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 Co-Chairs thank all of our observers for their diligent work in making scientifically useful measurements of our stars activity. Our goal is to make this Bulletin as informational as possible; if you have ideas for material you would like to see included, please email us at the address above. We are also looking for volunteers to write short (less than 500 words in length) articles related to solar observing or the sun in general. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Auroras from large solar flares

Galileo used the name Aurora Borealis in the *Il Saggiatore*, and testimonies at low magnetic latitudes are extremely rare, even under clear and dark skies, in recent times as in Antiquity. *Courtesy of Costantino Sigismondi, (ICRA, 2024)* [Reference 1]

Figure 1: The Aurora of March 6, 1582 in Augsburg, Bavaria (Germany), with nearly full Moon phase. *Iulius Obsequens, 661 ab Urbe Condita (93 bC) Liber Prodigiorum.*

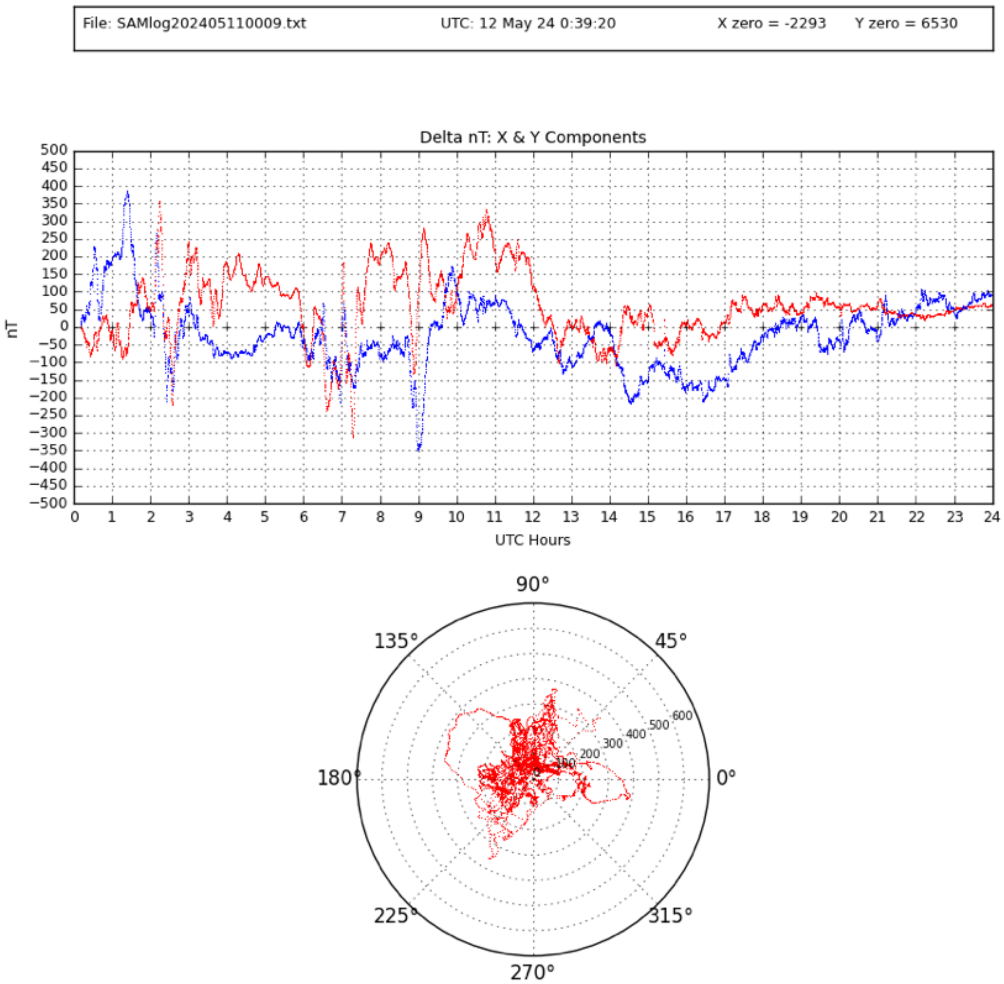

Figure 2: Fort Collins, Colorado, the magnetometer records the May 11 solar flare.

Using two flux gate magnetometers for Y (north) and X (east) we can see an estimate of the aurora at lower latitudes (circle). [Reference 2]

Figure 3: An aurora in Kansas from Susan Oatney (OATS) .

"Predictions on the KP index are available for a month ahead, but their validity for a strong geomagnetic storm, with effects on the sky, is reliable only within 24 hours. The activity of the Sun on 14-25 May 2024 may be a prelude of other X-ray flares, with CME aiming toward the Earth, restoring the exceptional conditions of 10/11 May, when the hemisphere of the sky was exposed to the Aurora for all that Moonless night. For Mediterranean observers the Aurora center was within 20 degrees from azimuth North, so it was mandatory to have this horizon clear from lightglows, better from mountains and free from low obstacles." *Courtesy of Costantino Sigismondi*
`https://www.spaceweatherlive.com/it/attivita-aurorale/previsione-aurora.html`

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

May 2024 (Figure 4): there were 4 C class, 5 M class and 2 X class flares recorded here in Fort Collins, Colorado, on May 11, which made a mess of the ionosphere. (U.S. Dept. of Commerce–NOAA, 2022).

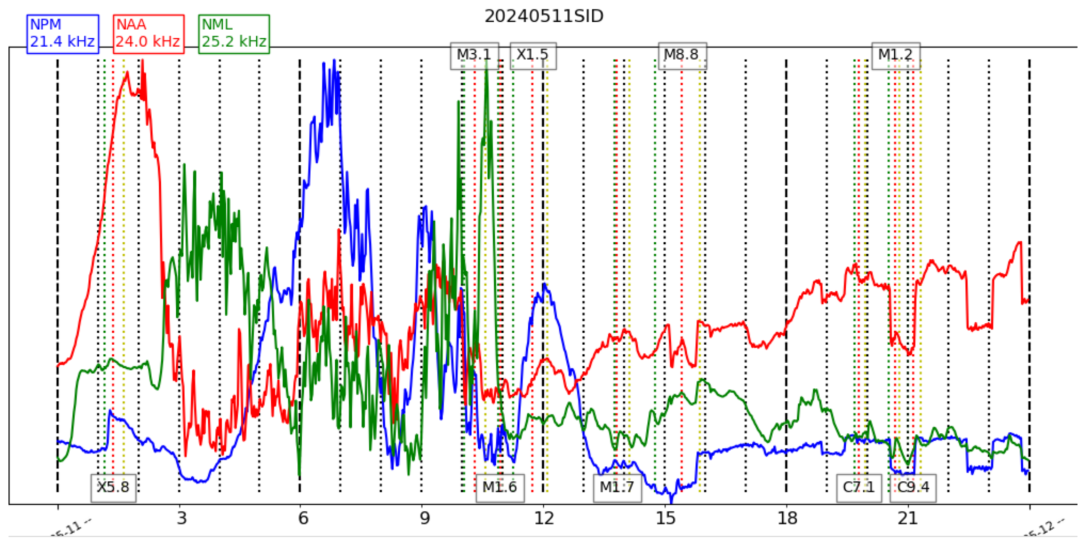

Figure 4: VLF recording from Fort Collins, Colorado for the 11th of May.

2.2 SID Observers

In May 2024 we had 14 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202405 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
G Silvis	A141	NAA NML NPM
L Pina	A148	NAA NML
J Wendler	A150	NAA
H Krumnow	A152	DHO FTA GBZ
J DeVries	A153	NAA
A Nebula	A156	DHO NSY

Figure 5 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.

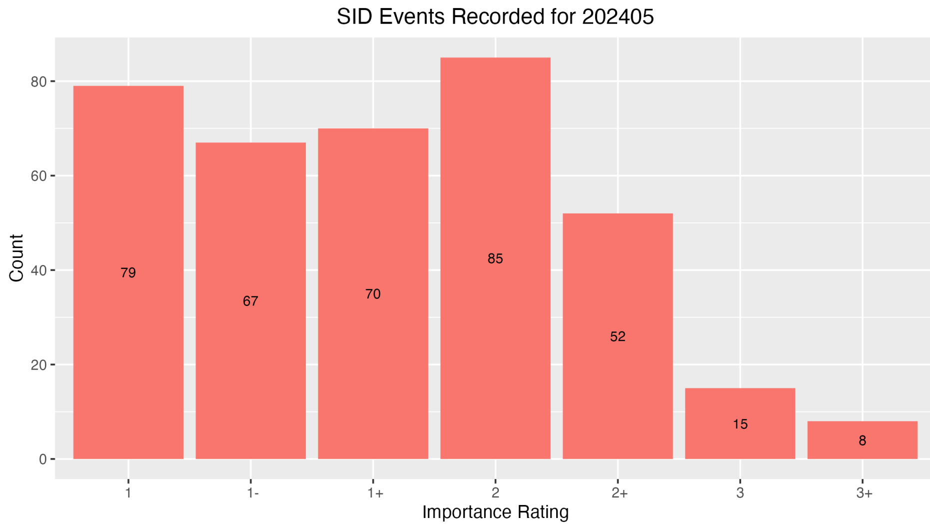

Figure 5: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In May 2024, There were 378 GOES-16 XRA flares: 21 X-class, 122 M-class, and 235 C-class. Far more flaring this month compared to last. (U.S. Dept. of CommerceNOAA, 2022). (see Figure 6).

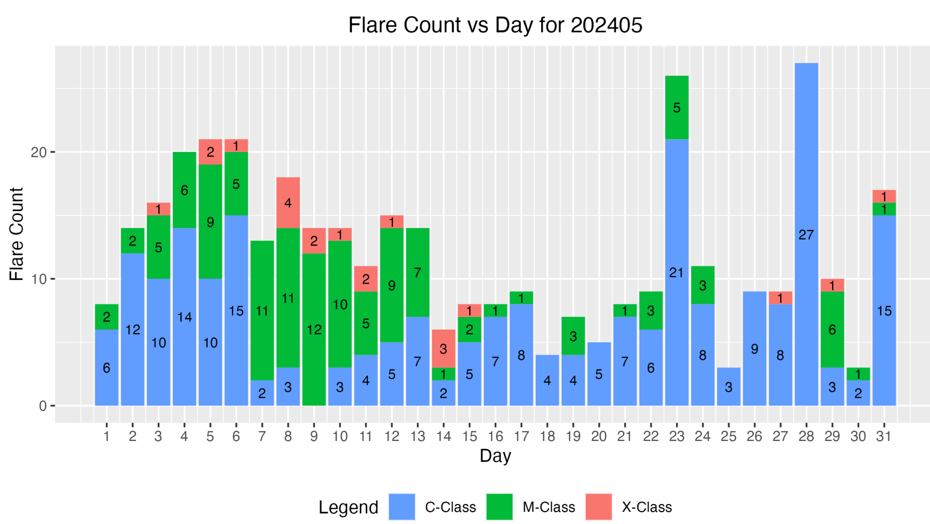

Figure 6: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 May 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 7.

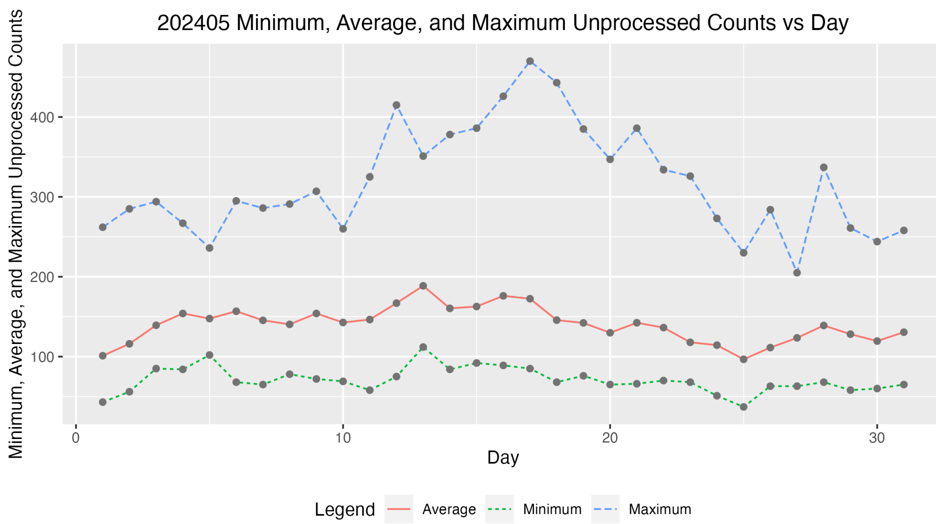

Figure 7: Raw Wolf number average, minimum and maximum by day of the month for all observers.

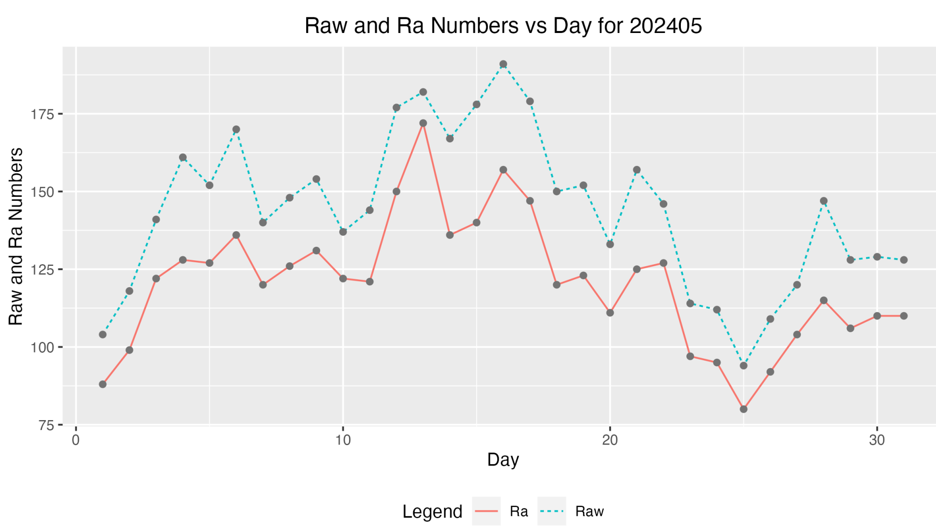

Figure 8: Raw Wolf average and R_a numbers by day of the month for all observers.

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 8, 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: 202405 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	35	104	88
2	32	118	99
3	27	141	122
4	37	161	128
5	34	152	127
6	26	170	136
7	39	140	120
8	34	148	126
9	40	154	131
10	41	137	122
11	43	144	121
12	34	177	150
13	35	182	172
14	30	167	136
15	32	178	140
16	32	191	157
17	37	179	147
18	29	150	120
19	38	152	123
20	40	133	111
21	39	157	125
22	38	146	127
23	43	114	97
24	40	112	95
25	42	94	80
26	38	109	92
27	27	120	104
28	31	147	115
29	35	128	106
30	34	129	110
31	29	128	110
Averages	35.2	143.9	120.5

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for May 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 (1091).

Table 3: 202405 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	19	Alexandre Amorim
AJV	20	J. Alonso
ARAG	31	Gema Araujo
ASA	3	Salvador Aguirre
BATR	3	Roberto Battaiola
BKL	11	John A. Blackwell
BMIG	22	Michel Besson
BTB	23	Thomas Bretl
BXZ	24	Jose Alberto Berdejo
BZX	26	A. Gonzalo Vargas
CIOA	5	Ioannis Chouinavas
CKB	26	Brian Cudnik
CLDB	13	Laurent Cambon
CMAB	5	Maurizio Cervoni
CNT	20	Dean Chantiles
CVJ	2	Jose Carvajal
DARB	20	Aritra Das
DAT	21	Adam Derdzikowski
DGIA	15	Giuseppe di Tommasco
DJOB	6	Jorge del Rosario
DJSA	1	Jeff DeVries
DJVA	27	Jacques van Delft
DMIB	16	Michel Deconinck
DUBF	25	Franky Dubois
EHOA	8	Howard Eskildsen
FERA	23	Eric Fabrigat
FLET	18	Tom Fleming
GIGA	23	Igor Grageda Mendez
GJLB	12	Josep Maria Llenas Garcia
HALB	13	Brian Halls
HKY	23	Kim Hay
HOWR	22	Rodney Howe
HSR	11	Serge Hoste
IEWA	10	Ernest W. Iverson
ILUB	3	Luigi Iapichino
JGE	3	Gerardo Jimenez Lopez
JSI	5	Simon Jenner
KAND	14	Kandilli Observatory

Continued

Table 3: 202405 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
KNJS	24	James & Shirley Knight
KTOC	9	Tom Karnuta
LKR	15	Kristine Larsen
LRRA	21	Robert Little
LVY	31	David Levy
MARC	3	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	19	Etsuiku Mochizuki
MJHA	29	John McCammon
MLL	6	Jay Miller
MMI	31	Michael Moeller
MSS	5	Sandy Mesics
MUDG	6	George Mudry
MWMB	16	William McShan
MWU	23	Walter Maluf
NMID	20	Milena Niemczyk
ONJ	13	John O'Neill
PLUD	19	Ludovic Perbet
RJV	18	Javier Ruiz Fernandez
SDOH	31	Solar Dynamics Obs - HMI
SNE	8	Neil Simmons
SQN	27	Lance Shaw
SRIE	24	Rick St. Hilaire
TDE	24	David Teske
TNIA	13	Nick Tonkin
TST	21	Steven Toothman
URBP	30	Piotr Urbanski
VIDD	17	Dan Vidican
WGI	1	Guido Wollenhaupt
WND	2	Denis Wallian
Totals	1091	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 9 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.

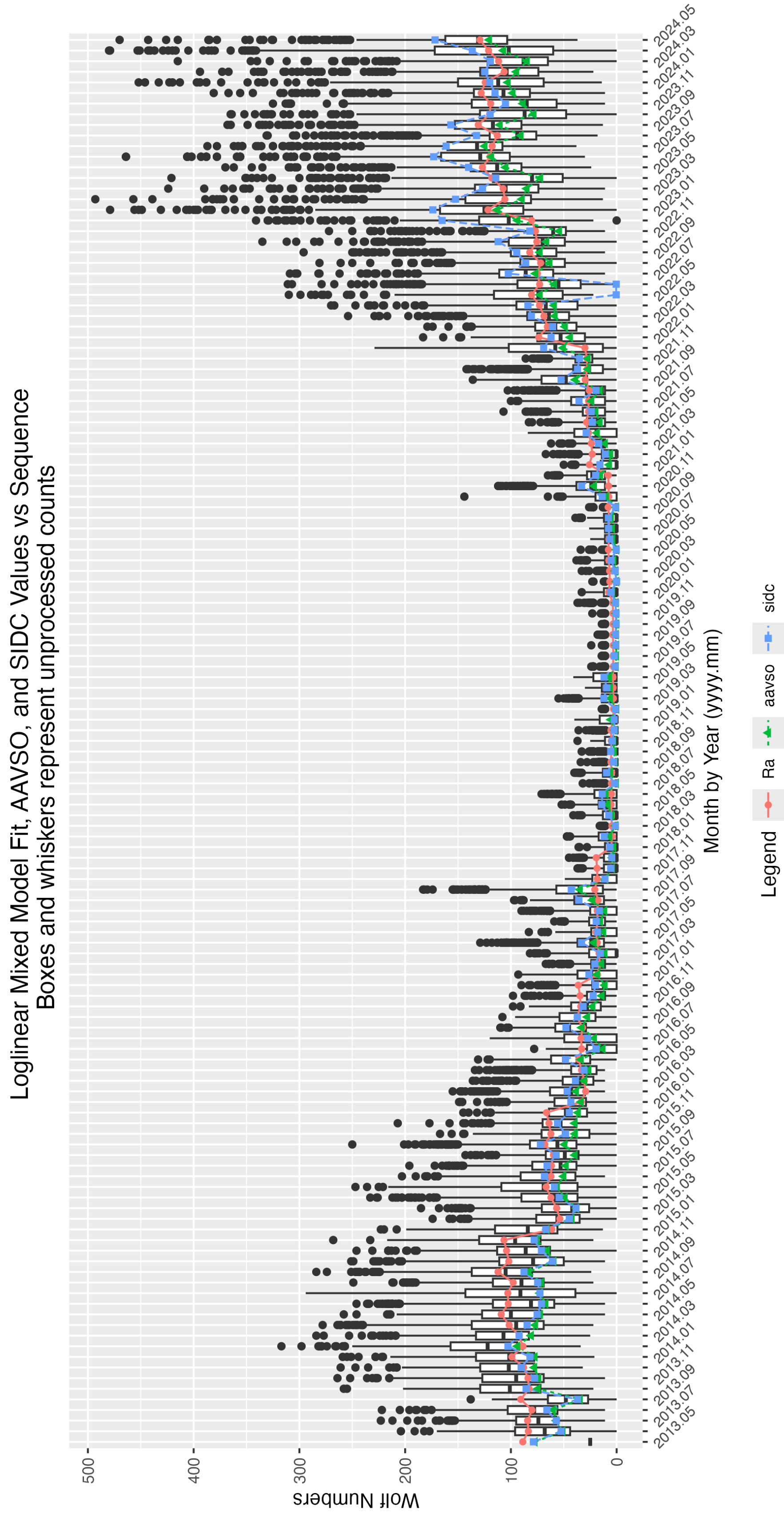

Figure 9: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

4.1 Antique telescope project

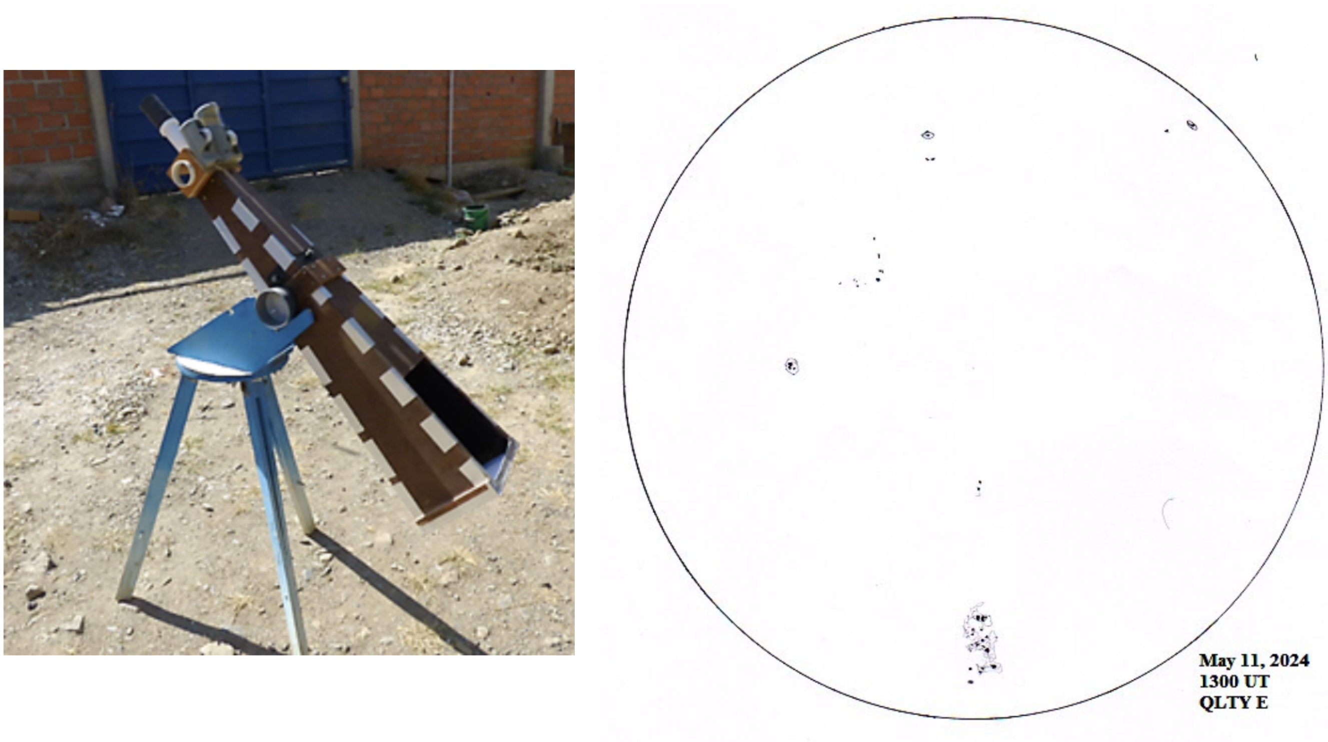

Figure 10: An antique telescope built by Gonzalo Vargas (BZX) (left). Drawing for the May 11, from Cochabamba, Bolivia (right).

5 References

ICRA, 2024 International Center for Relativistic Astrophysics, and AAVSO, SGQ
`https://www.icra.it/solar.html`

[1]*Aurora Boreale 1582*
`https://ingvambiente.com/2023/03/06/laurora-boreale-del-1582/`

[2] Fluxgate magnetometer:
`https://www.imperial.ac.uk/space-and-atmospheric-physics/research/areas/space-magnetometer-space-instrumentation-research/magnetometers/fluxgate-magnetometers/how-a-fluxgate-works/`

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