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 Sunspots: A Historical Perspective

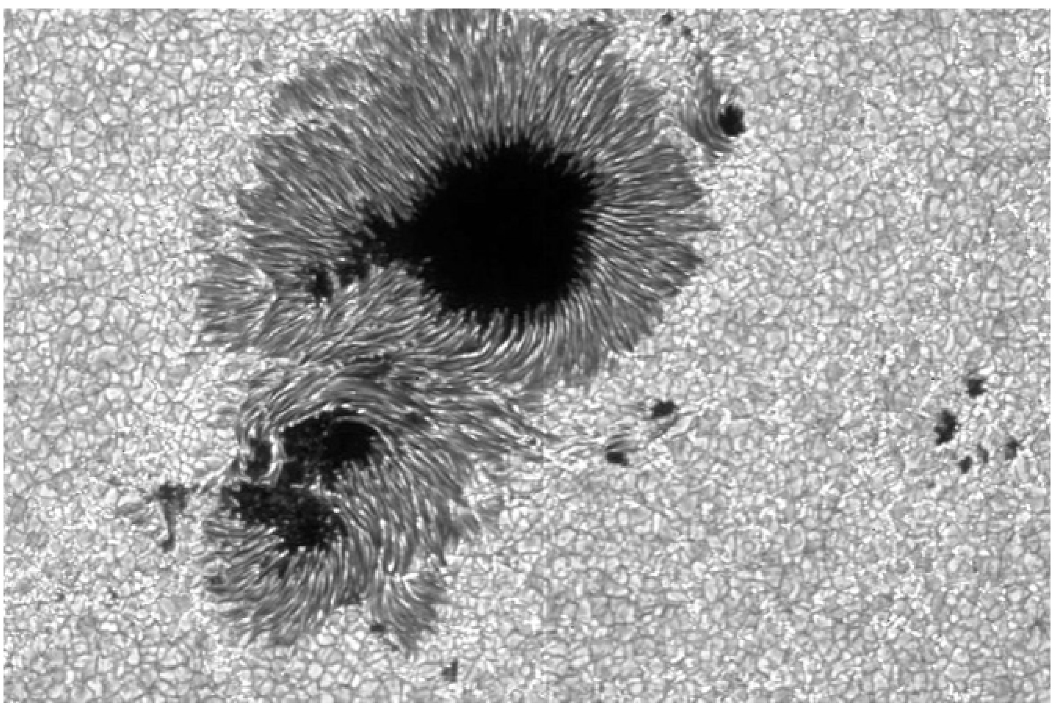

Figure 1: Sunspot group with clearly delineated umbra and penumbra. The mottled nature of the photosphere is called granulation, caused by the convection of hot plasma. NASA, Public domain.

Numerous misconceptions about sunspots can be found among the general public, including beliefs that they are made out of soot or mark volcanic eruptions/meteorite impacts on the Sun. Interestingly, many of these ideas mirror one-time scientific hypotheses concerning the nature of sunspots.

For instance, a 1619 pamphlet penned by astronomer Simon Marius compared sunspots with slag cinders that were ejected from hot furnaces (Heward 1075). In the eighteenth century, some astronomers considered the Sun to be merely a larger planetary body, hosting a solid, volcanically active surface under its brilliant atmosphere. Alexander Wilson, Chair of Astronomy at Glasgow University, noted in 1769 that as a large sunspot neared the limb (visible edge) of the sun it appeared to change shape, suggesting that sunspots represent depressions in the Sun's visible surface. Wilson's planetary model of the Sun was as a solid, dark globe, surrounded by three atmospheres. The first, nearest the black body of the sun, is a dense, cloudy covering, possessing high reflecting power. The second is called the photosphere. It consists of an incandescent gas, and is the seat of the light and heat of the sun. The third, or outer one, is transparent, very like our atmosphere (Steele 62). Famed astronomer William Herschel, the discoverer of Uranus, promoted a similar model. He described the Sun as "a very eminent, large and lucid planet" that was "richly stored with inhabitants " (Herschel 63, 68).

Our modern view of sunspots is as depressions in the photosphere that are about 2000 K (3500 F) cooler than the surrounding area. The lower temperature increases the transparency of the plasma, allowing us to see deeper into the Sun. Despite their appearance, sunspots are not black, but are more akin to the less brilliant embers of a dying campfire. In 1908 American astrophysicist George Ellery Hale demonstrated sunspots to be areas of intense magnetism using the Zeeman Effect, a change in the spectrum due to the presence of a strong magnetic field. The enhanced local magnetic field strength (as much as 4000 times that of the main photosphere) impedes the convection of the plasma, decreasing the temperature. While the idea of an inhabited Sun has long since fallen by the wayside, solar activity continues to impact life on our own planet. Sunspots are the proverbial tip of the iceberg in understanding the Sun's magnetic field, including solar activity such as flares and coronal mass ejections. The AAVSOs Solar Observing program continues in its decades-long tradition of recording daily sunspot activity and providing data to solar astronomers around the world.

Citations:

Herschel, William. "On the Nature and Construction of the Sun and Fixed Stars," *Philosophical Transactions of the Royal Society of London* 85 (1795): 63, 68.

Heward, E.V. "The Sun: Light and Life of the World," *The Fortnightly Review* 90 (1911): 1075.

Steele, J. Dorman. *Fourteen Weeks in Descriptive Astronomy* (A.S. Barnes and Company, 1869), 62.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

March 2025 (Figure 2): there were one X-class, 2 M-class, and 5 C-class flares on the 28th, recorded by Lionel Laudet (A118).

Figure 2: VLF recording of a X1.1 flare in the late morning hours: VLF transmitter DHO38 (22.4 kHz) from Lionel Loudet (A118) (`https://sidstation.loudet.org/data-en.xhtml`).

2.2 SID Observers

In March 2025 we had 12 AAVSO SID observers who submitted VLF data, as listed in Table 1.

Table 1: 202503 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO GQD
J Godet	A119	GBZ GQD ICV
J Karlovsky	A131	DHO
S Aguirre	A138	NAA
G Silvis	A141	NAA NML NPM
K Menzies	A146	NAA
L Pina	A148	NAA NLK
J Wendler	A150	NAA
H Krumnow	A152	DHO FTA GBZ
J DeVries	A153	NLK
M Cervoni	A154	ICV DHO

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.

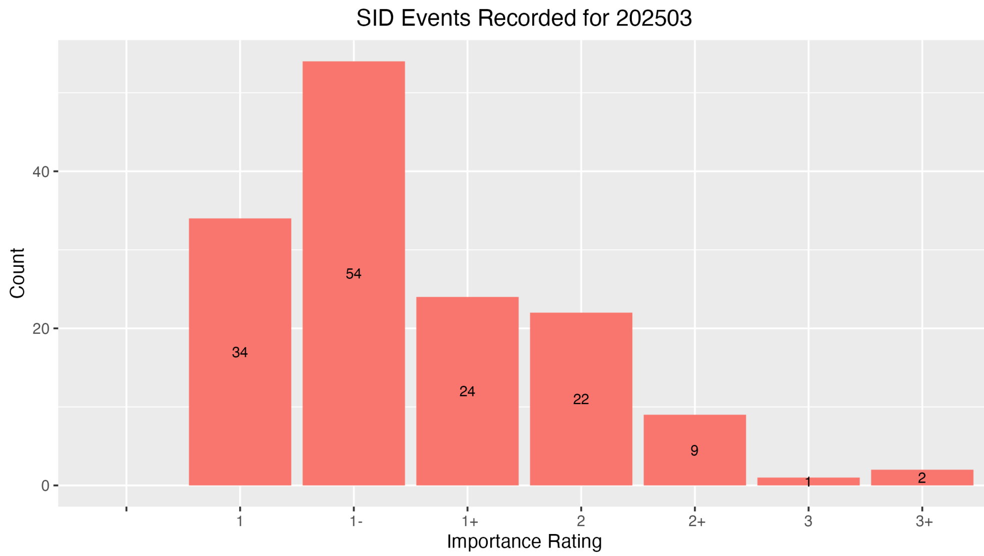

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In March 2025, there were 261 GOES-16 XRA flares, one X-class, 21 M-class, and 239 C-class. Not as much flaring was seen as last month. (U.S. Dept. of Commerce–NOAA, 2024). (see Figure 4).

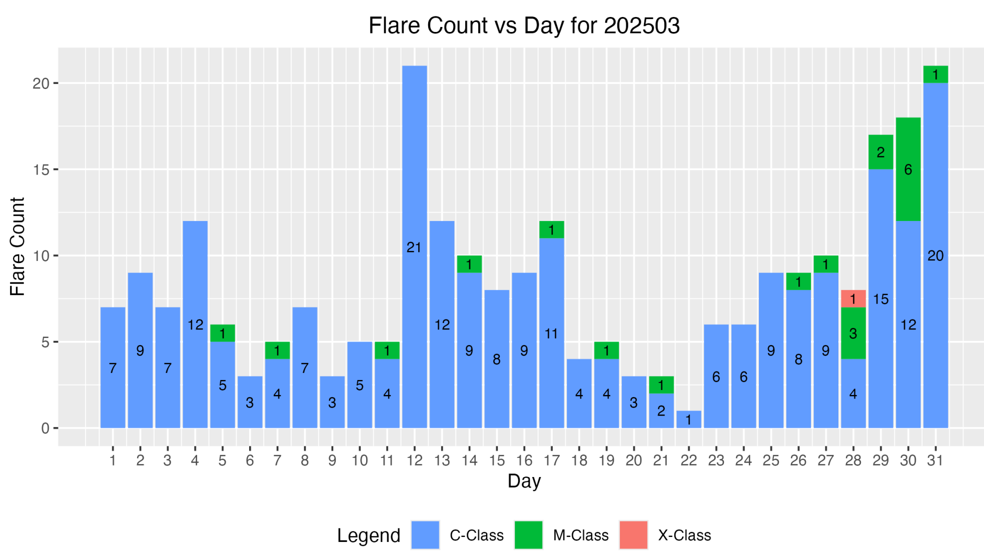

Figure 4: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2024).

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 March 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 5.

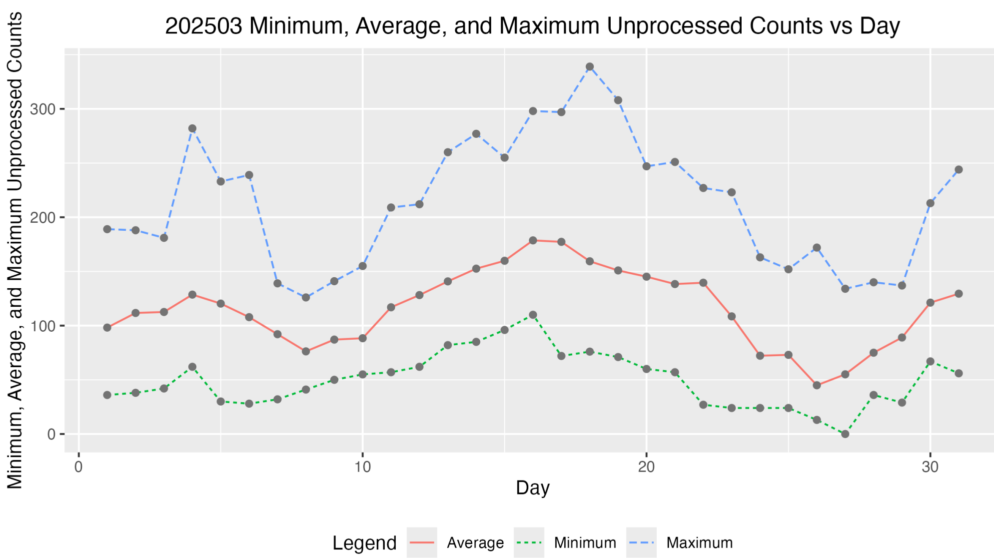

Figure 5: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

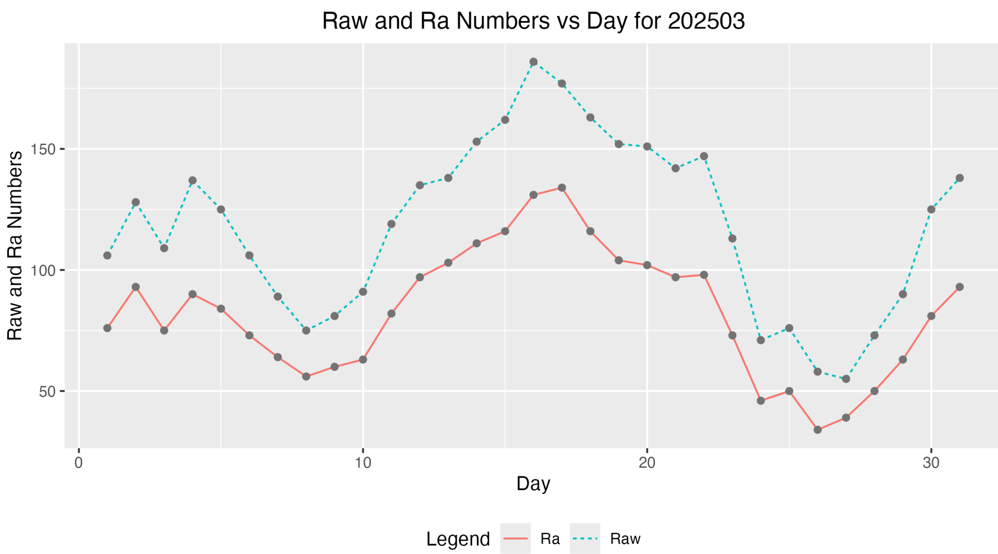

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202503 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	27	106	76
2	31	128	93
3	31	109	75
4	28	137	90
5	33	125	84
6	32	106	73
7	27	89	64
8	30	75	56
9	30	81	60
10	32	91	63
11	26	119	82
12	26	135	97
13	28	138	103
14	27	153	111
15	24	162	116

Continued

Table 2: 202503 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	26	186	131
17	34	177	134
18	35	163	116
19	34	152	104
20	26	151	102
21	33	142	97
22	26	147	98
23	28	113	73
24	26	71	46
25	33	76	50
26	28	58	34
27	33	55	39
28	20	73	50
29	33	90	63
30	29	125	81
31	32	138	93
Averages	29.3	118.4	82.4

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for March 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 (908).

Table 3: 202503 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	28	Alexandre Amorim
AJV	11	J. Alonso
ARAG	28	Gema Araujo
ASA	2	Salvador Aguirre
BATR	8	Roberto Battaiola
BKL	3	John A. Blackwell
BMIG	25	Michel Besson
BTB	2	Thomas Bretl
BVZ	10	Jesus E. Blanco
BXZ	17	Jose Alberto Berdejo
BZX	13	A. Gonzalo Vargas
CIOA	4	Ioannis Chouinavas
CKB	24	Brian Cudnik
CLDB	14	Laurent Cambon

Continued

Table 3: 202503 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CMAB	8	Maurizio Cervoni
CNT	18	Dean Chantiles
DARB	26	Aritra Das
DGIA	12	Giuseppe di Tommasco
DJOB	14	Jorge del Rosario
DJSA	2	Jeff DeVries
DJVA	29	Jacques van Delft
DMIB	11	Michel Deconinck
DUBF	29	Franky Dubois
EHOA	10	Howard Eskildsen
FERA	15	Eric Fabrigat
FJOF	5	Joe Fazio
FLET	25	Tom Fleming
GCNA	2	Cndido Gmez
HALB	18	Brian Halls
HKY	18	Kim Hay
HOWR	19	Rodney Howe
HSR	10	Serge Hoste
IEWA	2	Ernest W. Iverson
ILUB	8	Luigi Iapichino
JGE	2	Gerardo Jimenez Lopez
JSI	7	Simon Jenner
KAMB	31	Amoli Kakkar
KAND	21	Kandilli Observatory
KAPJ	16	John Kaplan
KNJS	27	James & Shirley Knight
KTOC	11	Tom Karnuta
LKR	5	Kristine Larsen
LRRA	21	Robert Little
MARC	3	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	12	Etsuiku Mochizuki
MJHA	29	John McCammon
MLL	13	Jay Miller
MMI	31	Michael Moeller
MUDG	7	George Mudry
MWMB	12	William McShan
MWU	23	Walter Maluf
NMID	8	Milena Niemczyk
PLUD	17	Ludovic Perbet
RJV	15	Javier Ruiz Fernandez
SNE	11	Neil Simmons
SQN	8	Lance Shaw

Continued

Table 3: 202503 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SRIE	13	Rick St. Hilaire
TDE	23	David Teske
TPJB	3	Patrick Thibault
TST	16	Steven Toothman
URBP	27	Piotr Urbanski
VIDD	12	Dan Vidican
WGI	1	Guido Wollenhaupt
Totals	908	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 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 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.

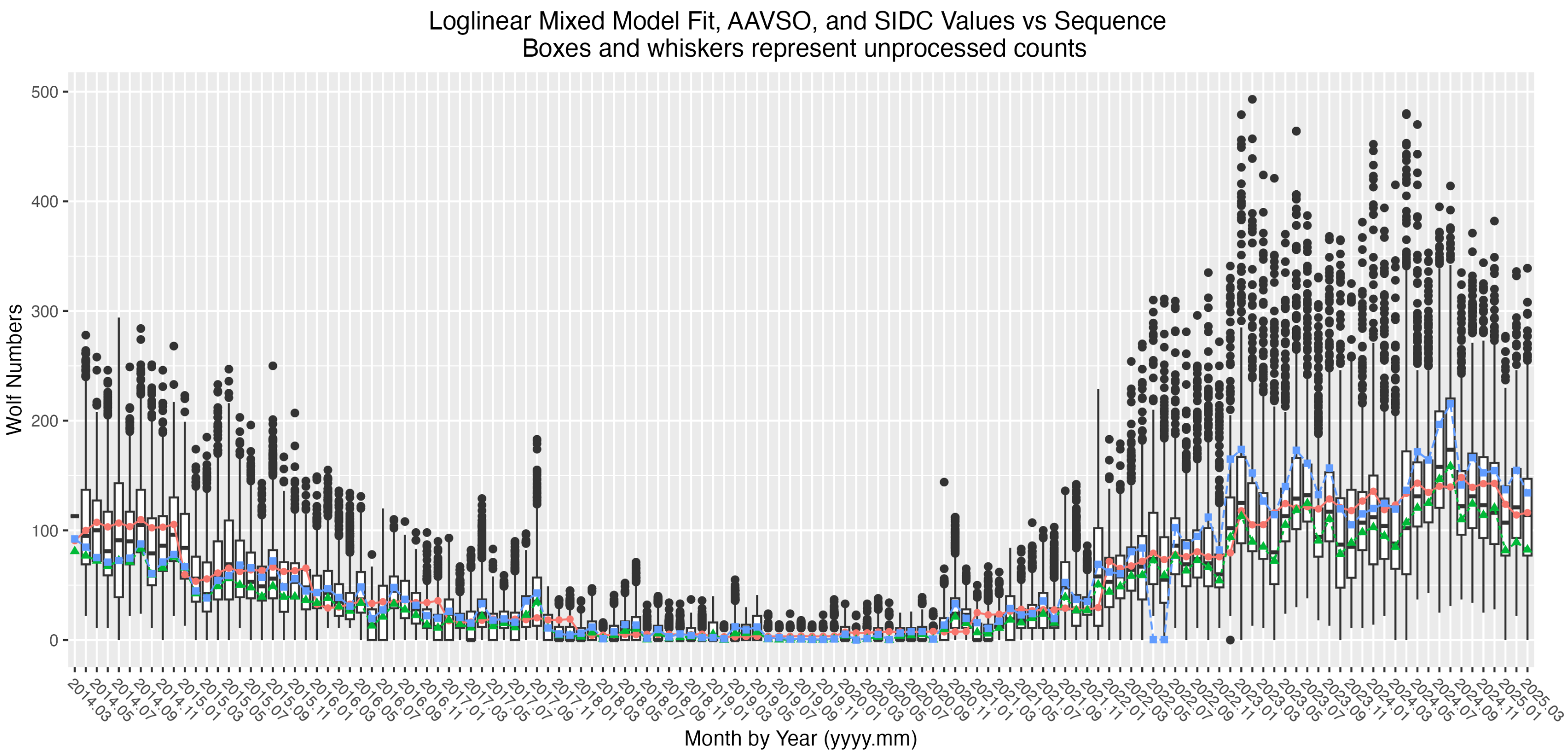

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

5 Partial Eclipse of the sun

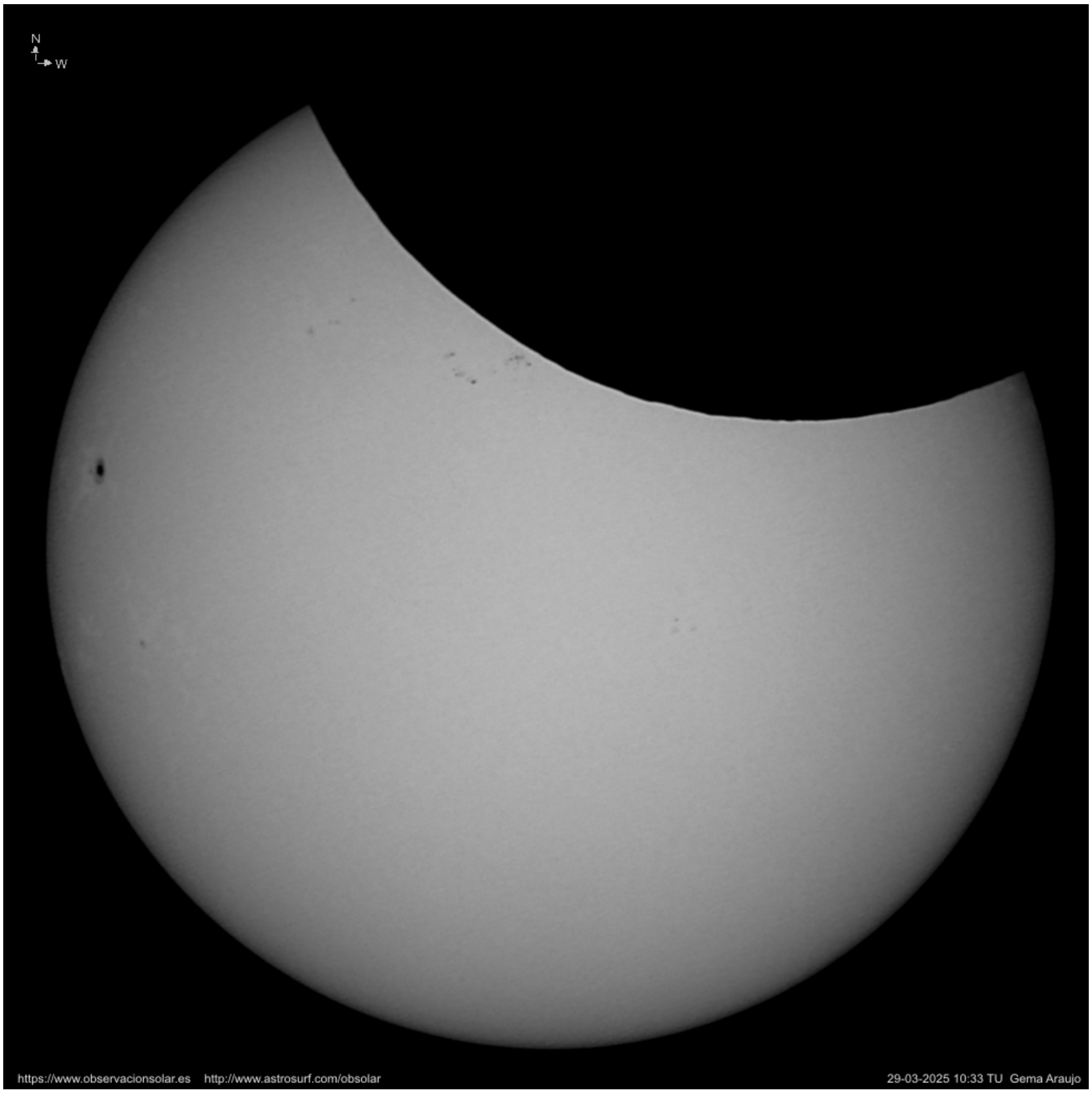

Figure 8: From Gema Arauja (ARAG): March 29 partial eclipse of the Sun.
(http://www.astrosurf.com/obsolar/inicio.html)

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/`