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 3. The relative sunspot numbers are in Section 4. Section 5 has endnotes.

1 South/North hemisphere period analysis is not enough

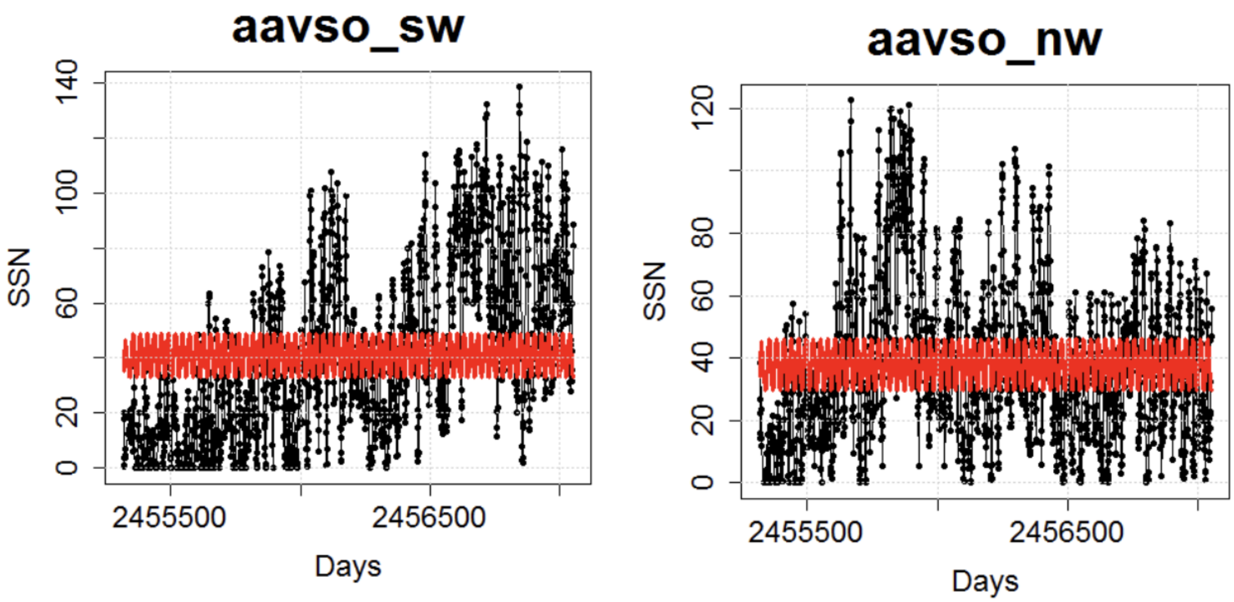

Figure 1: (left panel) South Hemisphere Wolf numbers from May 2010 through January 2014. The (right panel) North Hemisphere Wolf numbers, for the same time frame.

Notice how different these data look. The red lines are the daily periods in Table 1. (Using the AAVSO R routines Grant Foster wrote to create these graphs).

Here are the different rotation periods present in the AAVSO daily Wolf Numbers for the Northern hemisphere vs. the Southern hemisphere in the beginning of solar cycle 24:

Table 1: North/South Wolf Number periods

South	freq	power	amp	period
	0.03692037	28.47686	7.890845	27.08532
North	freq	power	amp	period
	0.03562280	42.01052	8.085696	28.07191

The Southern hemisphere average rotation period is one day less than the average Northern hemisphere rotation period. These data go from May 2010 through January 2014.

2 Frederic Clette of SILSO has concerns about these periods:

"I don't believe that you can extract a meaningful rotation period from a periodogram of the sunspot time series. I have co-authored several papers with the Wohl, Brajsa group: they get their results from the detailed tracking of a large number of small solar features. They don't only extract an average rotation rate but the full differential rotation profile. Here, they interpret the minute differences between those profiles. Two main limitations are acting in the case of the sunspot series: The time modulation, which allows to search for periods, is dominated by a few large long-lived groups. Therefore, you get a period associated with a very limited sample. The result has a lower accuracy and is not representative of the average rotation rate of all sunspots. Moreover, you integrate the signal from all sunspots while the average latitude of sunspots drift towards the equator over time. Therefore, the rotation period that you get is thus only reflecting the rotation of sunspots over a limited latitude range (one point along the differential rotation curve) and this mean latitude is not the same at two different times and may be different between hemispheres. This not because the rotation is different in both hemisphere but only because you sample a different mean latitude in each hemisphere. Even with totally identical differential rotation profiles, you will get different periods and thus rotation rates for both hemispheres. Therefore, changes in rotation rates and N/S asymmetries given by this Fourier analysis will result primarily from combined effects of the two above spatial-distribution effects, which will mask any possible small variation of the actual solar differential rotation. For this, you need to track sunspots individually in images, but even then, with sunspots you are limited in latitude as no spots emerge at latitudes higher than 40. This is why such studies are often tracking chromospheric features (filaments) or better, coronal bright points, which appear in large numbers and cover the whole disk including the poles. This is what we did using the whole-disk EUV images from SOHO/EIT. I co-authored many papers cited in the references of this 2010 paper (I am in the et al. for providing and preparing the base EIT image set). I had to turn to other topics after about 2005 but they have continued those studies over recent years, with my colleague Samuel Gissot. Sunspot numbers cannot give all the answers, unfortunately ... Best wishes, Frederic"

Wohl H., Brajsa R., Hanslmeier A., and Gissot S. F., A.A. 520, A29 (2010) DOI: `10.1051/0004-6361/200913081`, '*A precise measure of the solar differential rotation by tracing small bright coronal structures in SOHO–EIT images. Results and comparisons for the period 1998-2006* '

3 Sudden Ionospheric Disturbance (SID) Report

3.1 SID Records

December 2024 (Figure 2): there were 393 XRA flares: four X-class, 87 M-class, and 302 C-class, far more flaring this month than last month. (U.S. Dept. of Commerce–NOAA, 2022).

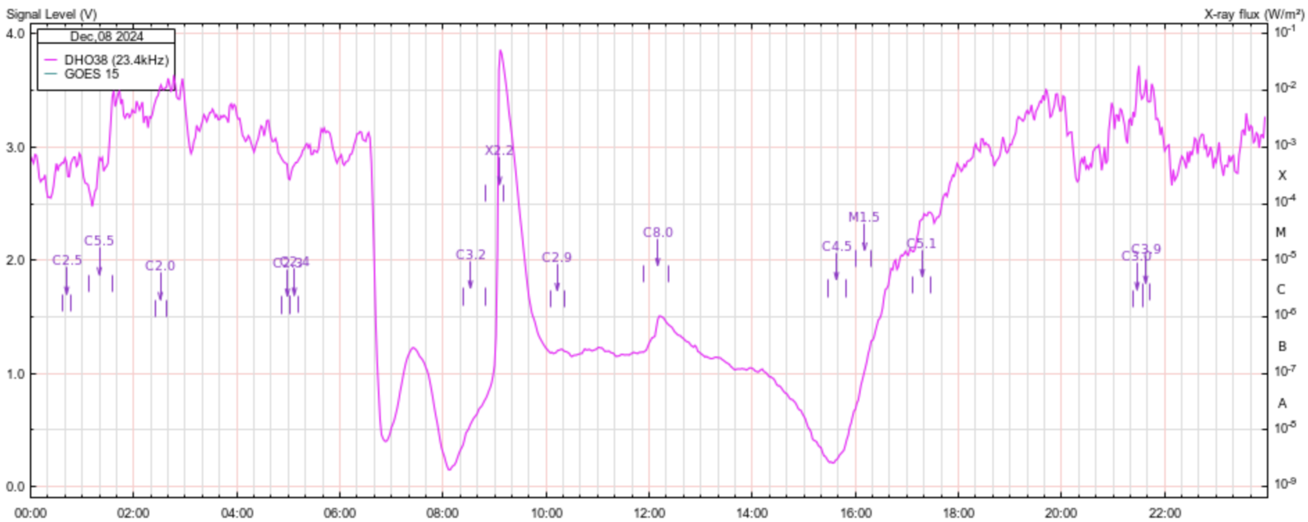

Figure 2: VLF recording of a X2.2 flare in the early morning hours: VLF transmitter DHO38 (22.4 kHz) from Lionel Loudet (A118) (`https://sidstation.loudet.org/data-en.xhtml`)

3.2 SID Observers

In December 2024 we had 13 AAVSO SID observers who submitted VLF data as listed in Table 2.

Table 2: 202412 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
A Son	A112	DHO
L Loudet	A118	DHO GQD
J Godet	A119	DHO GBZ GQD
J Karlovsky	A131	DHO
R Mrllak	A136	GQD NSY
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 Salo	A157	NLK

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.

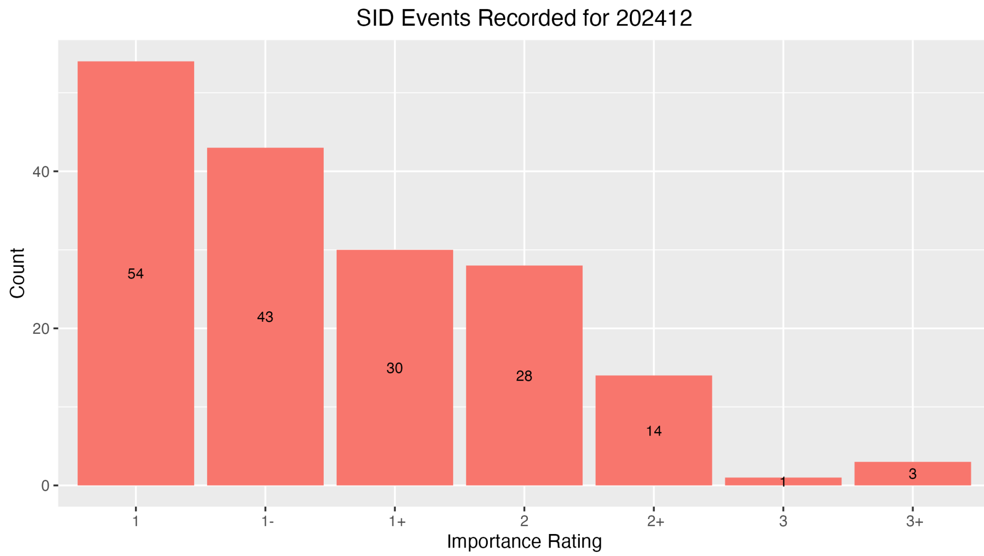

Figure 3: VLF SID Events.

3.3 Solar Flare Summary from GOES-16 Data

In December 2024, there were 393 XRA flares: four X-class, 87 M-class, and 302 C-class, far more flaring this month than last month. (U.S. Dept. of Commerce–NOAA, 2024). (see Figure 4).

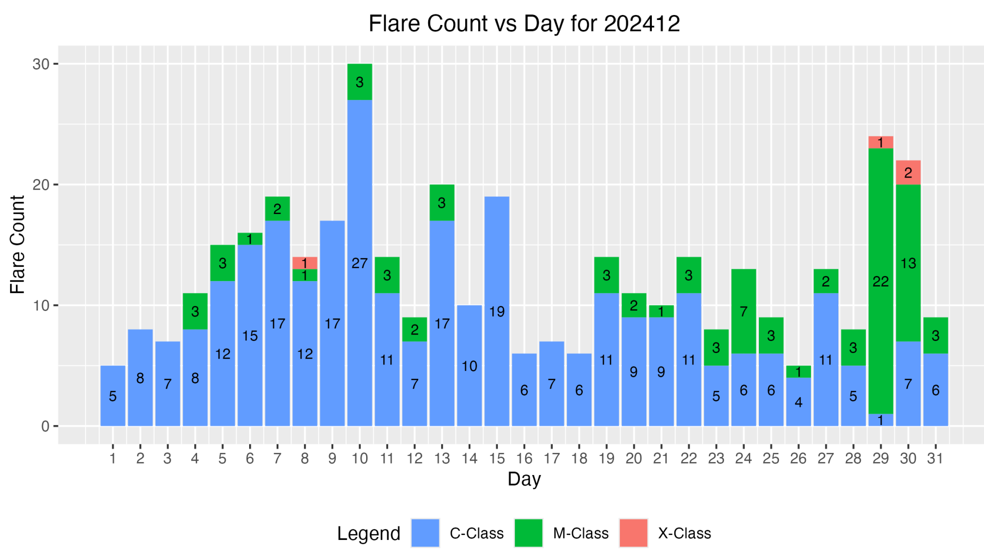

Figure 4: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2024).

4 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.

4.1 Raw Sunspot Counts

The raw daily sunspot counts consist of submitted counts from all observers who provided data in December 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 5.

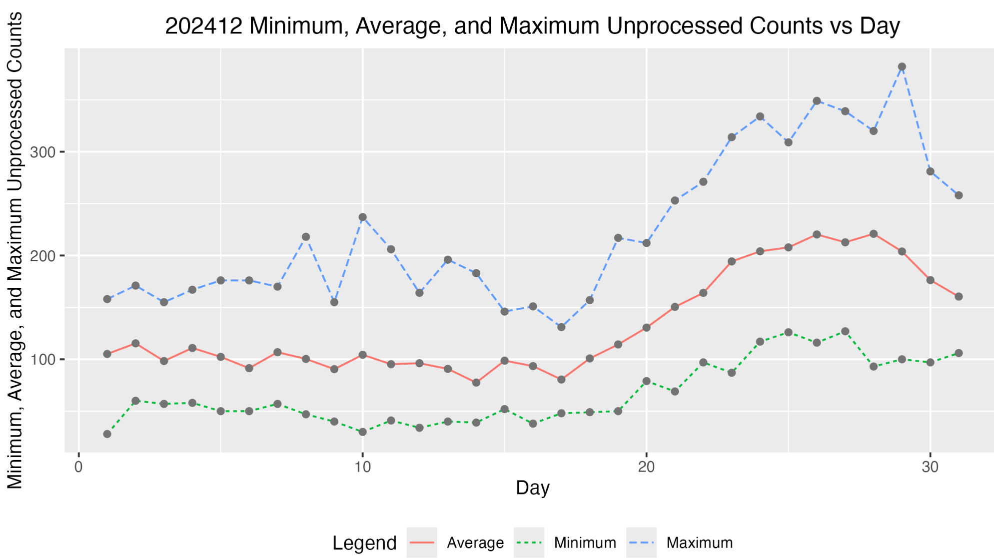

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

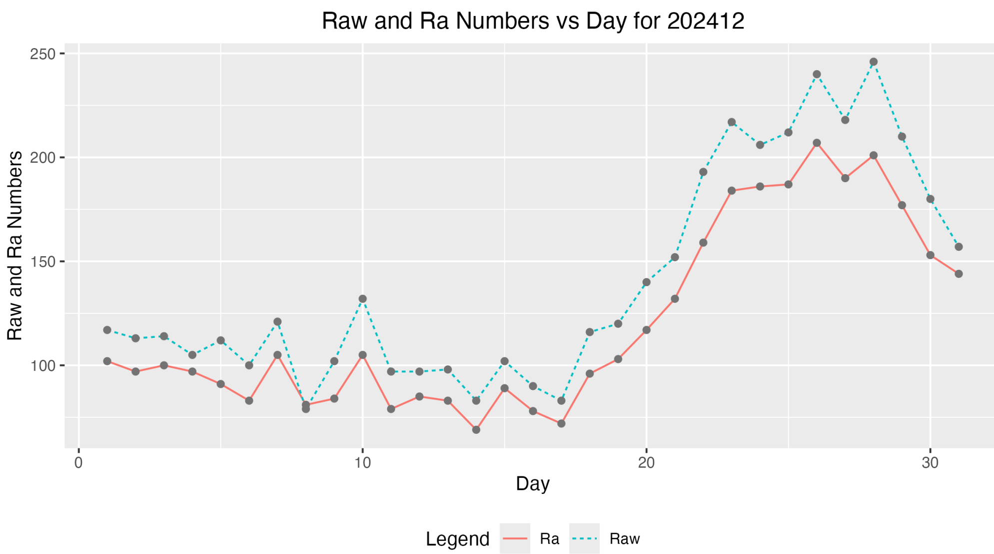

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

4.2 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 3 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 3: 202412 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	29	117	102
2	26	113	97
3	23	114	100
4	21	105	97
5	26	112	91
6	22	100	83
7	17	121	105
8	19	79	81
9	14	102	84
10	15	132	105
11	16	97	79
12	26	97	85
13	19	98	83
14	22	83	69
15	20	102	89

Continued

Table 3: 202412 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	24	90	78
17	24	83	72
18	24	116	96
19	25	120	103
20	22	140	117
21	23	152	132
22	18	193	159
23	20	217	184
24	15	206	186
25	18	212	187
26	19	240	207
27	23	218	190
28	21	246	201
29	24	210	177
30	21	180	153
31	27	157	144
Averages	21.4	140.4	120.5

4.3 Sunspot Observers

Table 4 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 2024, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (56), and total number of observations submitted (663).

Table 4: 202412 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	22	Alexandre Amorim
AJV	10	J. Alonso
ARAG	31	Gema Araujo
ASA	2	Salvador Aguirre
BATR	9	Roberto Battaiola
BMIG	18	Michel Besson
BTB	2	Thomas Bretl
BXZ	21	Jose Alberto Berdejo
BZX	14	A. Gonzalo Vargas
CIOA	2	Ioannis Chouinavas
CKB	20	Brian Cudnik
CLDB	11	Laurent Cambon
CMAB	4	Maurizio Cervoni
CNT	26	Dean Chantiles

Continued

Table 4: 202412 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CPAD	3	Panagiotis Chatzistamatiou
DARB	22	Aritra Das
DGIA	8	Giuseppe di Tommasco
DJOB	14	Jorge del Rosario
DJSA	2	Jeff DeVries
DJVA	31	Jacques van Delft
DMIB	6	Michel Deconinck
DUBF	10	Franky Dubois
EHOA	13	Howard Eskildsen
FJOF	2	Joe Fazio
FLET	22	Tom Fleming
GIGA	17	Igor Grageda Mendez
HALB	4	Brian Halls
HKY	13	Kim Hay
HOWR	14	Rodney Howe
HSR	5	Serge Hoste
IEWA	8	Ernest W. Iverson
ILUB	7	Luigi Iapichino
JGE	9	Gerardo Jimenez Lopez
KAND	16	Kandilli Observatory
KTOC	13	Tom Karnuta
LKR	5	Kristine Larsen
LRRA	11	Robert Little
LVY	24	David Levy
MARC	2	Arnaud Mengus
MARE	15	Enrico Mariani
MCE	30	Etsuiku Mochizuki
MJHA	27	John McCammon
MLL	2	Jay Miller
MWMB	4	William McShan
MWU	17	Walter Maluf
NMID	7	Milena Niemczyk
PLUD	13	Ludovic Perbet
RJV	9	Javier Ruiz Fernandez
SNE	3	Neil Simmons
SQN	7	Lance Shaw
SRIE	6	Rick St. Hilaire
TDE	16	David Teske
TST	9	Steven Toothman
URBP	16	Piotr Urbanski
VIDD	3	Dan Vidican
WWM	6	William M. Wilson

Continued

Table 4: 202412 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
Totals	663	56

4.4 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 4 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.

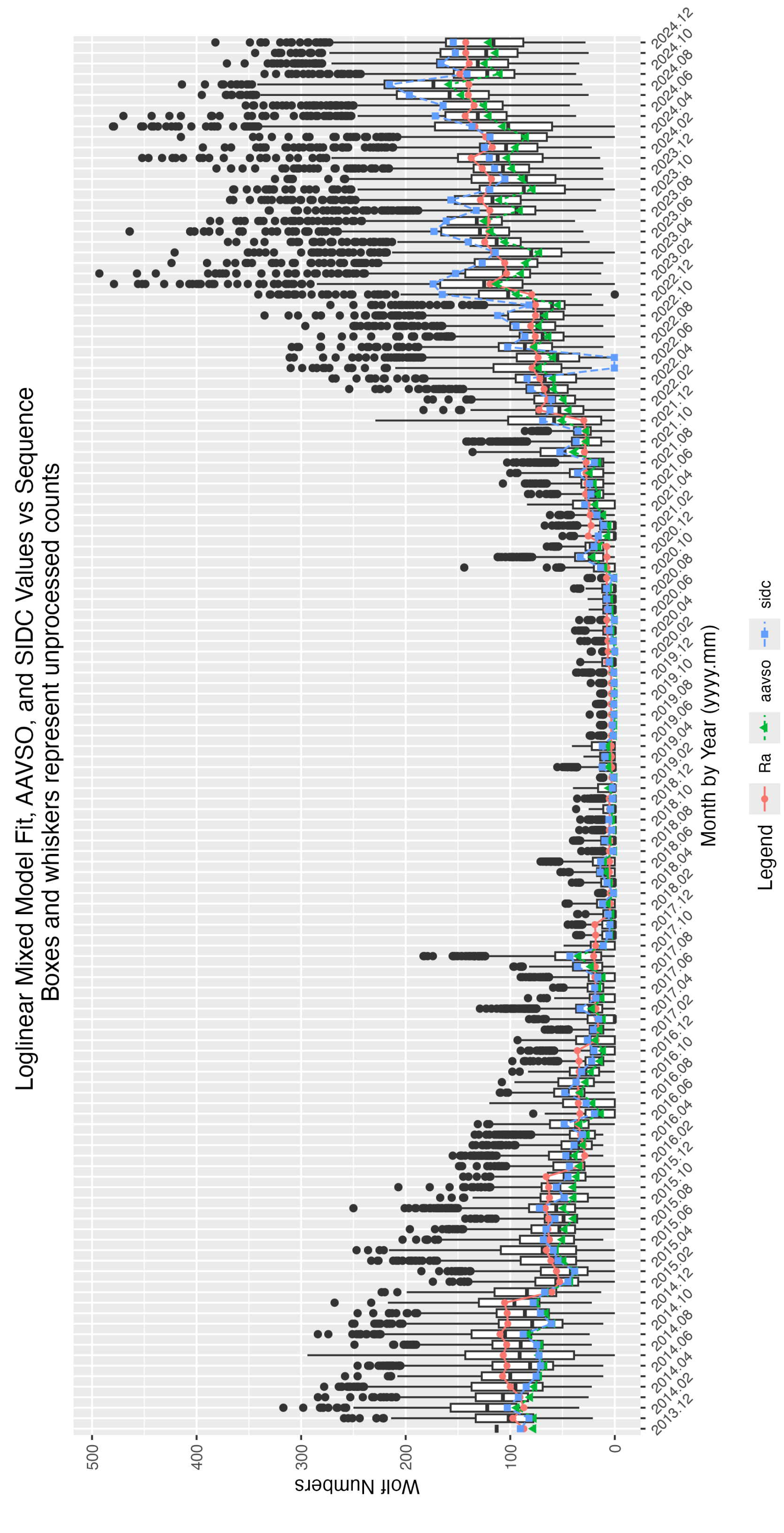

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

5 Endnotes

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

6 Antique telescope project

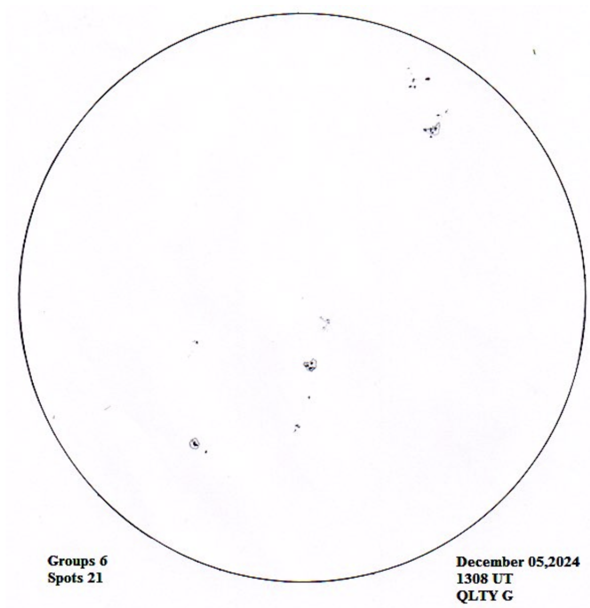

Figure 8: A recent replica of an antique telescope built by Gonzalo Vargas (BZX) in Cochabamba, Bolivia (left), and a drawing for the 5th of December (right). For more information about the antique telescope solar observing program, see the recent AAVSO blog post (`https://www.aavso.org/blog/solar-section-future`).

7 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/`