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 months 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 AAVSO needs visual observations, not satellite image counts

Although visual counting of spots may sound archaic in comparison with the many advanced modern solar data collected by ground-based observing networks and space missions (25-year old SOHO, SDO, Parker Probe, Solar Orbiter), they remain our sole link to the distant past. In order to put this detailed but mostly very recent solar knowledge in a temporal perspective, it must be attached to a long-term standard. We need to be able to answer one vital question: is the Sun, as we observe it today, equivalent and representative of the state of the Sun several centuries or millennia in the past and in the future? Therefore, today, we need to continue this heritage series in parallel with all other techniques, in order to calibrate the relation between various solar parameters (spectral irradiance, solar wind flux, global magnetic fields) and the sunspot number, and all of this over the whole range of possible activity regimes (See for example Svalgaard, 2017). This means that we must continue to observe the way we have for at least one or more solar cycles (Clette 2021).

The bottom line is that solar scientists need reliable visual observations that are done in a way that is consistent with the way observations have been done for nearly two centuries. Through the use of k-factors and other statistical analysis we can turn what one might consider the problem of variance in human interpretations into a solid, reliable timeline of solar activity.

1.1 15 Groups and 18 Sunspots

Here's an example of relying on NOAA's magnetic active region designations for group counts; where there are too many NOAA groups with no spots. (U.S. Dept. of Commerce–NOAA, 2022)

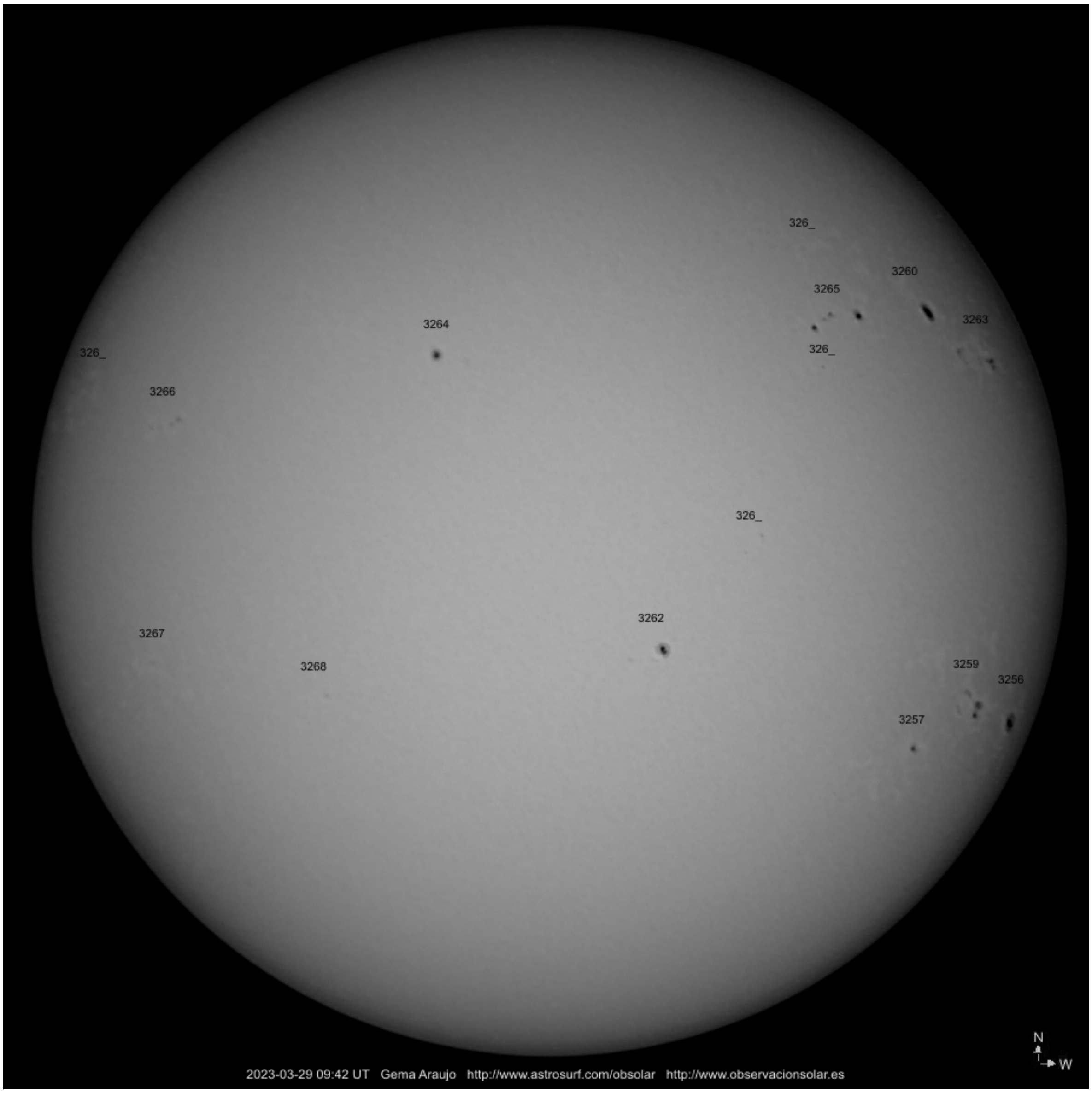

Figure 1: From Gema Araujo (ARAG): "I send you an image captured form Spain for solar bulletin. Date: 2023-03-29 09:42, White Light: Refractor 102ED f/9; AstroSolar D 3.8 filter, eyepiece Plossl 20mm, variable polarized filter, Solar Continuum. Camera: DSC-W100." http://observacionsolar.es

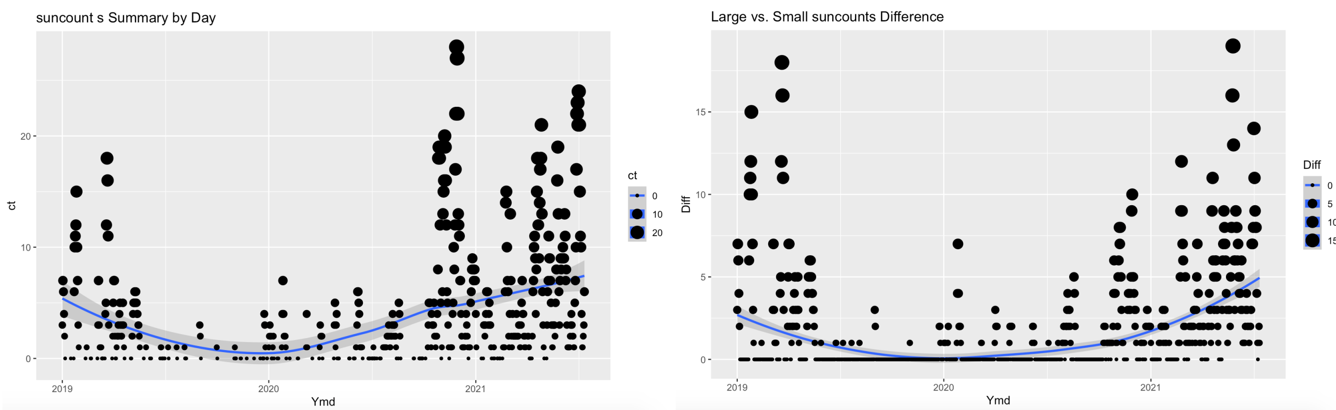

Figure 2: Sunspot satellite large counts vs. visual low counts (left panel) and the difference between the two (right panel).

These are AAVSO observations during the last solar minimum (cycle 24 - 25) where sunspot counts above the blue line are daily counts from satellite images, below the blue line are daily visual counts. The left panel are raw sunspot counts, the right panel is the difference of high vs. low sunspot counts. Notice how with the difference of counts between visual vs. satellite counts, the blue line goes to zero and the Y-axis shows a lower overall sunspot count, which exaggerates the difference between the high satellite counts and lower visual daily sunspot counts. The question is should we include satellite high counts along with visual observations from earth based telescopes? If we include the satellite counts the American R_a will be inflated.

The AAVSO exists to help observers collect scientifically useful data on variable stars, including the sun, and house those data in a historically robust database for the use of the scientific community. This has been our mission for more than a century. It is an amazing honor and responsibility to be involved in the process of making sure that our database remains a gold standard.

To achieve this goal, the Solar Section has a variety of resources linked to our website that are meant to help you become the most careful observer you can be, beginning with our Solar Observing manual. However, there is no substitute for experience. We therefore continue to encourage you to observe on every clear day (if possible). Carefully following the observing procedures in our manual will keep you safer and assure that your observations are scientifically useful as part of the AAVSO solar database.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

March 2023 (Figure 3): There was a nice X2.1 flare at 18:00 UT on the 3rd of March recorded here in Fort Collins, Colorado (U.S. Dept. of Commerce–NOAA, 2022).

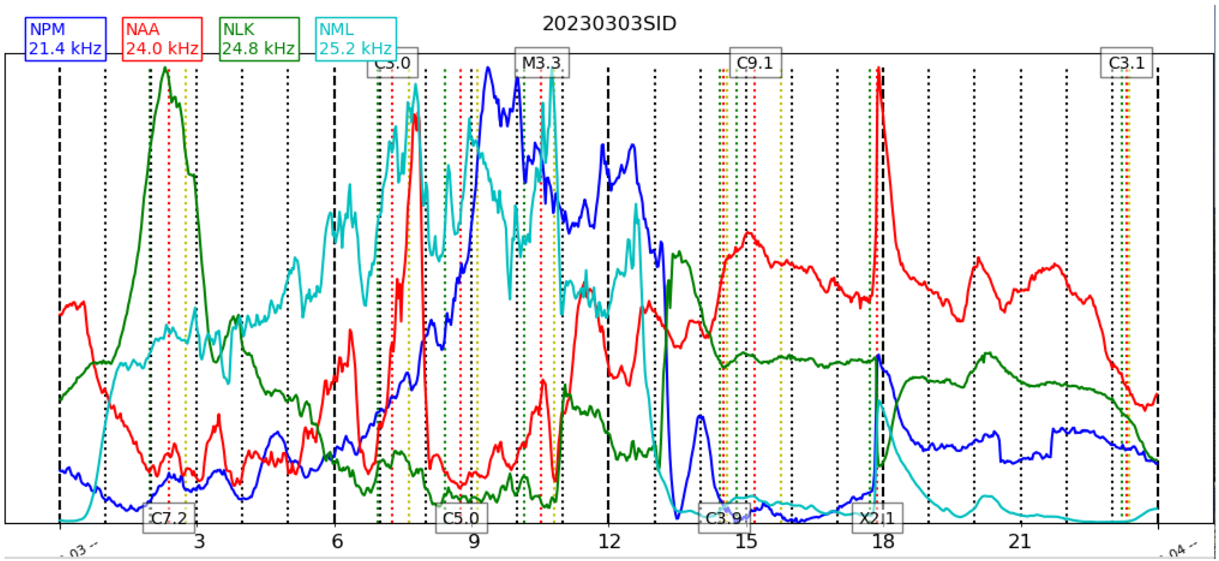

Figure 3: VLF recording from Fort Collins, Colorado for the 3rd.

2.2 SID Observers

In March 2023 we had 14 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202303 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

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.

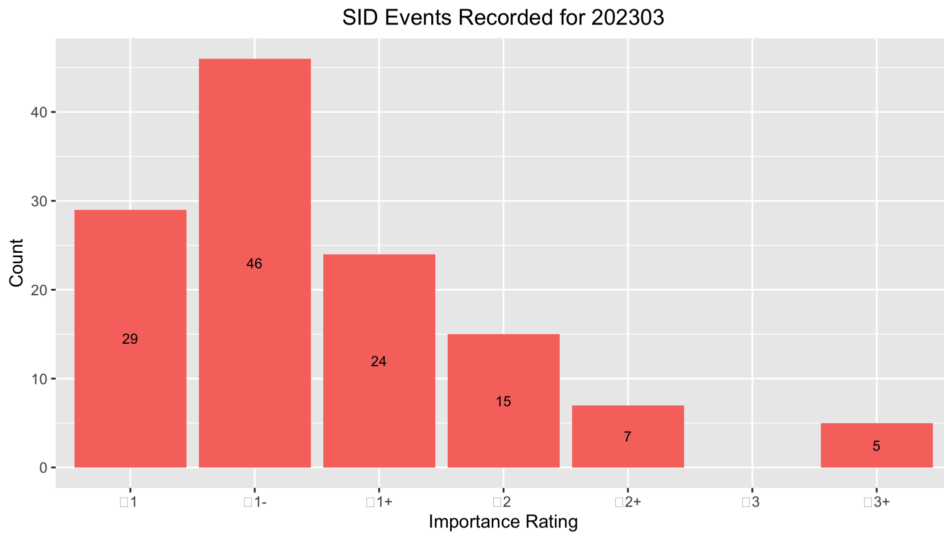

Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In March 2023, there were 200 GOES-16 XRA flares this month: two X class, 19 M class, 172 C class and 7 B class flares. Far less flaring this month compared to last. (U.S. Dept. of CommerceNOAA, 2022). (see Figure 5).

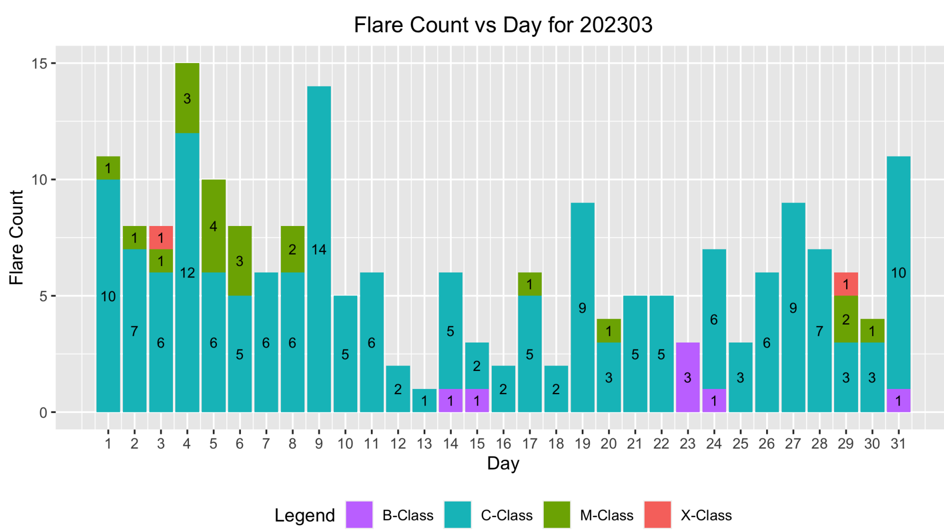

Figure 5: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 March 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.

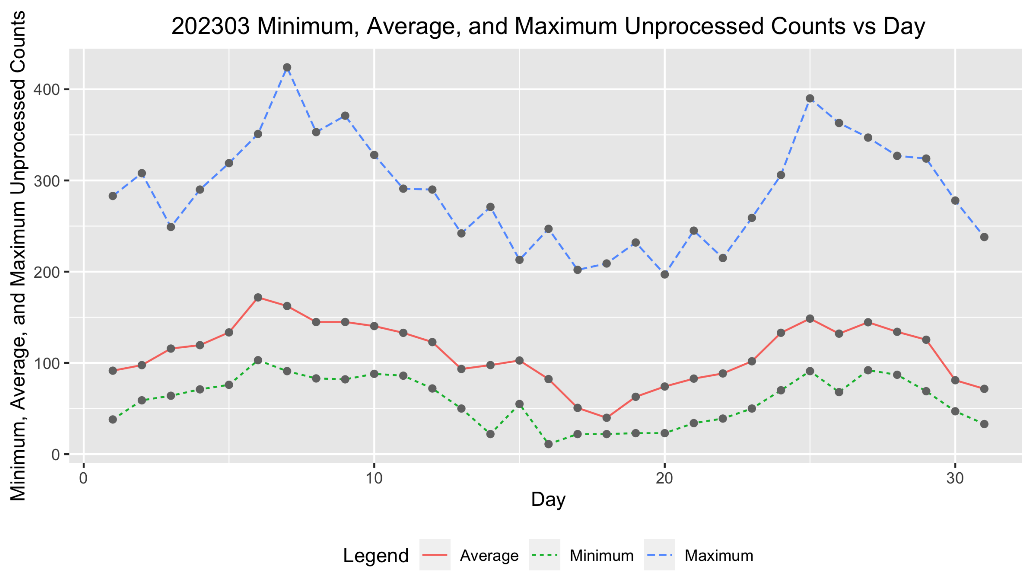

Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

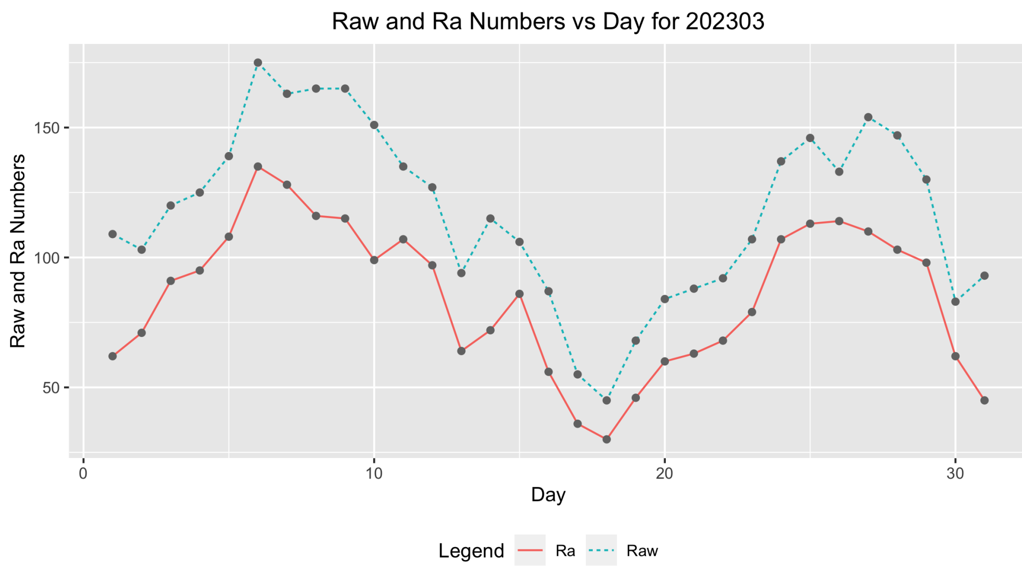

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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: 202303 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	23	109	62
2	28	103	71
3	28	120	91
4	29	125	95
5	31	139	108
6	35	175	135
7	30	163	128
8	28	165	116
9	29	165	115
10	26	151	99
11	28	135	107
12	36	127	97
13	27	94	64
14	30	115	72

Continued

Table 2: 202303 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	38	106	86
16	25	87	56
17	32	55	36
18	39	45	30
19	34	68	46
20	32	84	60
21	34	88	63
22	31	92	68
23	30	107	79
24	32	137	107
25	31	146	113
26	36	133	114
27	35	154	110
28	32	147	103
29	38	130	98
30	36	83	62
31	22	93	45
Averages	31.1	117.5	85

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for March 2023, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (65), and total number of observations submitted (965).

Table 3: 202303 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	27	Alexandre Amorim
AJV	22	J. Alonso
ARAG	30	Gema Araujo
ASA	16	Salvador Aguirre
ATE	19	Teofilo Arranz Heras
BATR	8	Roberto Battaiola
BKL	3	John A. Blackwell
BMF	18	Michael Boschat
BMIG	25	Michel Besson
BROB	13	Robert Brown
BXZ	25	Jose Alberto Berdejo
BZX	21	A. Gonzalo Vargas
CIOA	1	Ioannis Chouinavas

Continued

Table 3: 202303 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CKB	22	Brian Cudnik
CMAB	10	Maurizio Cervoni
CNT	24	Dean Chantiles
DARB	8	Aritra Das
DELS	7	Susan Delaney
DFR	6	Frank Dempsey
DJOB	16	Jorge del Rosario
DJSA	17	Jeff DeVries
DMIB	29	Michel Deconinck
DUBF	19	Franky Dubois
EGMA	5	Georgios Epitropou
EHOA	16	Howard Eskildsen
ERB	14	Bob Eramia
FERA	19	Eric Fabrigat
FLET	25	Tom Fleming
GIGA	23	Igor Grageda Mendez
HALB	5	Brian Halls
HKY	17	Kim Hay
HMQ	4	Mark Harris
HOWR	20	Rodney Howe
IEWA	16	Ernest W. Iverson
ILUB	2	Luigi Iapichino
JGE	5	Gerardo Jimenez Lopez
JSI	1	Simon Jenner
KAMB	31	Amoli Kakkar
KAND	12	Kandilli Observatory
KAPJ	4	John Kaplan
KNJS	31	James & Shirley Knight
LKR	6	Kristine Larsen
LRRA	21	Robert Little
MARC	4	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	21	Etsuiku Mochizuki
MJHA	29	John McCammon
MLL	3	Jay Miller
MMI	31	Michael Moeller
MSS	8	Sandy Mesics
MWU	10	Walter Maluf
ONJ	10	John O'Neill
PLUD	11	Ludovic Perbet
RJV	14	Javier Ruiz Fernandez
SDOH	31	Solar Dynamics Obs - HMI
SNE	3	Neil Simmons

Continued

Table 3: 202303 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SRIE	13	Rick St. Hilaire
TDE	26	David Teske
TNIA	3	Nick Tonkin
TPJB	4	Patrick Thibault
TST	18	Steven Toothman
URBP	15	Piotr Urbanski
VIDD	18	Dan Vidican
WGI	1	Guido Wollenhaupt
WWM	16	William M. Wilson
Totals	965	65

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.

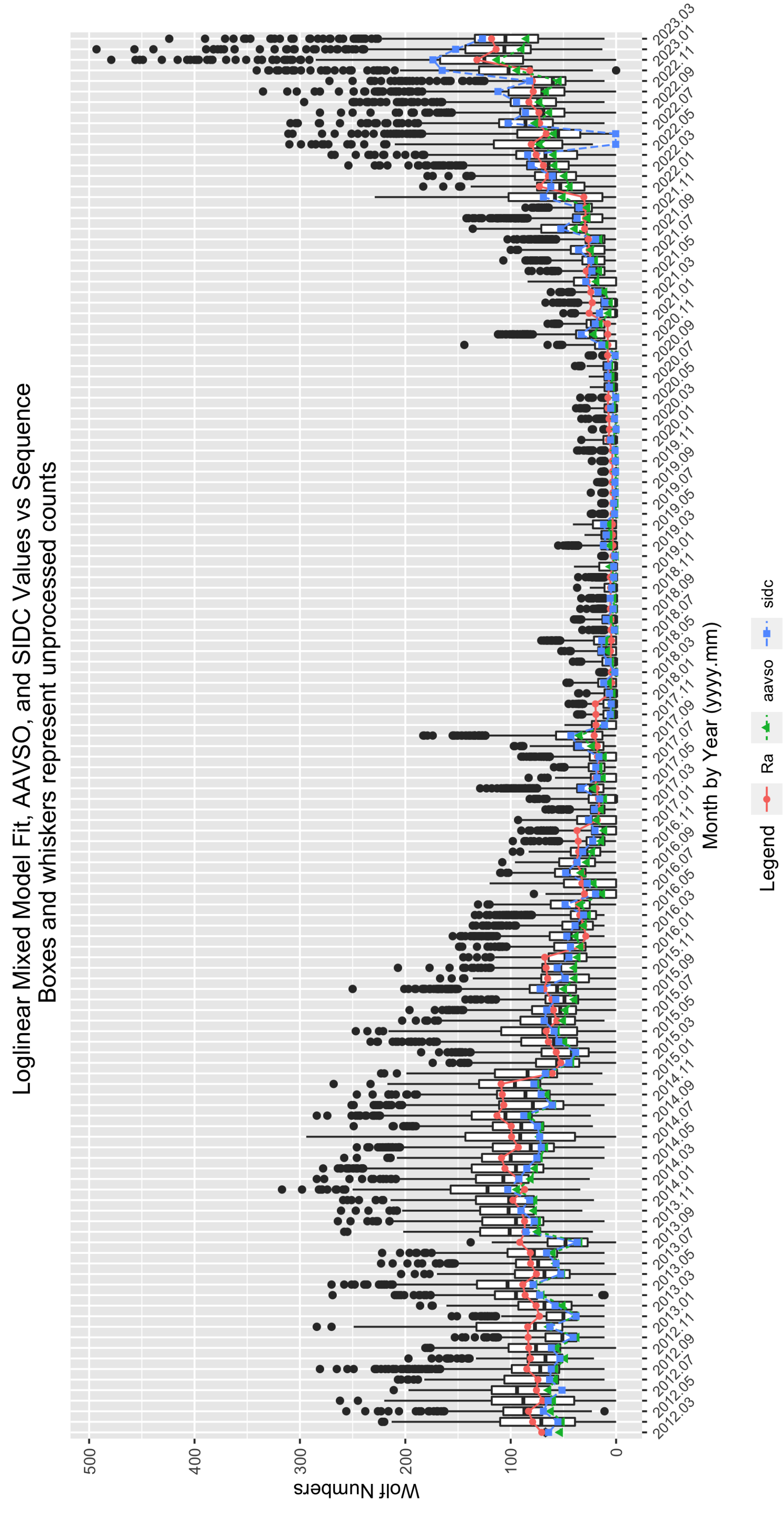

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

5 References

Clette, Frederic (2021) The Sunspot Number: *Reconstructing the Past Solar Cycle for the Future.* [data set]. Space Research Today 210: 10-23. Royal Observatory of Belgium. https://www.sidc.be/silso/datafiles.

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Svalgaard, (2017), *Sunspot Group Numbers Since 1900 and Implications for the Long-term Record of Solar Activity* https://www.researchgate.net/publication/316736457_Sunspot_Group_Numbers_Since_1900_and_Implications_for_the_Long-term_Record_of_Solar_Activity

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