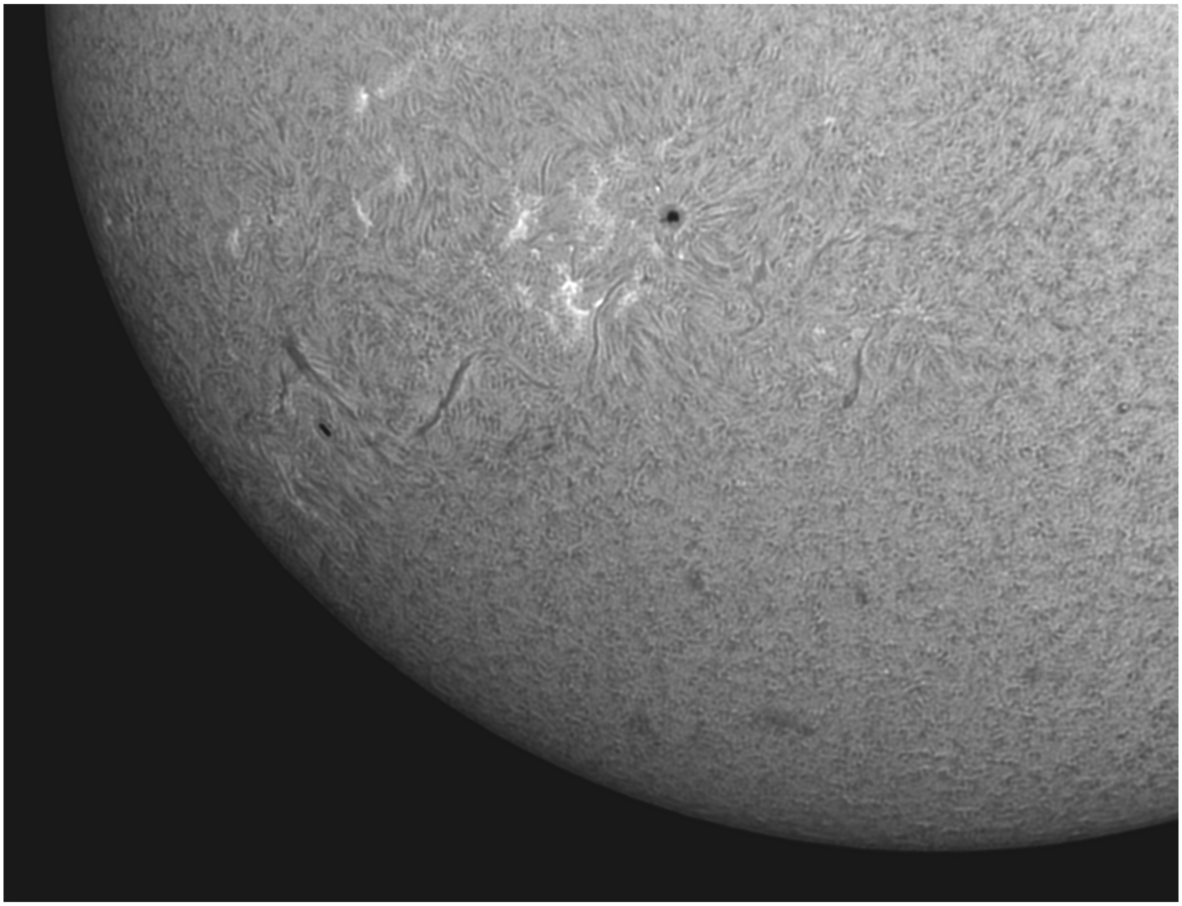

Figure 8: "I wish to send you a nice image of the photosphere captured on April 28, 2022 in which the regions 2999, 3000 and 3001 are visible. Telescope: LUNT LS50THa Blocking filter B600 Etalon pressure tuner. Camera: ZWO ASI 120 barlow 2.0X. Capture Software: Ekos/KStars. Image processing: Siril, imppg, Gimp2." Best regards, Moise Carlo (CMOD)

5 References

T. Willamo, I. G. Usoskin, and G. A. Kovaltsov, 2017, Updated sunspot group number reconstruction for 1749 thru 1996 using the active day fraction method (http://cc.oulu.fi/~usoskin/personal/Willamo_ADF_AA_17.pdf)