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 Samuel Heinrich Schwabe, King of Sunspot Observations

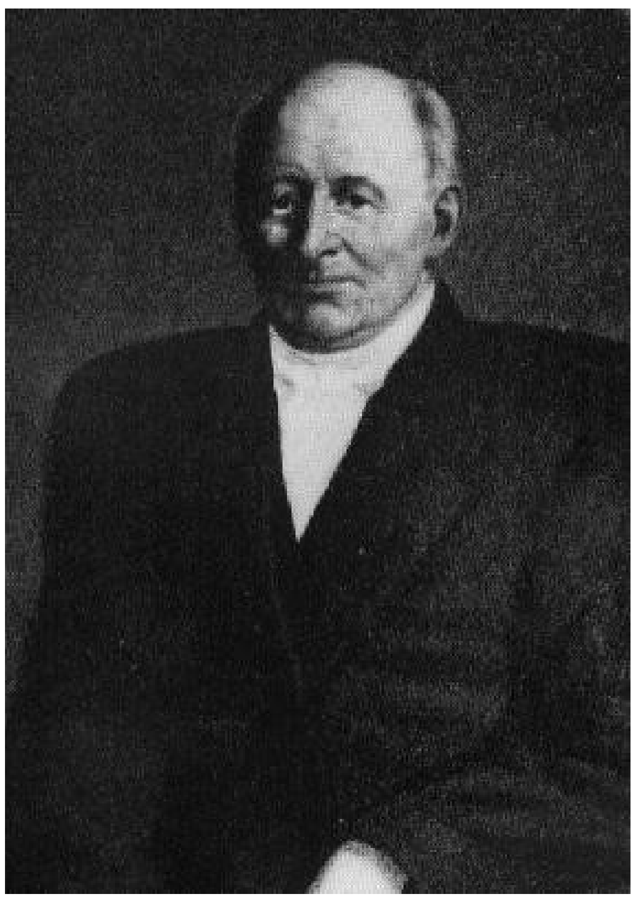

Figure 1: Portrait of Schwabe. Courtesy of Wikimedia Commons, public domain image. `https://commons.wikimedia.org/wiki/File:Samuel_Heinrich_Schwabe.jpg`

As we exit the peak of Solar Cycle 25, we should recognize that not only has the existence of the sunspot cycle been established for less than two centuries, but that our understanding and ability to predict future behavior of the so-called Schwabe cycle is less than iron-clad. Historical observations of solar activity continue to provide important clues today, including those of Schwabe himself. While detailed observations of the Moon, planets, aurora, comets and myriad other astronomical phenomenon can be found in his 39 logbook volumes (gifted by Schwabe to the Royal Astronomical Society), it is the sun that secured Samuel Heinrich Schwabe's place in astronomical history, and which we celebrate 150 years after his death on April 11, 1875.

Born in Dessau, Sachsen-Anhalt, Germany, on October 25, 1789, this eldest of eleven children became fascinated in botany and astronomy while studying in Berlin. The death of his father and grandfather – a noted physician and pharmacist, respectively – in rapid succession forced the abandonment of Schwabe's studies, as he became responsible for running the family pharmacy in 1812. A telescope won in a lottery was quickly turned towards solar observations, initially to join the search for a supposed intra-mercurial planet. While the imaginary planet remained elusory, the daily changes in the number, size, and appearance of sunspots increasingly fascinated Schwabe. He sold the family business in 1829 and bought a house on which he built an observing tower. [1] In a move familiar to many amateur astronomers, Schwabe continued to adapt his personal observatory to the needs of his telescopes and transit instrument, going so far as to erect markers on other homes for the purpose of calibrating his instruments, and even breaking a hole in the wall one night to adjust the cross hairs.[2]

Figure 2: Schwabe's house, with its observing tower. Photograph by Vinicius Arcaro, courtesy of Wikimedia Commons, public domain dedication. Image cropped. `https://commons.wikimedia.org/wiki/File:Samuel_Heinrich_Schwabe_house_in_Dessau.jpg`

Schwabe began observing the sun on November 5, 1825, and by 1843 had aggregated sufficient daily observations to not only recognize that sunspot activity waxed and waned in a periodic way, but "if one now compares the number of groups and spot-free days with each other, one finds that the sunspots had a period of approximately 10 years." While he did not offer any explanation for the cycle, he offered that "the future must show whether this period shows some stability." [3] Although his estimate of the cycle length was later updated to just over 11 years (on average), the cycle itself has become an important proxy for studying the sun's internal magnetic field. In 1857 the Royal Astronomical Society bestowed a Gold Medal upon Schwabe, with President M.J. Johnson opining that

> For thirty years never has the sun exhibited his disk above the horizon of Dessau without being confronted by Schwabe's imperturbable telescope. This is, I believe, an instance of devoted persistence (if the word were not equivocal, I should say, pertinacity) unsurpassed in the annals of astronomy. The energy of one man has revealed a phenomenon that had eluded even the suspicion of astronomers for 200 years! [4]

Long after his death, Schwabe's observations are still aiding in our understanding of the solar cycle. His logbooks contain four solar cycles worth of data, specifically nearly 8500 full-disk drawings of the sun marking about 135,000 positions and sizes of individual sunspots, as well as identifications of sunspot groups. These sketches are augmented with 3,700 written reports of day-to-day changes in sunspot activity. [5] Schwabe's data were digitized over a decade ago, allowing for detailed analysis, and greatly extending our understanding of the latitudinal and hemispheric changes in sunspot activity over time. [6]

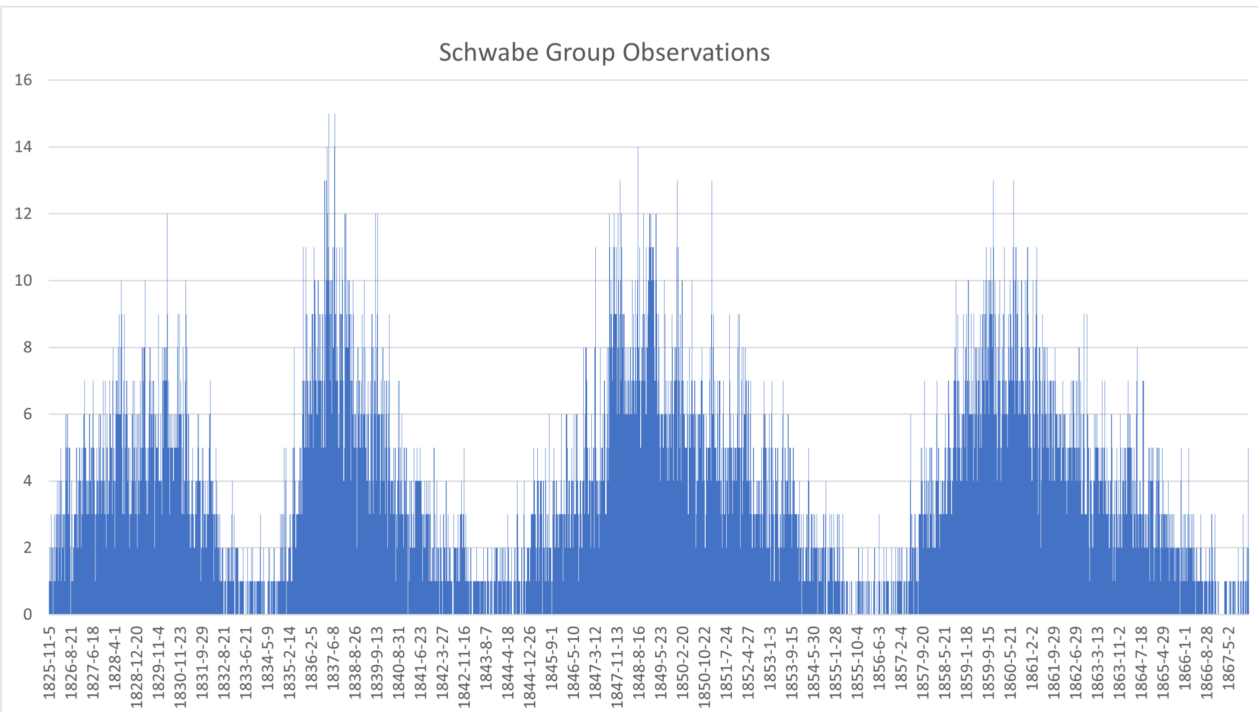

Figure 3: Schwabe's sunspot group data, 1825-1867, from SILSO group number database:(`https://www.sidc.be/SILSO/groupnumberv3`). Courtesy of Rodney Howe, AAVSO Solar Section.

Citations:

1. Arlt, Rainer. [2014]. "Sunspots from the past, treasures for today, *Astronomy and Geophysics*, vol. 55, pp. 3.24-3.27; Sheehan, William. [2014]. "Schwabe, Samuel Heinrich, in Hockey, Thomas, ed. [2014]. *Biographical Encyclopedia of Astronomers, 2nd ed.* Springer Reference, p.1959.

2. Arlt, Rainer. [2011]. "The sunspot observations by Samuel Heinrich Schwabe, *Astronomische Nachrichten*, vol. 332, p. 806.

3. Schwabe, S.H. [1844]. "Sonnen-Beobachtungen im Jahre 1843 [Solar Observations in the Year 1843], *Astronomische Nachrichten*, vol. 21, pp. 235-6, via Google Translate.

4. Johnson, M.J. [1857]. "Address Delivered by the President, M.J. Johnson, Esq., on Presenting the Medal of the Society to M. Schwabe",*Monthly Notices of the Royal Astronomical Society*, vol. 17, p. 129.

5. Arlt, R., R. Leussu, N. Giese et al. [2013] "Sunspot positions and sizes for 1825-1867 from the observations by Samuel Heinrich Schwabe, *Monthly Notices of the Royal Astronomical Society*, vol. 433, p. 3165; Arlt [2014], p. 3.24.

6. Arlt et al., p. 3171.

Kristine Larsen, Central Connecticut State University

Figure 4: This is an encouragement to disseminate details for the June 7 webinar. Please use the following link: `https://us02web.zoom.us/webinar/register/4417452723770/WN_llJHm6zkT1a1wpKOWLjBCg`

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

April 2025 (Figure 5): The most active day for VLF SID Events was April 12, with 7 M-class and 15 C-class flares: recorded by Lionel Laudet (A118).

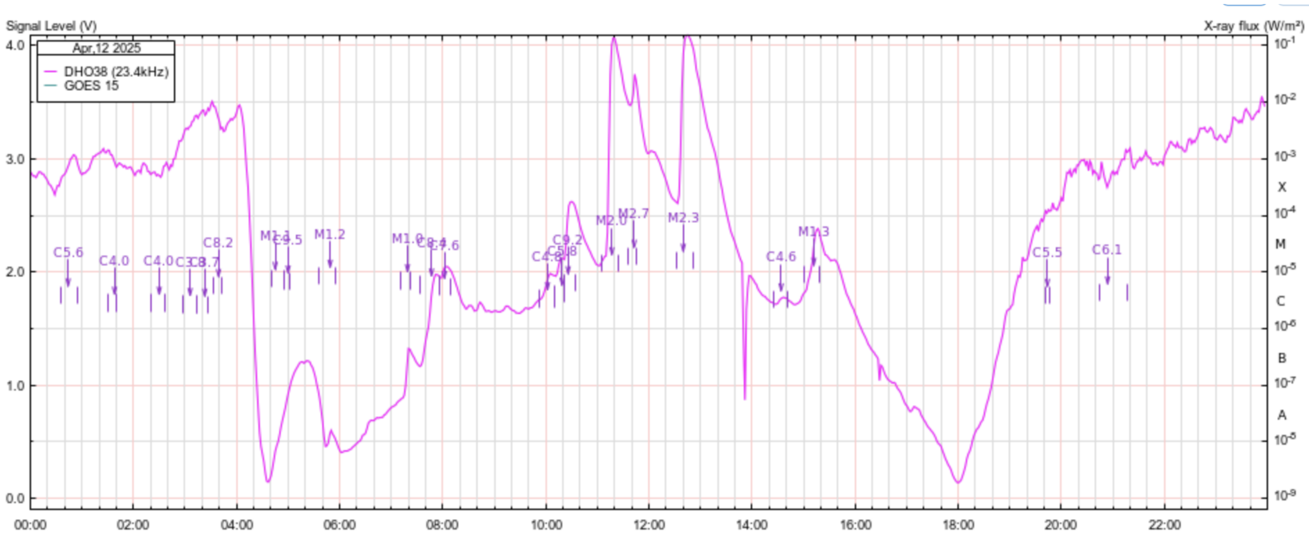

Figure 5: VLF transmitter DHO38 (22.4 kHz) from Lionel Loudet (A118) (`https://sidstation.loudet.org/data-en.xhtml`).

2.2 SID Observers

In April 2025 we had 11 AAVSO SID observers who submitted VLF data, as listed in Table 1.

Table 1: 202504 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	DHO GBZ GQD
S Aguirre	A138	NLK
G Silvis	A141	HWU NAU NLK
L Pina	A148	NAA NML
J Wendler	A150	NAA
H Krumnow	A152	DHO GBZ
J DeVries	A153	NLK
M Cervoni	A154	DHO ICV

Figure 6 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.

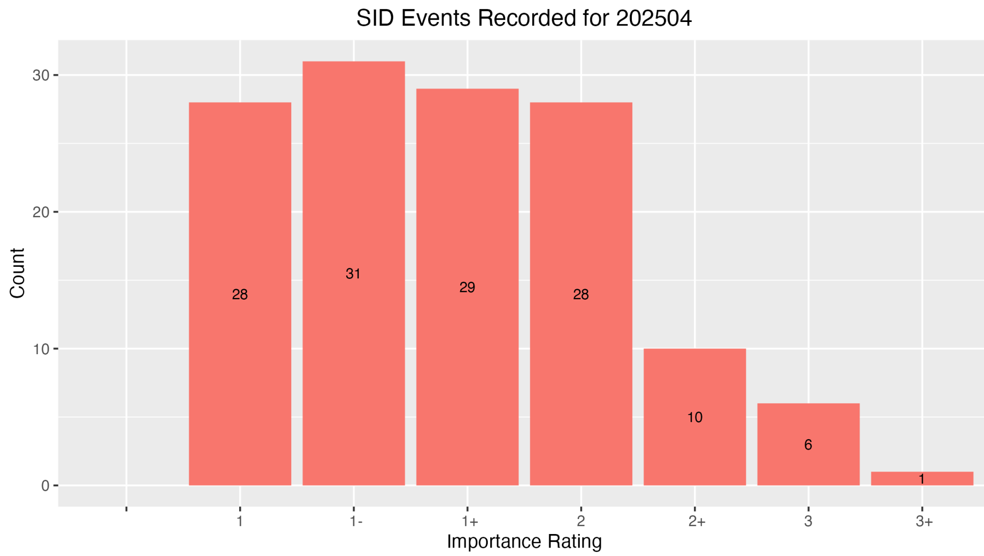

Figure 6: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In April 2025, there were 228 GOES-16 XRA flares: 34 M-Class and 194 C-Class. Far less flaring this month compared to last month. (U.S. Dept. of Commerce–NOAA, 2024). (see Figure 7).

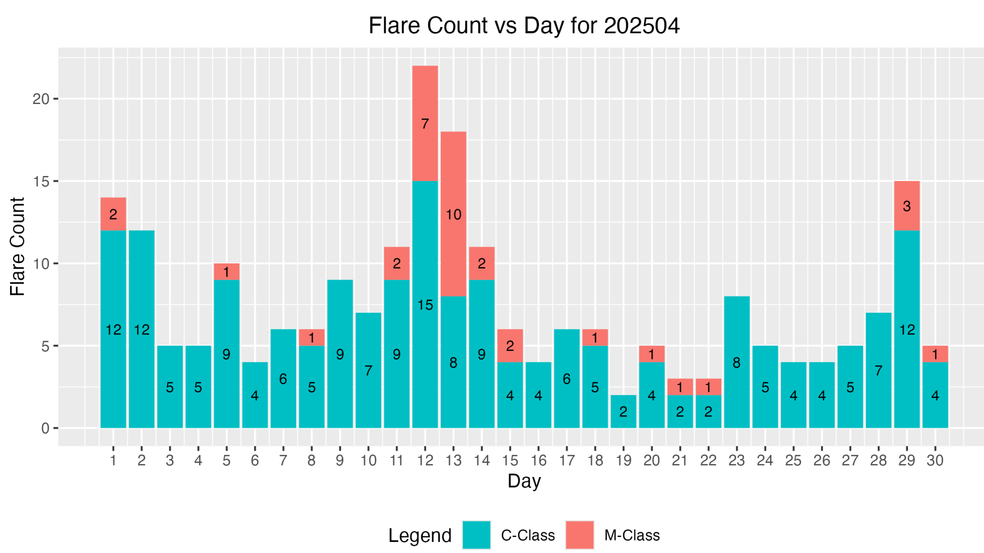

Figure 7: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2024).

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 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 8.

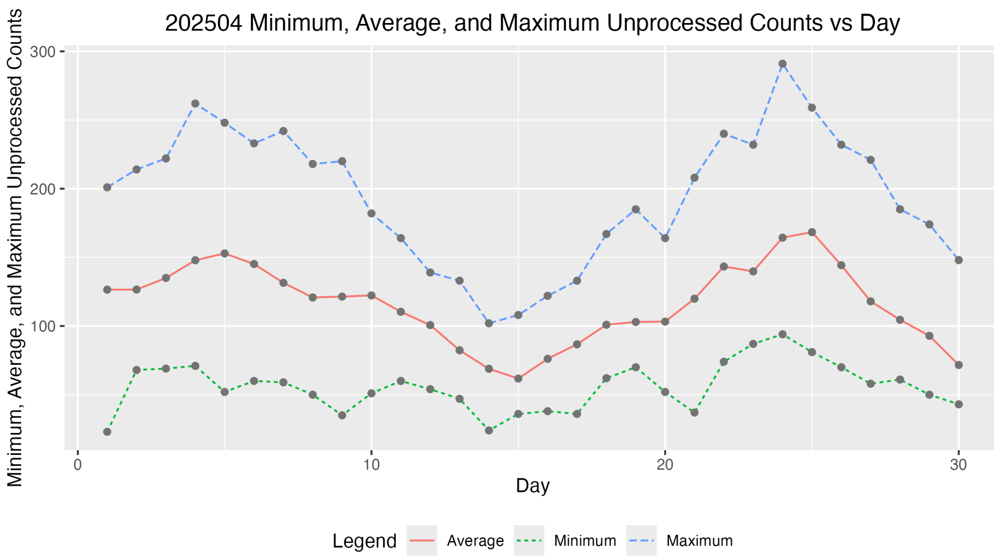

Figure 8: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

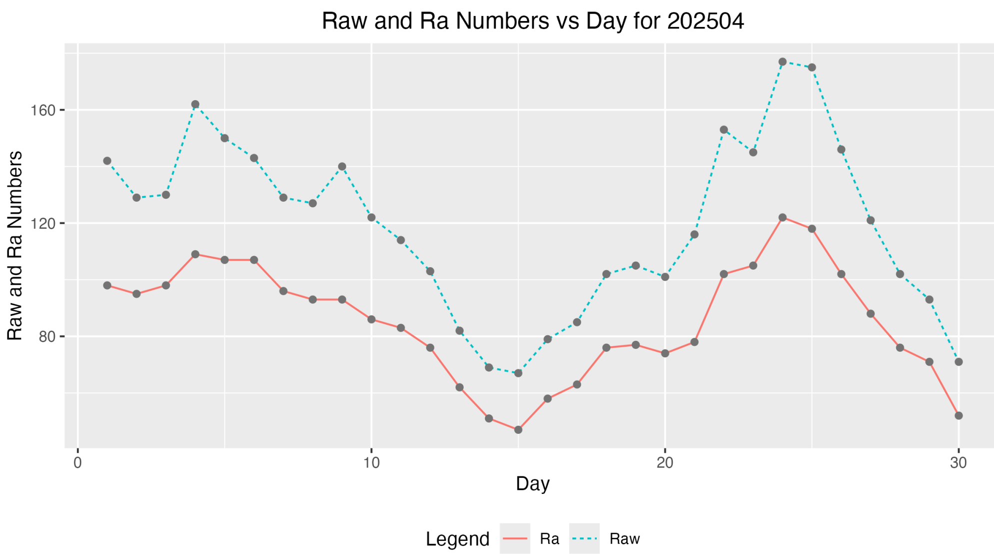

Figure 9: Raw Wolf average and R_a numbers by day of the month for all observers.

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 9, 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: 202504 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	30	142	98
2	24	129	95
3	23	130	98
4	29	162	109
5	32	150	107
6	36	143	107
7	31	129	96
8	31	127	93
9	42	140	93
10	33	122	86
11	37	114	83
12	32	103	76
13	26	82	62
14	28	69	51
15	26	67	47

Continued

Table 2: 202504 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	28	79	58
17	35	85	63
18	31	102	76
19	23	105	77
20	28	101	74
21	29	116	78
22	28	153	102
23	29	145	105
24	23	177	122
25	29	175	118
26	26	146	102
27	31	121	88
28	36	102	76
29	37	93	71
30	40	71	52
Averages	30.4	119.3	85.4

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for April 2025, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (64), and total number of observations submitted (913).

Table 3: 202504 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AJV	18	J. Alonso
ARAG	30	Gema Araujo
ASA	3	Salvador Aguirre
BATR	6	Roberto Battaiola
BKL	5	John A. Blackwell
BMIG	26	Michel Besson
BTB	9	Thomas Bretl
BVZ	20	Jesus E. Blanco
BXZ	24	Jose Alberto Berdejo
BZX	22	A. Gonzalo Vargas
CIOA	1	Ioannis Chouinavas
CKB	23	Brian Cudnik
CLDB	16	Laurent Cambon
CMAB	13	Maurizio Cervoni
CNT	23	Dean Chantiles

Continued

Table 3: 202504 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DARB	23	Aritra Das
DGIA	17	Giuseppe di Tommasco
DJOB	5	Jorge del Rosario
DJSA	2	Jeff DeVries
DJVA	22	Jacques van Delft
DMIB	16	Michel Deconinck
DUBF	26	Franky Dubois
EHOA	12	Howard Eskildsen
FARC	1	Arnaud Fiocret
FERA	17	Eric Fabrigat
FJOF	1	Joe Fazio
FLET	16	Tom Fleming
GCNA	1	Candido Gomez
GVIF	6	Vicent Garcia
HALB	26	Brian Halls
HKY	17	Kim Hay
HOWR	17	Rodney Howe
HSR	5	Serge Hoste
IEWA	3	Ernest W. Iverson
ILUB	6	Luigi Iapichino
JGE	5	Gerardo Jimenez Lopez
JSI	5	Simon Jenner
KAMB	30	Amoli Kakkar
KAND	23	Kandilli Observatory
KAPJ	18	John Kaplan
KNJS	26	James & Shirley Knight
KTOC	19	Tom Karnuta
LKR	10	Kristine Larsen
LRRA	22	Robert Little
MARC	6	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	14	Etsuiku Mochizuki
MJHA	26	John McCammon
MLL	6	Jay Miller
MMI	30	Michael Moeller
MUDG	4	George Mudry
MWMB	6	William McShan
MWU	21	Walter Maluf
NMID	9	Milena Niemczyk
RJV	21	Javier Ruiz Fernandez
SLIH	3	Liana Nadhirah
SNE	8	Neil Simmons
SQN	17	Lance Shaw

Continued

Table 3: 202504 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SRIE	12	Rick St. Hilaire
TDE	17	David Teske
TST	20	Steven Toothman
URBP	28	Piotr Urbanski
VIDD	4	Dan Vidican
WND	12	Denis Wallian
Totals	913	64

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 10 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.

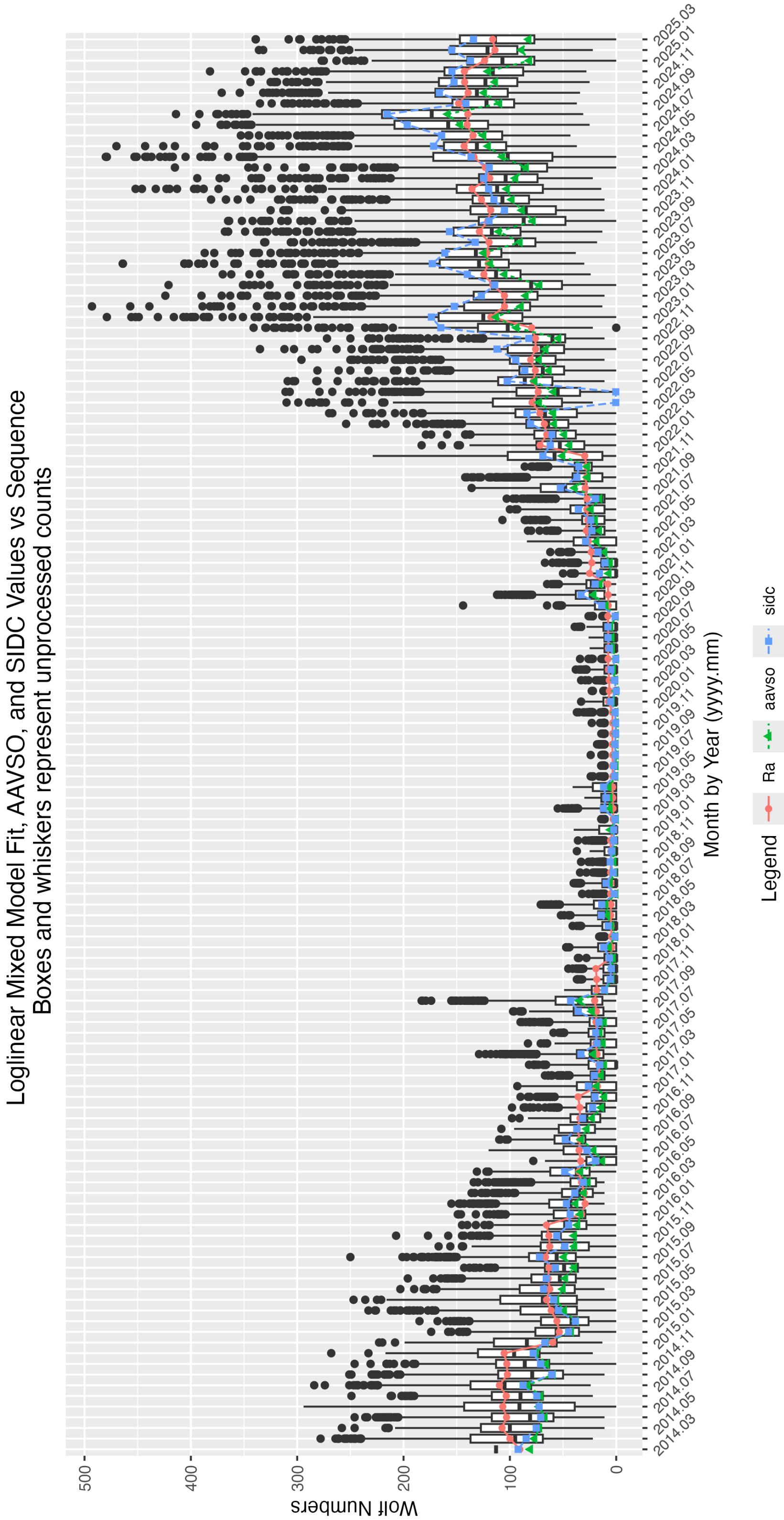

Figure 10: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

5 Easter viewing of the sun

Figure 11: Patrick Thibault (TPJB) on Easter, 21st of April 2025. AAVSO Solar observer Patrick Thibault, along with the Librarian, set up a short presentation for the Students on April 21st. He also set up his telescope for Solar Observing in front of the library (Atwater, MN, USA) around noon. The students had this day off from school, and though not many showed up at this time, the day picked up. Also, students made a few sundials. Patrick is hoping that they will try this again for the summer solstice.

6 References

Riggs, Jamie (2017), Solar System Science Section Head, International Astrostatistics (using R Statistical Software [2023]), TSA Libraries: (`https://cran.r-project.org`)

U.S. Dept. of Commerce–NOAA, Space Weather Prediction Center (2024). *GOES-16 XRA data.* `ftp://ftp.swpc.noaa.gov/pub/indices/events/`