Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

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ISSN 0271-8480

Volume 78 Number 5 May 2022

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 Compare the GOES-16 XRA flares with AAVSO R_a index

Each month we can compare GOES-16 XRA flares to the AAVSO R_a index. The AAVSO R_a index is using the Shapley method with k-factors to be compared to GOES-16 XRA flare production from the NOAA data. With various group and sunspot classification schemes these GOES-16 XRA data can be compared to visual observations. See the Reference section for details.

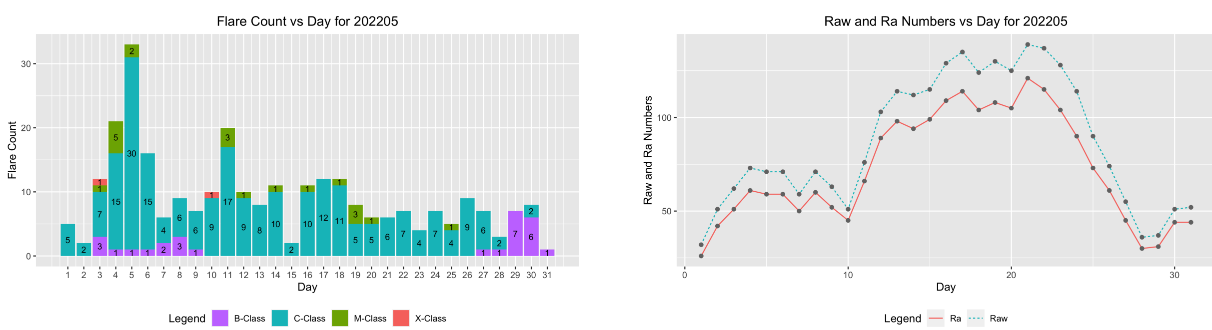

Figure 1: How do the GOES-16 XRA (NOAA, 2022) Solar flares match to AAVSO observer data and the AAVSO R_a index. The GOES-16 XRA flares have 4 categories: B, C, M, X class flares on a log scale. The AAVSO R_a is also on a log scale, so making a match up can be done with Rolling Correlations of the monthly time series.

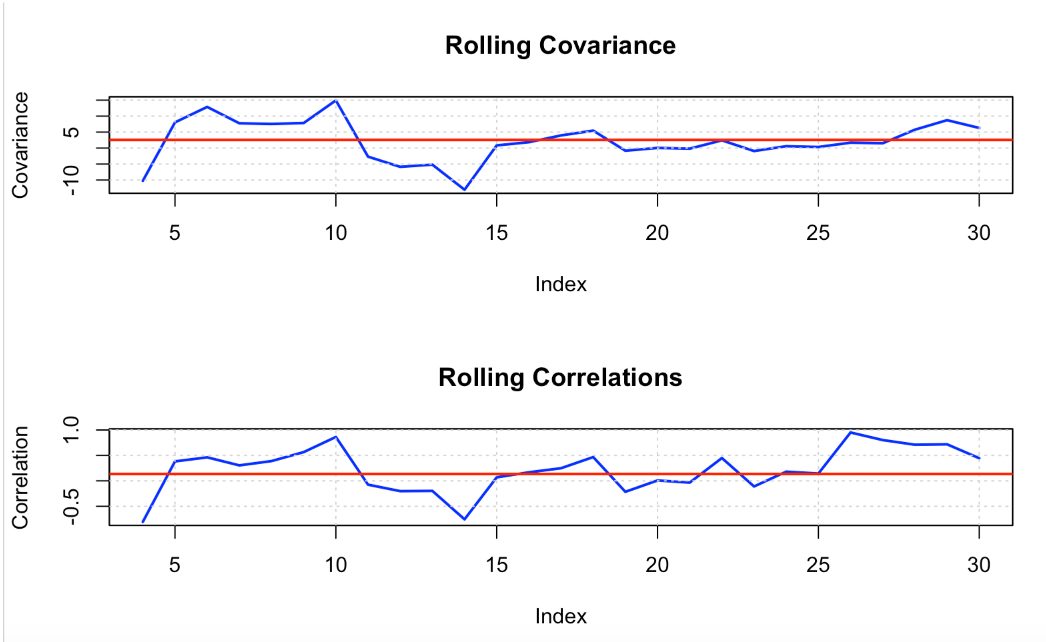

Figure 2: The Rolling Covariance and Rolling Correlations indicate that on three occasions in May, the GOES-16 XRA (NOAA, 2022) flares approximated positive values with the AAVSO Ra index created from visual observations. However, GOES-16 XRA flaring did not follow the upward trend of AAVSO sunspot counts from the middle to the end of the month, and Rolling Covariance and Correlations were not positive. The red line represents the mean daily value of these matrices.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

May 2022 (Figure 3) "I monitored 20.9kHz HWU. I also inserted some graph: on 16 the signal was disturbed by noise from thunderstorms (I inserted a zoom in this graph). Regards, Roberto Battaiola (A96)." See the End Notes section for an image of sunspots on the 16th of May.

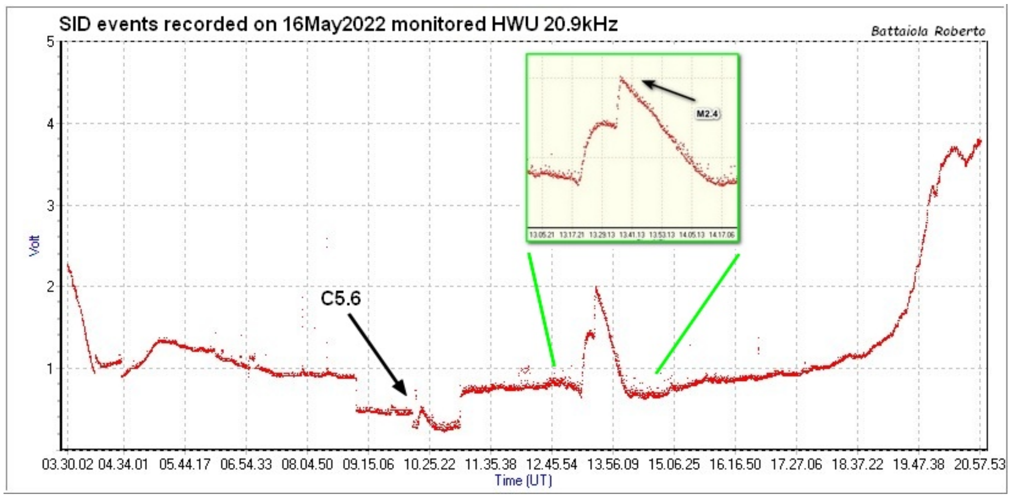

Figure 3: VLF recording on the 16th of May.

2.2 SID Observers

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

Table 1: 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
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.

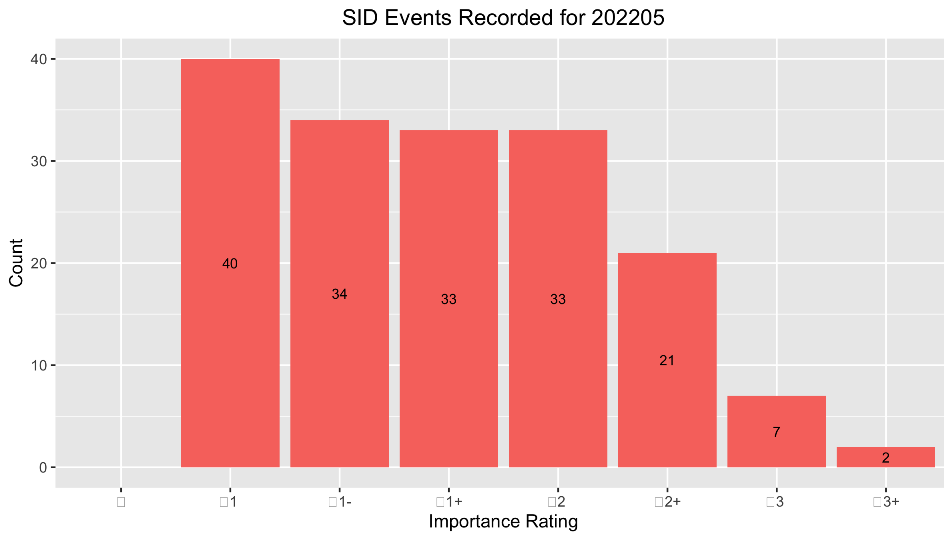

Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In May 2022, there were 285 GOES-16 XRA flares: 2 X class, 20 M class, 235 C class and 28 B class flares. About the same amount of flaring as last month (Figure 5).

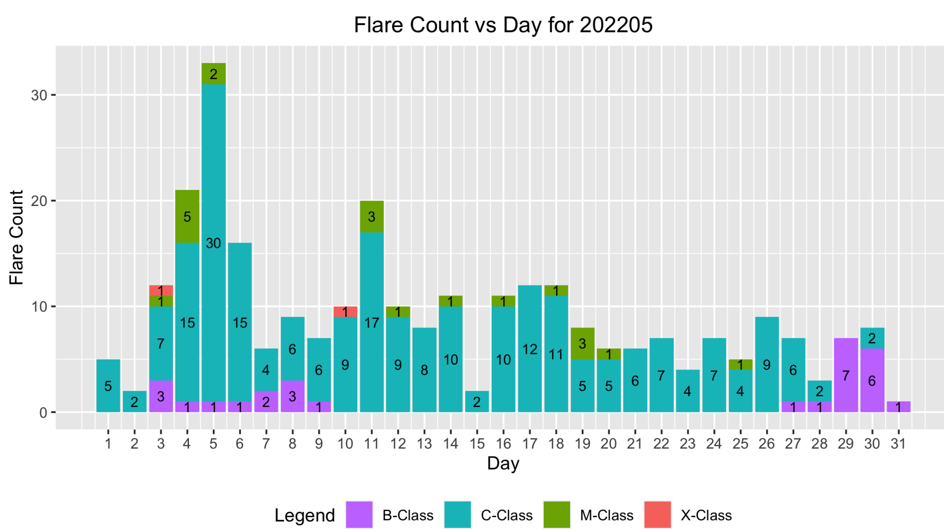

Figure 5: GOES-16 XRA (NOAA, 2022) flares.

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 May 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 6.

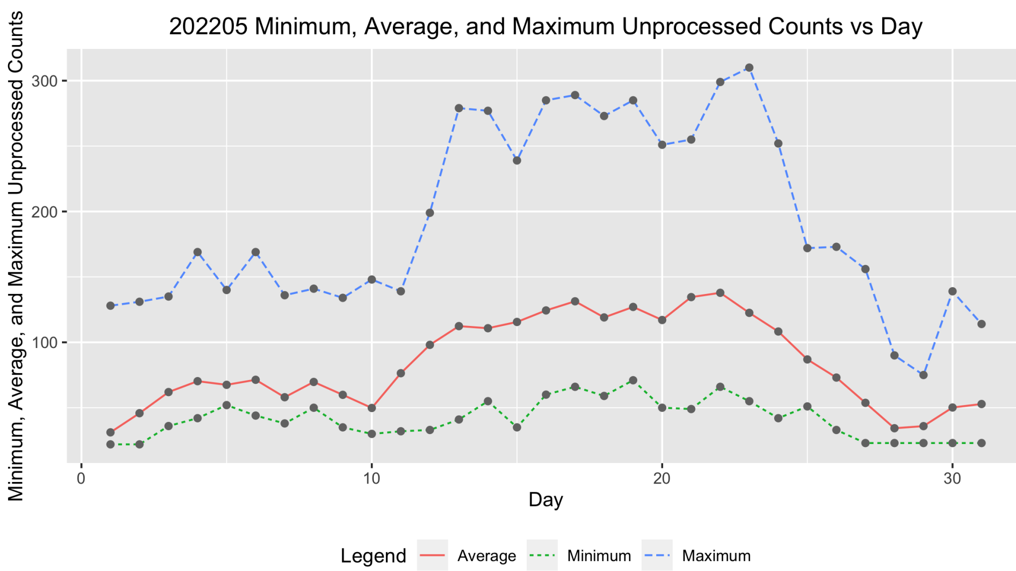

Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

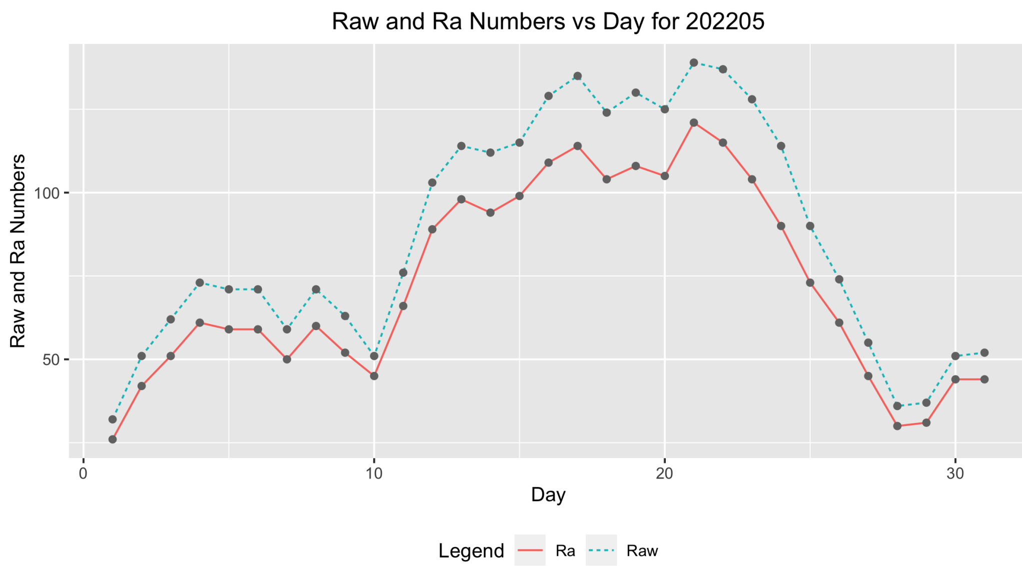

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 (`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 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: 202205 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	39	32	26
2	33	51	42
3	34	62	51
4	34	73	61
5	43	71	59
6	36	71	59
7	44	59	50
8	47	71	60
9	44	63	52
10	50	51	45
11	44	76	66
12	46	103	89
13	47	114	98
14	49	112	94

Continued

Table 2: 202205 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	47	115	99
16	45	129	109
17	45	135	114
18	43	124	104
19	40	130	108
20	39	125	105
21	46	139	121
22	41	137	115
23	38	128	104
24	32	114	90
25	38	90	73
26	38	74	61
27	35	55	45
28	46	36	30
29	45	37	31
30	47	51	44
31	37	52	44
Averages	41.7	86.5	72.5

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for May 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 (1312).

Table 3: 202205 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	23	Alexandre Amorim
AJV	19	J. Alonso
ARAG	31	Gema Araujo
ASA	22	Salvador Aguirre
ATE	27	Teofilo Arranz Heras
BATR	9	Roberto Battaiola
BKL	16	John A. Blackwell
BMF	25	Michael Boschat
BMIG	28	Michel Besson
BROB	28	Robert Brown
BXZ	28	Jose Alberto Berdejo
BZX	29	A. Gonzalo Vargas
CANG	11	Andrew Corkill

Continued

Table 3: 202205 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CIOA	15	Ioannis Chouinavas
CKB	29	Brian Cudnik
CMOD	7	Mois Carlo
CNT	29	Dean Chantiles
CVJ	18	Jose Carvajal
DARB	15	Aritra Das
DFR	13	Frank Dempsey
DJOB	14	Jorge del Rosario
DUBF	28	Franky Dubois
EHOA	12	Howard Eskildsen
ERB	19	Bob Eramia
FERA	23	Eric Fabrigat
FLET	28	Tom Fleming
GIGA	25	Igor Grageda Mendez
HALB	13	Brian Halls
HKY	20	Kim Hay
HMQ	4	Mark Harris
HOWR	16	Rodney Howe
HRUT	23	Timothy Hrutkay
IEWA	27	Ernest W. Iverson
ILUB	5	Luigi Iapichino
JDAC	3	David Jackson
JGE	7	Gerardo Jimenez Lopez
JSI	4	Simon Jenner
KAND	26	Kandilli Observatory
KAPJ	19	John Kaplan
KNJS	29	James & Shirley Knight
KZAD	14	Zachary Knoles
LKR	10	Kristine Larsen
LRRA	17	Robert Little
MARC	6	Arnaud Mengus
MARE	12	Enrico Mariani
MCE	18	Etsuiku Mochizuki
MJAF	31	Juan Antonio Moreno Quesada
MJHA	27	John McCammon
MLL	13	Jay Miller
MMAY	31	Max Surlaroute
MMI	31	Michael Moeller
MSS	3	Sandy Mesics
MUDG	8	George Mudry
MWU	21	Walter Maluf
OAAA	20	Al Sadeem Astronomy Obs.
ONJ	19	John O'Neill

Continued

Table 3: 202205 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
PEKT	2	Riza Pektas
PLUD	26	Ludovic Perbet
RJUB	4	Justus Randolph
RJV	21	Javier Ruiz Fernandez
SDOH	31	Solar Dynamics Obs - HMI
SNE	9	Neil Simmons
SQN	7	Lance Shaw
SRIE	21	Rick St. Hilaire
TDE	30	David Teske
TST	15	Steven Toothman
URBP	27	Piotr Urbanski
VIDD	26	Dan Vidican
WGI	4	Guido Wollenhaupt
WND	17	Denis Wallian
WWM	24	William M. Wilson
Totals	1312	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 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 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.

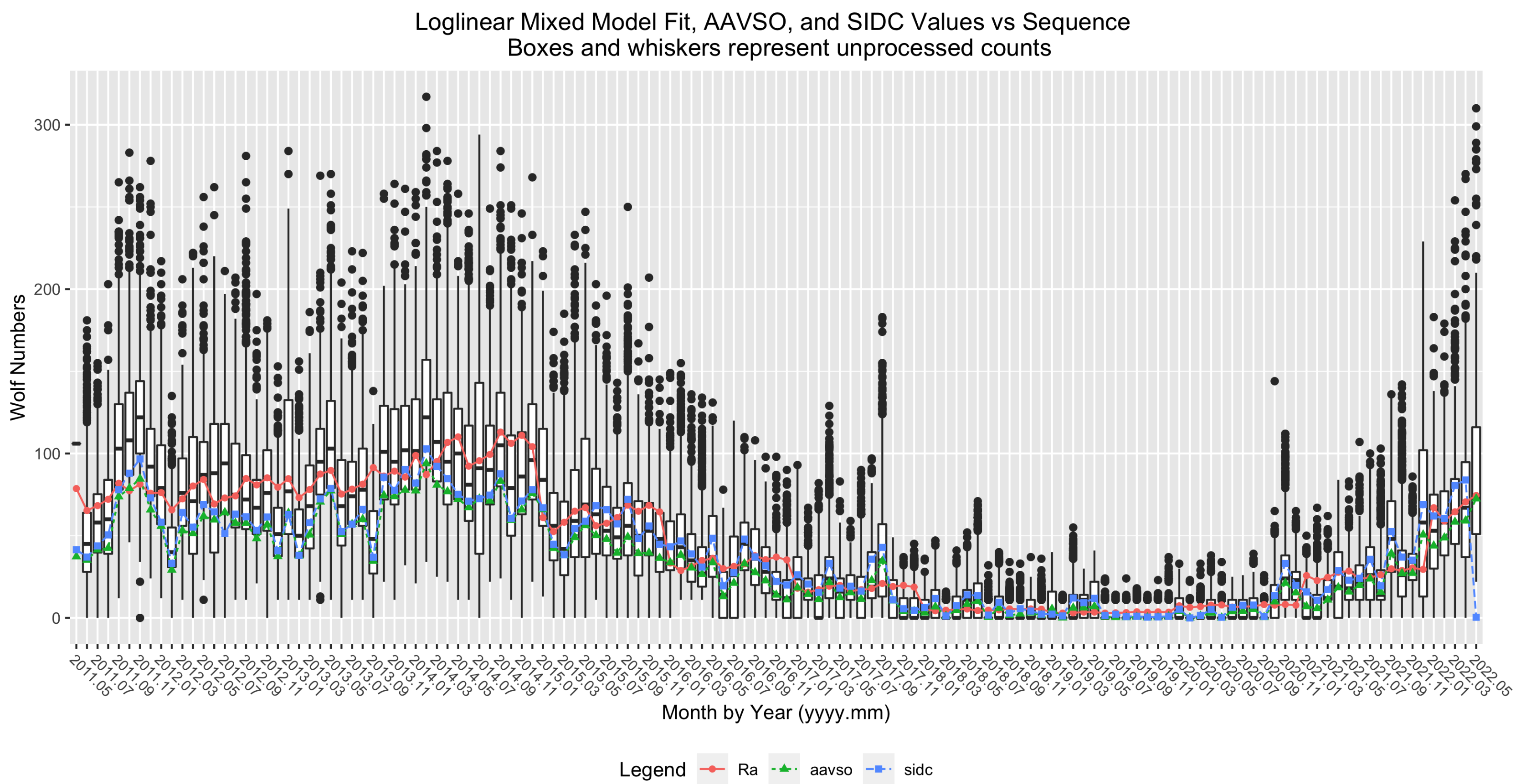

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

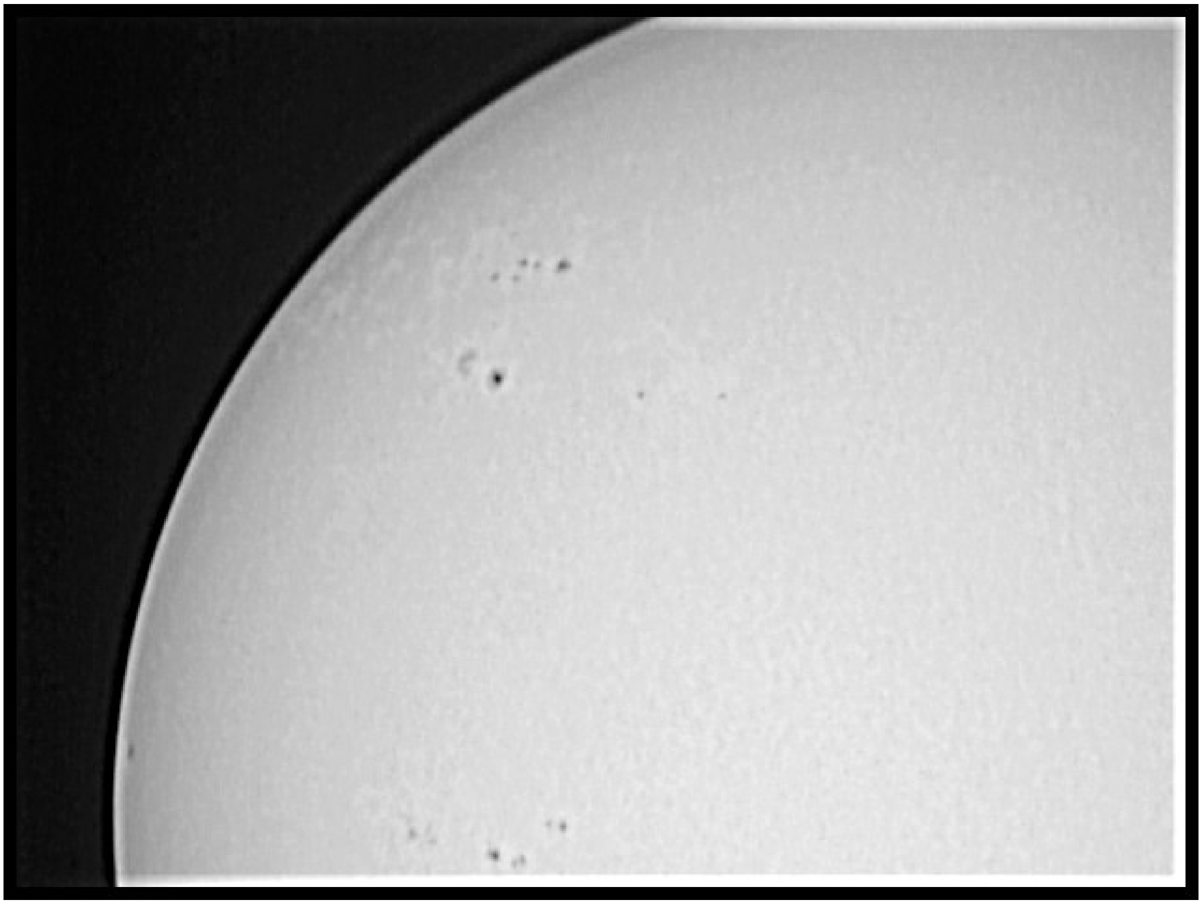

Figure 9: "Please find attached some imagery on the main sunspot groups, from May 2022 (Day 16), N is up; W is at right. Best regards, Dan Vidican (VIDD)."

5 References

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

S. Eren, et al., 2016, Flare-production potential associated with different sunspot groups (http://academic.oup.com/mnras/article/465/1/68/2417463?login=false).

SILSO, World Data Center - Sunspot Number and Long-term Solar Observations, Royal Observa-tory of Belgium, on-line Sunspot Number catalogue: (https://www.sidc.be/silso/datafiles)