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 Radio flux proxies for solar cycles match up to WSO magnetic polarity reversals

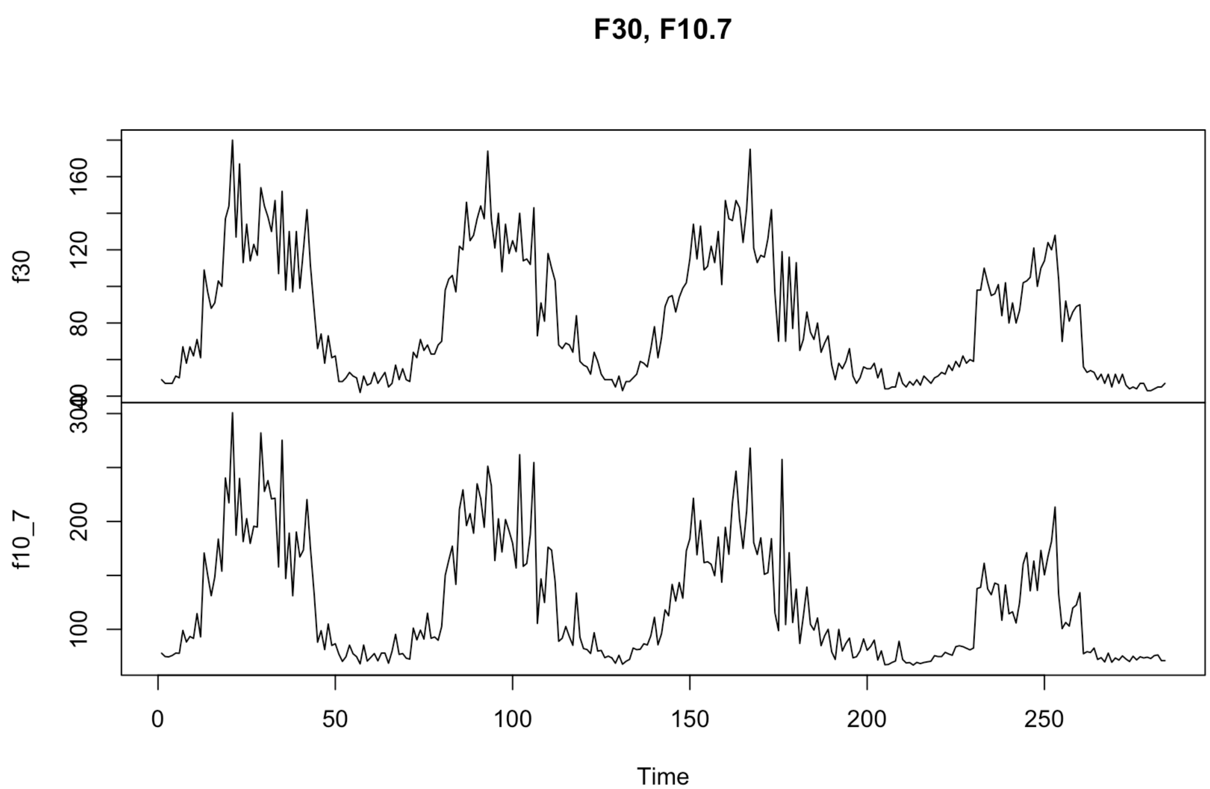

Figure 1: Radio flux cycle of F30 cm and F10.7 cm from 1975 to 2020.

"The 10.7 cm radio flux (F10.7) is widely used as a proxy for solar UV forcing of the upper atmosphere. However, radio emissions at other centimetric wavelengths have been routinely monitored since the 1950s, thereby offering prospects for building proxies that may be better tailored to space weather needs. Here we advocate the 30 cm flux (F30) as a proxy that is more sensitive than F10.7 to longer wavelengths in the UV and show that it improves the response of the thermospheric density to solar forcing, as modelled with DTM (Drag Temperature Model). In particular, the model bias drops on average by 0 to 20 percent" (Dudok de Wit, 2016) (`https://spaceweather.cls.fr`).

1.1 WSO north and south polar magnetic cycle reversals match to solar maximums

We can compare the radio flux solar maxima of F30 and F10.7 to the north and south magnetic field polarities from the WSO magnetic data of the Calcium II spectrum. And we can see where the cross over of these polarity field lines match up with the solar cycles radio flux maxima. WSO data: (`http://wso.stanford.edu/Polar.html`) "The polar field reversal, occurs at, or just after, sunspot maximum for each solar cycle. It is triggered by magnetic flux migrating up from sunspot groups towards the poles which cancels out the pre-existing flux of opposite polarity already situated there (Harvey 1996). This behaviour is clearly visible in photospheric magnetogram data" (Thomas et al. 2013).

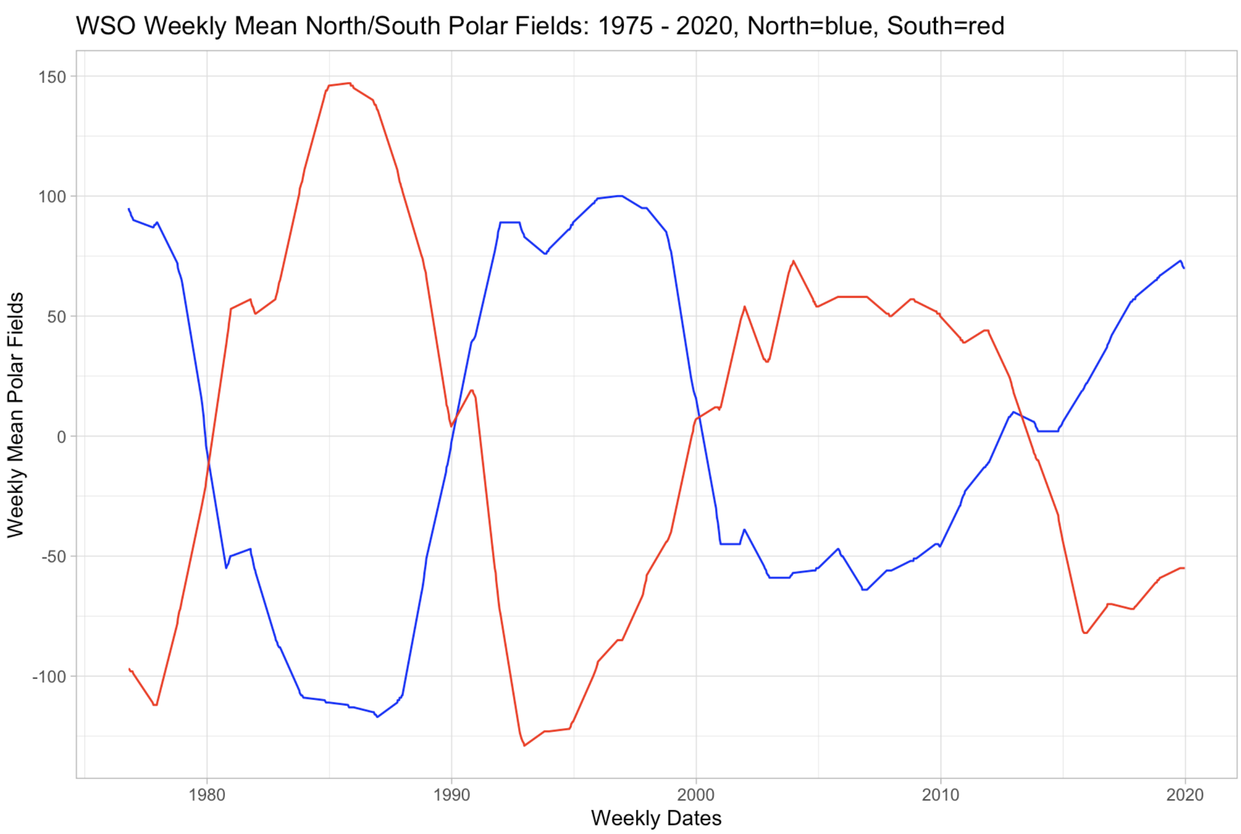

Figure 2: Wilcox Solar Observatory Polar Field Observations

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

June 2024 (Figure 3): Only 2 C class flares were recorded here in Fort Collins, Colorado, on June 26, which made the ionosphere smooth out with no SID Events. (U.S. Dept. of Commerce–NOAA 2022). Compare the SID Events with the large number of groups and sunspots, Figure 9.

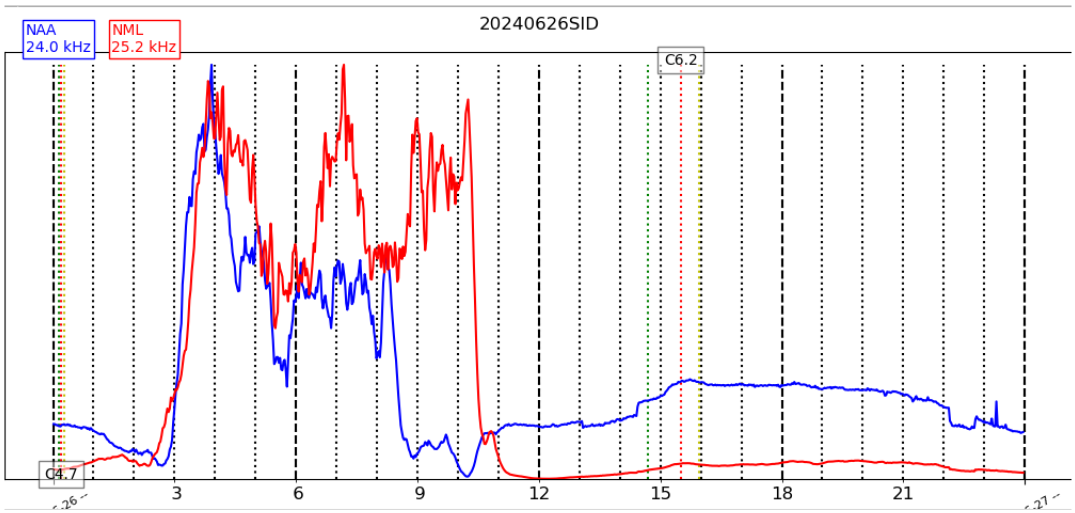

Figure 3: VLF recording from Fort Collins, Colorado, for June 26.

2.2 SID Observers

In June 2024 we had 13 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202406 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
A Son	A112	DHO
L Loudet	A118	DHO
J Godet	A119	GBZ GQD ICV
J Karlovsky	A131	DHO FTA
R Mrllak	A136	GQD NSY
S Aguirre	A138	NAA
L Pina	A148	NAA NML
J Wendler	A150	NAA
J DeVries	A153	NAA
A Nebula	A156	DHO NSY
M Salo	A157	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.

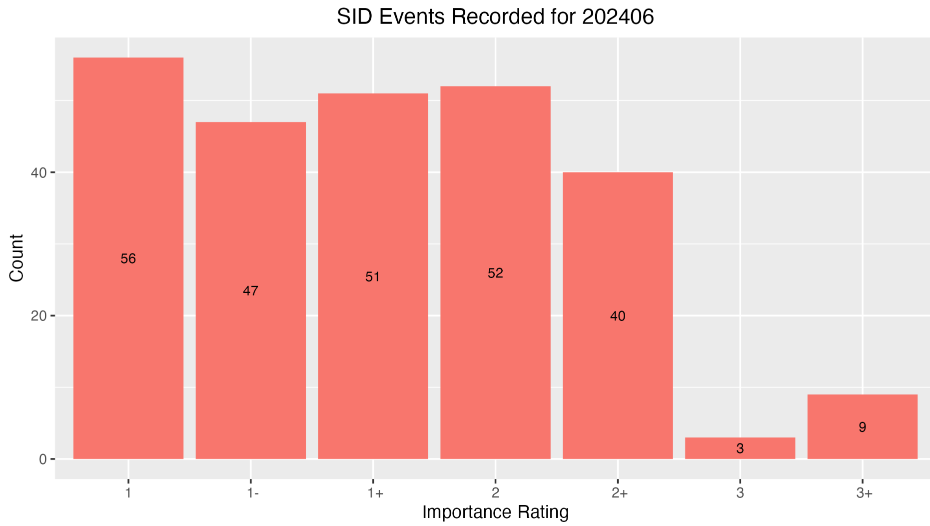

Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In June 2024, there were 319 XRA GOES-16 flares: 3 X-class, 53 M-class, and 263 C-class flares. Less flaring than last month. (U.S. Dept. of CommerceNOAA 2022). (see Figure 5).

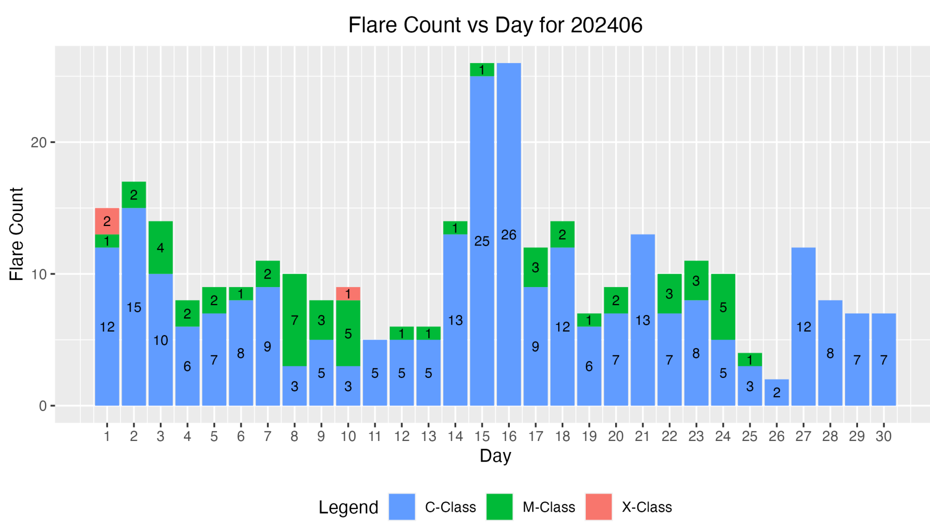

Figure 5: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA 2022).

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 June 2024. 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.

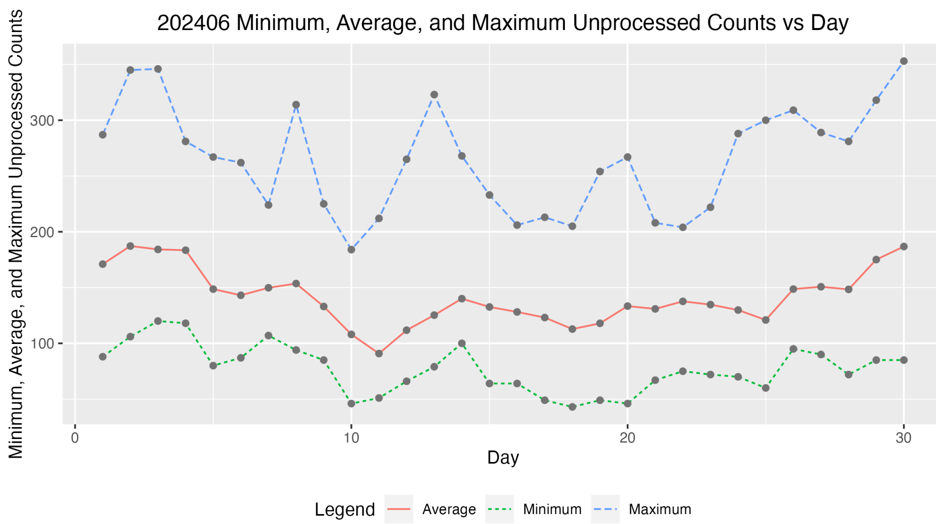

Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

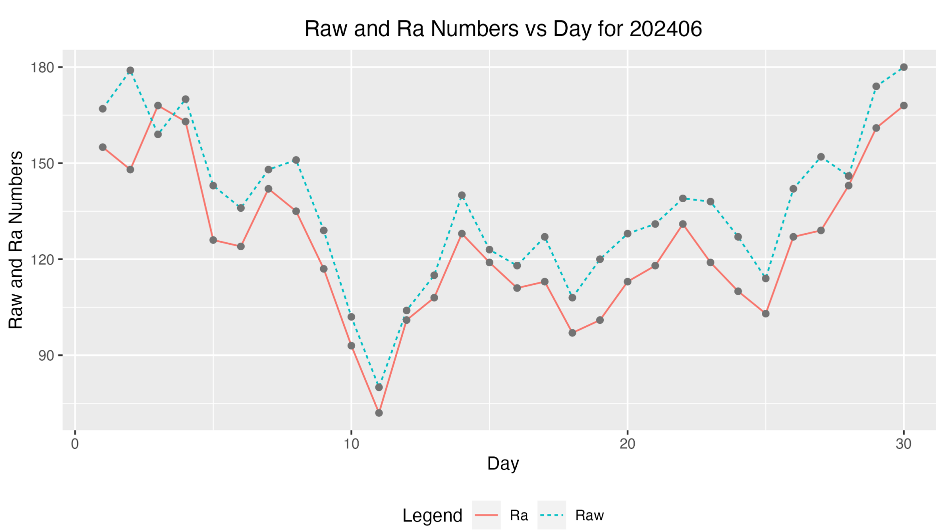

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202406 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	37	167	155
2	30	179	148
3	35	159	168
4	35	170	163
5	44	143	126
6	41	136	124
7	43	148	142
8	31	151	135
9	32	129	117
10	35	102	93
11	33	80	72
12	38	104	101
13	42	115	108
14	30	140	128
15	41	123	119
16	31	118	111
17	43	127	113
18	41	108	97
19	28	120	101
20	31	128	113
21	38	131	118
22	32	139	131
23	39	138	119
24	41	127	110
25	43	114	103
26	33	142	127
27	36	152	129
28	42	146	143
29	30	174	161
30	31	180	168
Averages	36.2	136.3	124.8

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for June 2024, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (68), and total number of observations submitted (1086).

Table 3: 202406 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	21	Alexandre Amorim
AJV	25	J. Alonso
ARAG	28	Gema Araujo
ASA	2	Salvador Aguirre
BATR	2	Roberto Battaiola
BKL	12	John A. Blackwell
BMIG	18	Michel Besson
BTB	19	Thomas Bretl
BXZ	27	Jose Alberto Berdejo
BZX	24	A. Gonzalo Vargas
CIOA	11	Ioannis Chouinavas
CKB	28	Brian Cudnik
CLDB	14	Laurent Cambon
CMAB	5	Maurizio Cervoni
CMOD	3	Mois Carlo
CNT	26	Dean Chantiles
CVJ	3	Jose Carvajal
DARB	21	Aritra Das
DAT	14	Adam Derdzikowski
DELS	3	Susan Delaney
DGIA	16	Giuseppe di Tommasco
DJOB	6	Jorge del Rosario
DJSA	7	Jeff DeVries
DJVA	26	Jacques van Delft
DMIB	15	Michel Deconinck
DUBF	23	Franky Dubois
EHOA	13	Howard Eskildsen
FERA	24	Eric Fabrigat
FLET	23	Tom Fleming
GFAD	11	Fabrizio Guida
GIGA	25	Igor Grageda Mendez
HALB	10	Brian Halls
HKY	20	Kim Hay
HOWR	22	Rodney Howe
HSR	11	Serge Hoste
IEWA	22	Ernest W. Iverson
ILUB	1	Luigi Iapichino
JGE	6	Gerardo Jimenez Lopez

Continued

Table 3: 202406 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
JSI	9	Simon Jenner
KAND	30	Kandilli Observatory
KNJS	24	James & Shirley Knight
KTOC	9	Tom Karnuta
LKR	15	Kristine Larsen
LRRA	22	Robert Little
LVY	30	David Levy
MARC	2	Arnaud Mengus
MARE	11	Enrico Mariani
MJHA	29	John McCammon
MLL	10	Jay Miller
MMAE	4	Aaron McNeely
MMI	30	Michael Moeller
MUDG	4	George Mudry
MWMB	9	William McShan
MWU	27	Walter Maluf
NMID	16	Milena Niemczyk
ONJ	18	John O'Neill
PLUD	17	Ludovic Perbet
RJV	13	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SNE	2	Neil Simmons
SQN	22	Lance Shaw
SRIE	19	Rick St. Hilaire
TDE	26	David Teske
TST	24	Steven Toothman
URBP	28	Piotr Urbanski
VIDD	10	Dan Vidican
WGI	1	Guido Wollenhaupt
WND	8	Denis Wallian
Totals	1086	68

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.

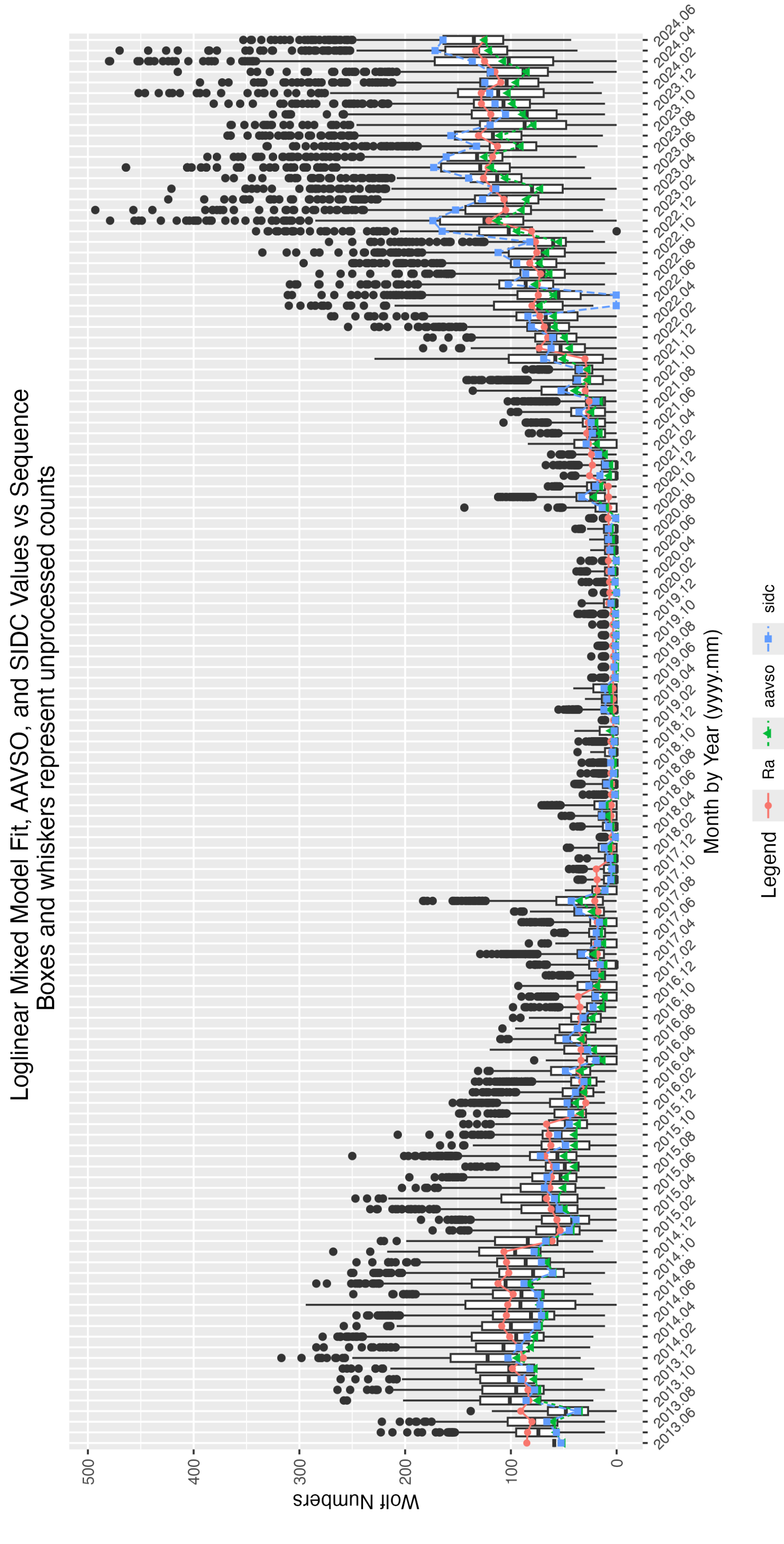

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

4.1 Antique telescope project

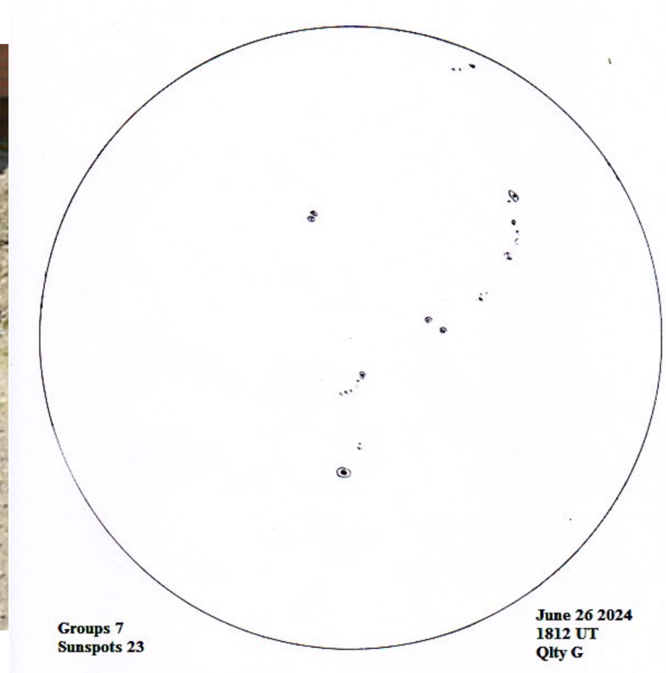

Figure 9: An antique telescope built by Gonzalo Vargas (BZX) (left). Drawing for June 26, from Cochabamba, Bolivia (right). Compare the 7 groups and 23 sunspots with the lack of VLF SID Events for June 26, Figure 3 - this shows how weak sunspot magnetic structure affects flaring.

5 References

U.S. Dept. of Commerce–NOAA, Space Weather Prediction Center (2023), *GOES-16 XRA data.* `ftp://ftp.swpc.noaa.gov/pub/indices/events/`

Harvey, K. L. (1996) *Large Scale Patterns of Magnetic Activity and the Solar Cycle.* Am. Astron. Soc. 28, 867.

Thomas, S., et al. (2013) *The 22-Year Hale Cycle in Cosmic Ray Flux - Evidence for Direct Heliospheric*, EGU General Assembly 2013, held 7-12 April, 2013 in Vienna, Austria, id. EGU2013-312.
Modulation

Dudok de Wit. (2016) *The 30 cm radio flux as a solar proxy for thermosphere density modelling.* `https://spaceweather.cls.fr.`