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.

1 Snapshots and Experiences During the April 8 Solar Eclipse

1.1 The view from Paris, Arkansas

Figure 1: Alexandra Rivera took these shots with her camera.

For the eclipse, I went to Paris, Arkansas. Fortunately there was no cloud cover in the middle of the path for totality. I loved getting to drive through Cherokee Nation to get there, the land is so green and full of wildlife! Totality is such a surreal experience. It was definitely worth the trip. I only had my phone camera with me, but I think I got better photos than what my friends are posting on their social medias! – Alexandra Rivera

1.2 The view from Waco and Killeen, Texas, Selling the Sun

Figure 2: Left to right: A street vendor in Waco, TX; Eclipse specials in Killeen, TX. Images by author – Kristine Larsen (LKR).

Like many astronomers, professional and amateur alike, I made my reservations to travel to Central Texas several years before the eclipse. As the date approached, and the weather forecast deteriorated, those who could change their plans frequently did. Therefore, the predicted crush of eclipse crowds never materialized along the Texas eclipse path. This did not, however, decrease efforts by creative capitalists to make a profit off the event, as noted in this sample of advertisements. The Texas Department of Transportation likewise did not eclipse its efforts to educate the public on solar viewing safety, including nearly constant reminders to use approved solar filters and, above all else, to NOT stop along the roadways to view the event!

Figure 3: Left to right: Cautionary billboard in Killeen, TX; Advertisement in bar, Waco, TX. Images by author – Kristine Larsen (LKR).

While the forecast probably led numerous bar owners, restauranteurs, t-shirt vendors, and even those seen charging up to 200 dollars for the privilege of parking in private driveways, to feel a pinch in their profit margins, the enthusiasm generated by those who were able to observe the event (yours truly included) regardless of the perilous prognostication was certainly priceless. While the marketing mavens of numerous Florida theme parks are probably already working on their plans for the 2045 events, I am more eager to turn some people's new-found interest in our star towards safe solar observing without the moon in the way. – Kristine Larsen (LKR)

1.3 The view from Yarker, Ontario, Canada

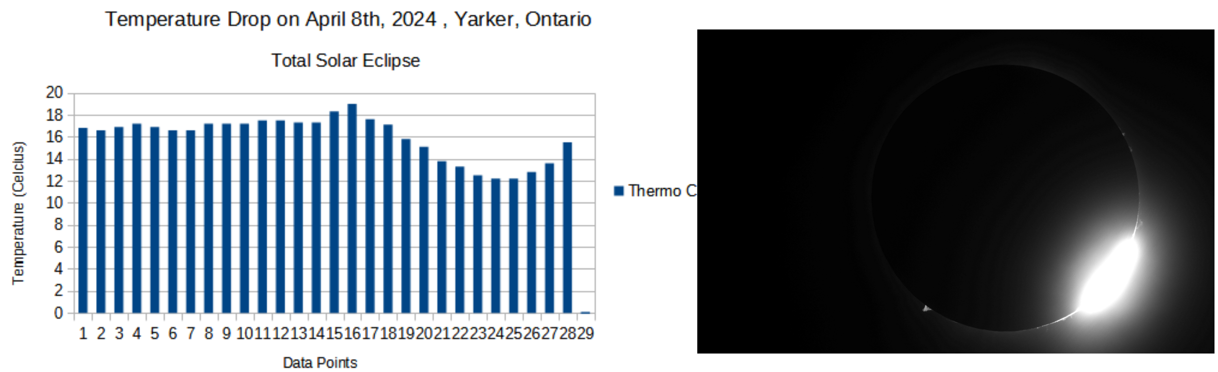

Figure 4: Left panel is a graph of the temperatures during totality (Celcius). Right panel shows an image taken with 80 mm Celestron C80ED-R apochromatic refractor, 1000 Oaks Type II glass filter. Using an ASI174mm to take a video. I used PIP to extract each frame for a still image of the diamond ring, which became a tiff file. – Kim Hay (HKY)

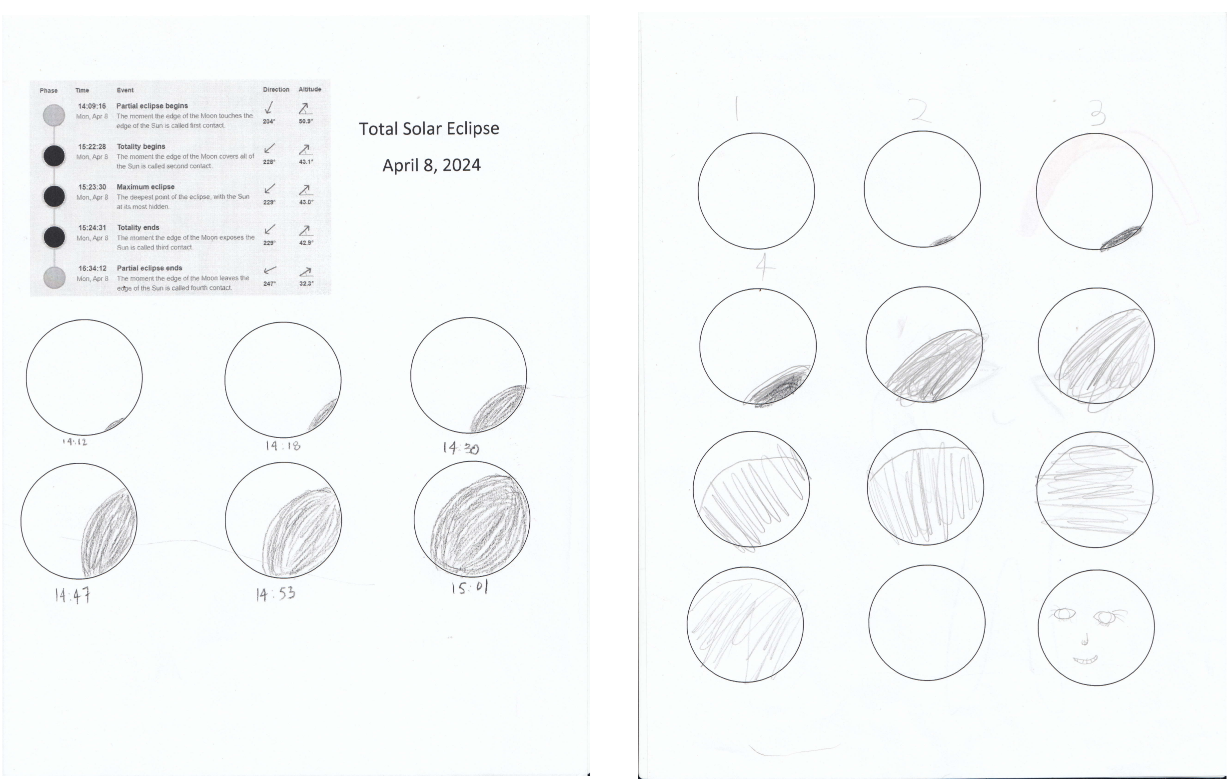

Figure 5: Left panel are drawings from daughter Sara. Right panel are drawings from granddaughter Ella. 3 generations watching the Total Solar Eclipse - very special – Kim Hay (HKY).

1.4 The view from Houlton, Maine

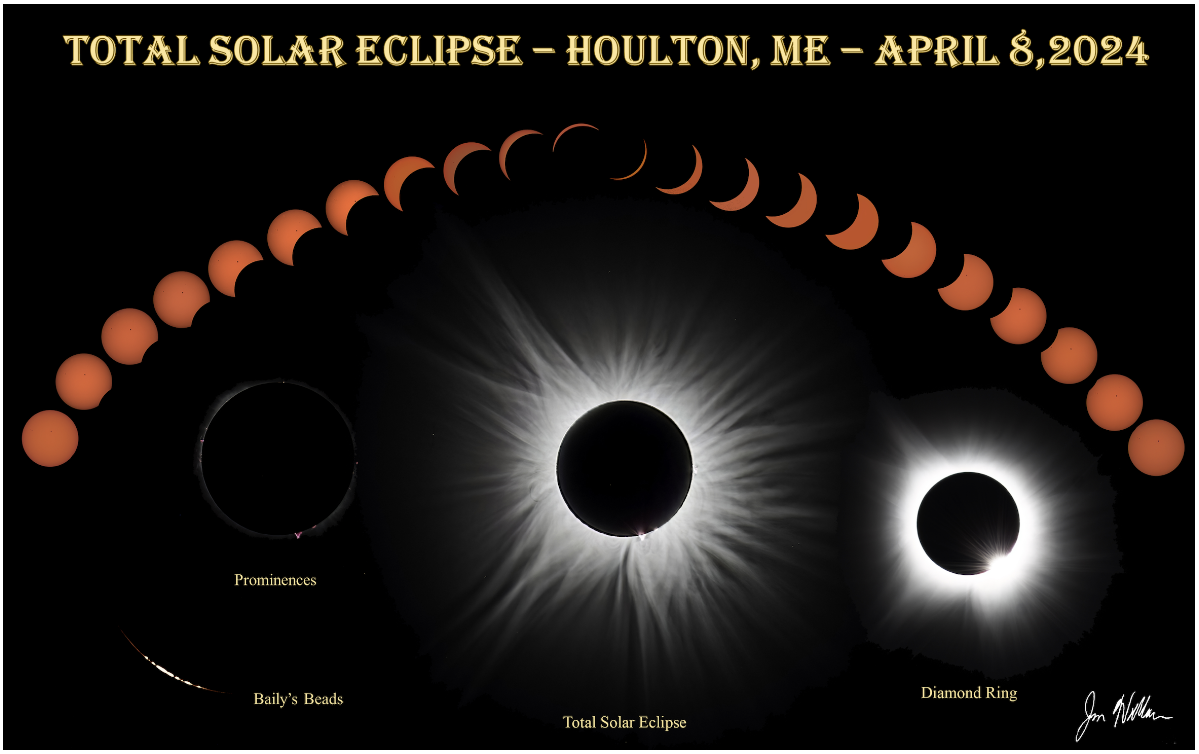

Figure 6: I was a photographer for Houlton, Maine and took the family and had a wonderful experience! First time to see totality, since I normally volunteer to do sessions in my hometown. Here is a poster I made up for Houlton showing all the 'main' events and one is from my Seestar S50 digital scope that I used for close-ups and it shows some incredible detail in the lower Corona. – Jon Wallace (A97).

2 Sudden Ionospheric Disturbance (SID) Report

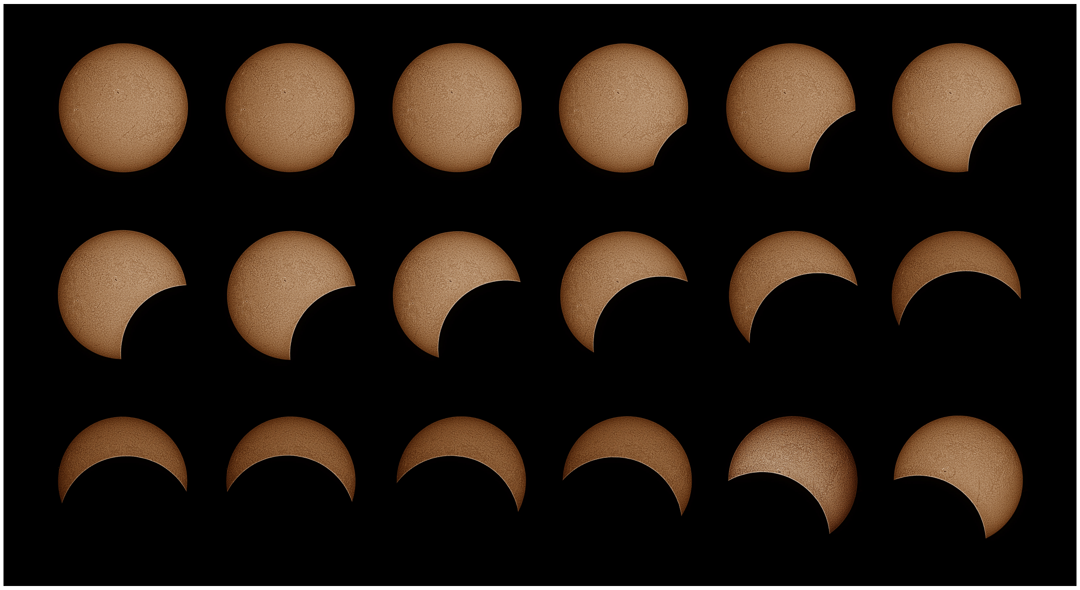

Figure 7: Partial eclipse sequence from Fort Collins, Colorado. Assembled by the local astronomy club: `http://www.nocoastro.org`

2.1 SID Records

The partial eclipse's impact on VLF signals monitored from Fort Collins matches up with the photographic sequence of the eclipse taken for the same time period, 18:00 to 2:00 UT (Figure 7). This can be seen in the rise in the ionosphere and SID Event reflected in the signal from two northern Naval stations, NLK and NML April 2024 (Figure 8):

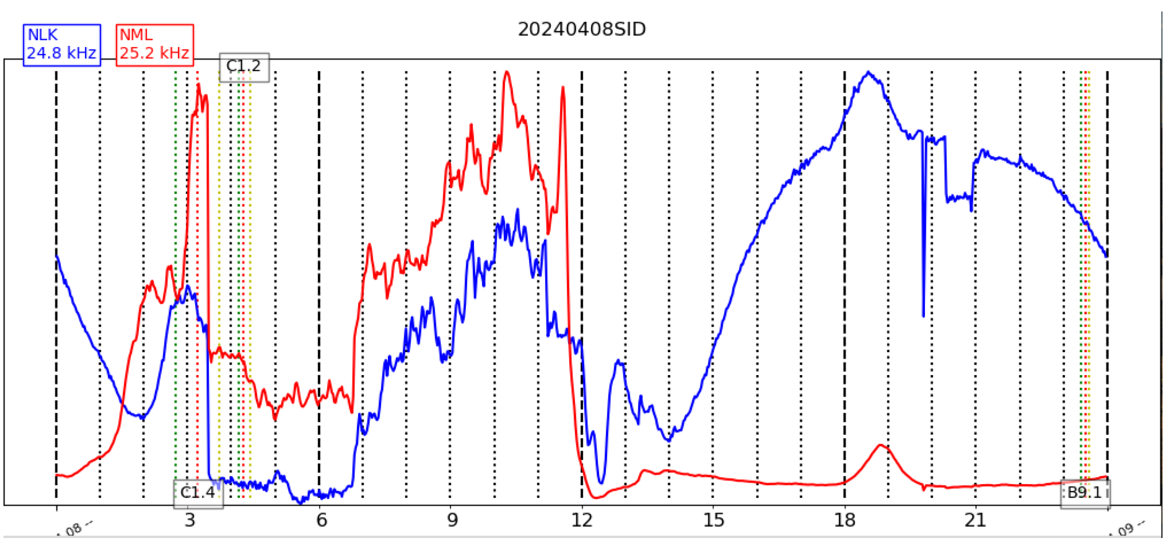

Figure 8: VLF recording from Fort Collins, Colorado for April 8th.

2.2 SID Observers

In April 2024 we had 15 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202404 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
M Salo	A157	NLK

Figure 9 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.

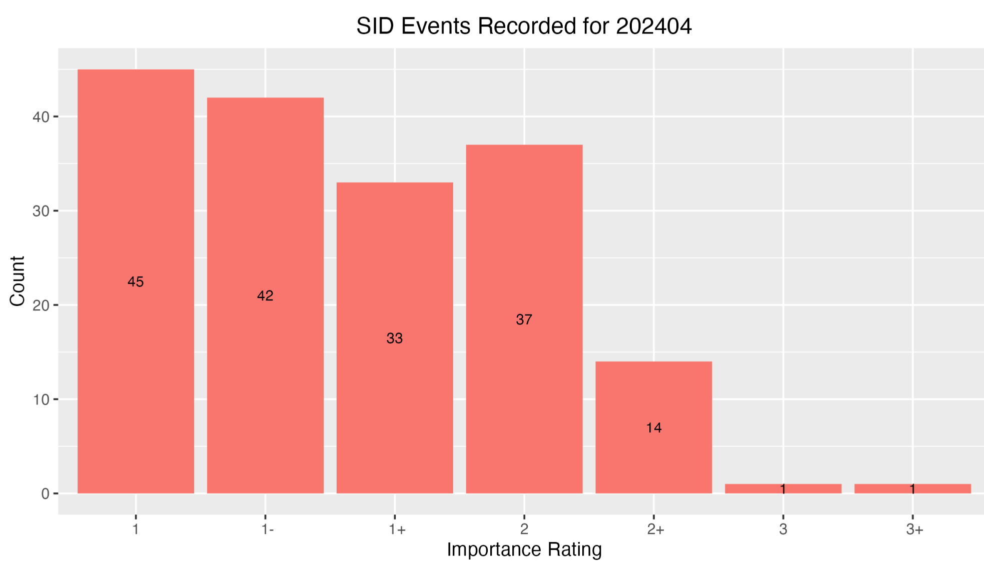

Figure 9: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In April 2024, there were 253 GOES-16 XRA flares; 47 M-Class, 184 C-Class, and 22 B-Class flares for April 2024. Less flaring this month compared to the flares for last month. (U.S. Dept. of Commerce–NOAA, 2022). (see Figure 10).

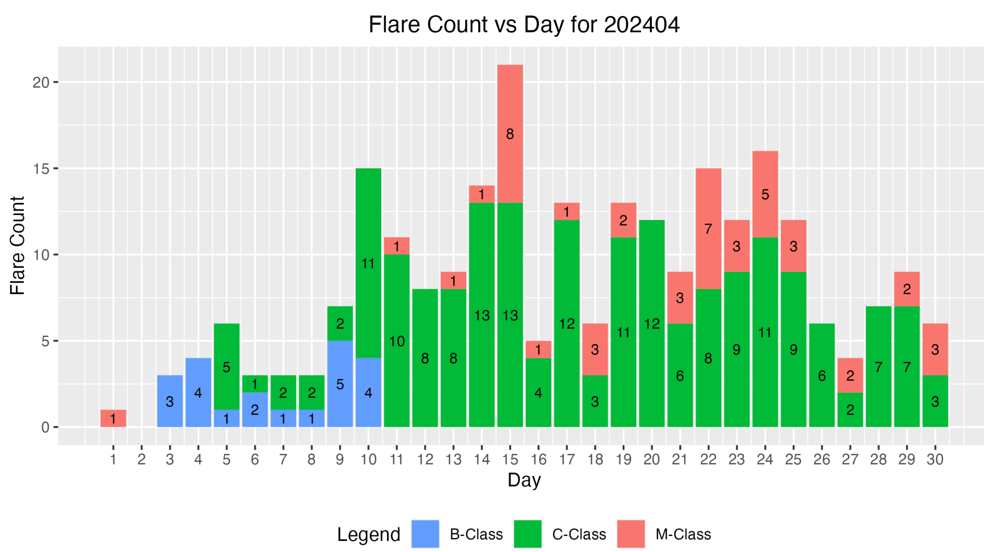

Figure 10: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

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 April 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 11.

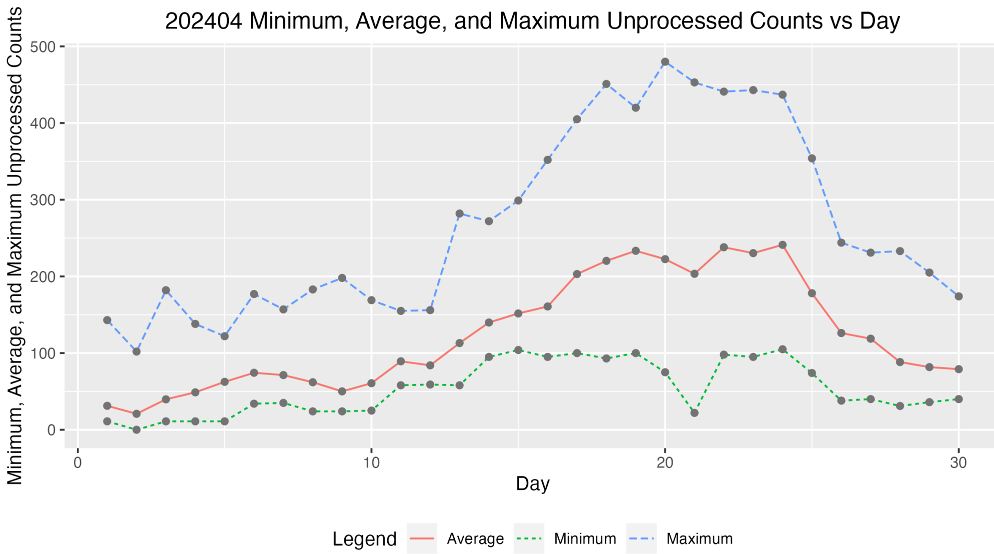

Figure 11: Raw Wolf number average, minimum and maximum by day of the month for all observers.

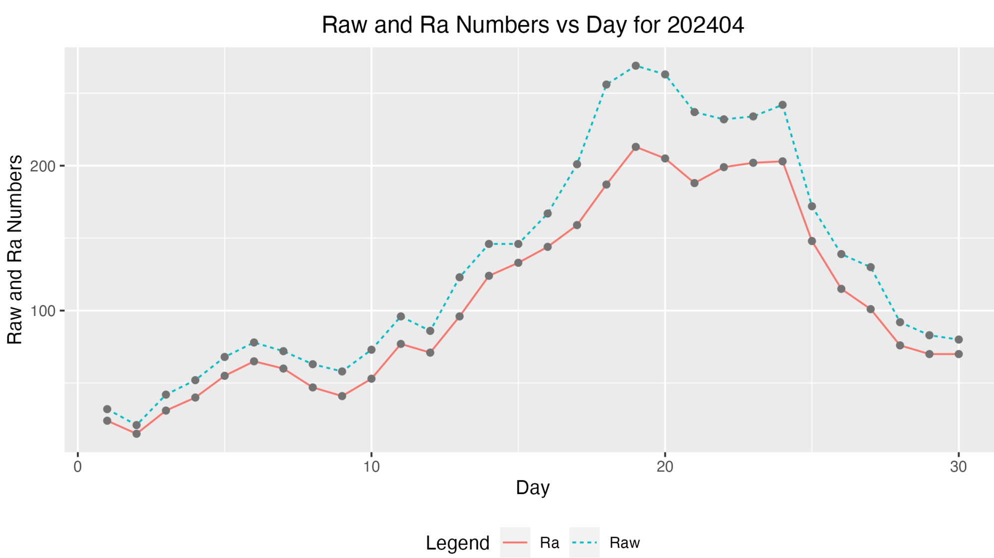

Figure 12: Raw Wolf average and R_a numbers by day of the month for all observers.

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 12, 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: 202404 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	36	32	24
2	34	21	15
3	30	42	31
4	30	52	40
5	35	68	55
6	33	78	65
7	35	72	60
8	25	63	47
9	27	58	41
10	24	73	53
11	29	96	77
12	34	86	71
13	42	123	96
14	40	146	124
15	29	146	133
16	36	167	144
17	30	201	159
18	26	256	187
19	29	269	213
20	30	263	205
21	40	237	188
22	37	232	199
23	36	234	202
24	27	242	203
25	29	172	148
26	32	139	115
27	29	130	101
28	30	92	76
29	38	83	70
30	36	80	70
Averages	32.3	131.8	107.1

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for April 2024, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (67), and total number of observations submitted (968).

Table 3: 202404 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	18	Alexandre Amorim
AJV	16	J. Alonso
ARAG	29	Gema Araujo
ASA	2	Salvador Aguirre
BATR	7	Roberto Battaiola
BKL	2	John A. Blackwell
BMIG	11	Michel Besson
BTB	20	Thomas Bretl
BXZ	26	Jose Alberto Berdejo
BZX	21	A. Gonzalo Vargas
CIOA	3	Ioannis Chouinavas
CKB	25	Brian Cudnik
CLDB	16	Laurent Cambon
CMAB	2	Maurizio Cervoni
CNT	22	Dean Chantiles
CVJ	2	Jose Carvajal
DARB	24	Aritra Das
DAT	12	Adam Derdzikowski
DELS	2	Susan Delaney
DGIA	17	Giuseppe di Tommasco
DJOB	18	Jorge del Rosario
DJSA	8	Jeff DeVries
DJVA	18	Jacques van Delft
DMIB	18	Michel Deconinck
DUBF	30	Franky Dubois
EHOA	23	Howard Eskildsen
FERA	17	Eric Fabrigat
FLET	18	Tom Fleming
HALB	10	Brian Halls
HKY	16	Kim Hay
HOWR	18	Rodney Howe
HSR	19	Serge Hoste
IEWA	14	Ernest W. Iverson
ILUB	6	Luigi Iapichino
JGE	4	Gerardo Jimenez Lopez
JSI	1	Simon Jenner
KAND	24	Kandilli Observatory
KNJS	25	James & Shirley Knight

Continued

Table 3: 202404 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
KTOC	11	Tom Karnuta
LKR	8	Kristine Larsen
LRRA	19	Robert Little
LVY	27	David Levy
MARC	5	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	16	Etsuiku Mochizuki
MJHA	26	John McCammon
MLL	4	Jay Miller
MMI	30	Michael Moeller
MSS	8	Sandy Mesics
MUDG	4	George Mudry
MWMB	14	William McShan
MWU	20	Walter Maluf
NMID	18	Milena Niemczyk
ONJ	7	John O'Neill
RJV	15	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SNE	6	Neil Simmons
SQN	23	Lance Shaw
SRIE	15	Rick St. Hilaire
TDE	17	David Teske
TNIA	2	Nick Tonkin
TPJB	2	Patrick Thibault
TST	13	Steven Toothman
URBP	25	Piotr Urbanski
VIDD	17	Dan Vidican
WGI	4	Guido Wollenhaupt
WWM	5	William M. Wilson
Totals	968	67

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 13 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.

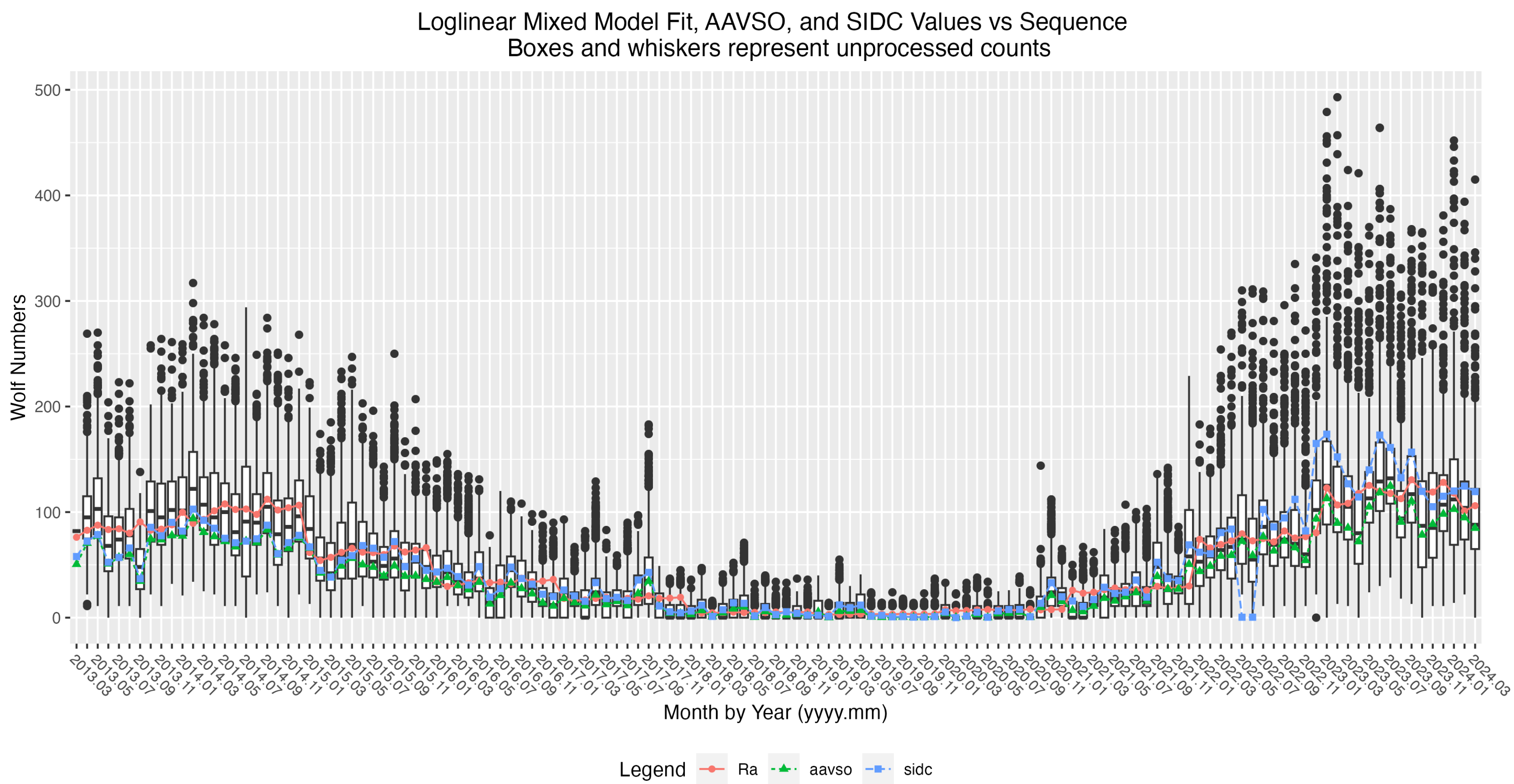

Figure 13: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

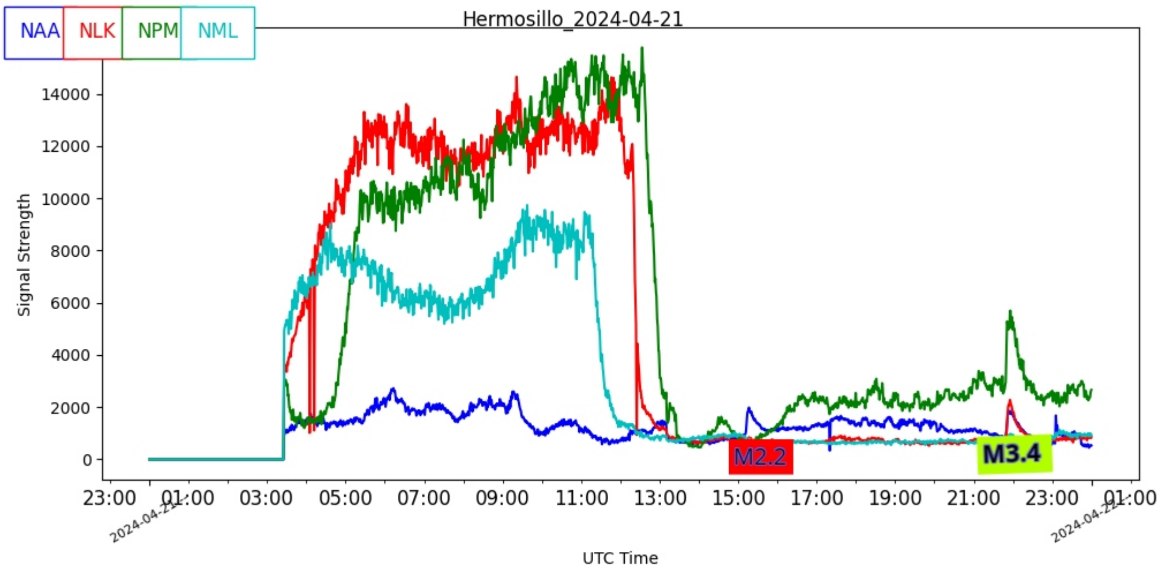

Figure 14: Here are a couple of M -class flares captured on April 21 by Salvador Aguirre (A138) looking at multiple Naval stations.

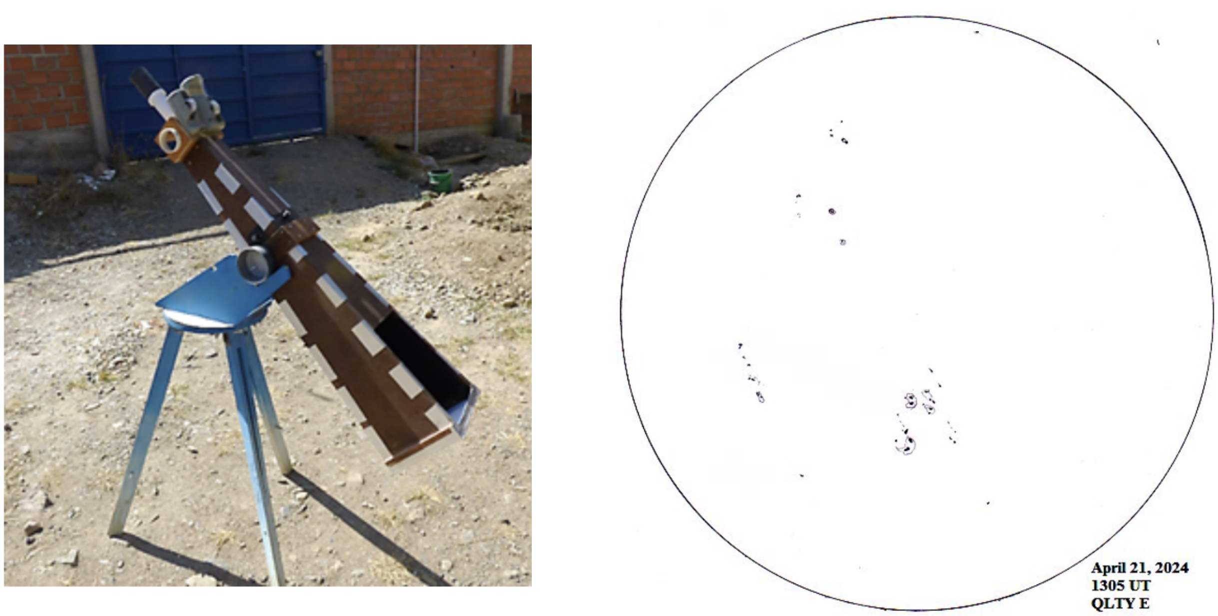

Figure 15: A recent replica of an antique telescope built by Gonzalo Vargas (BZX) in Cochabamba, Bolivia (left), and a drawing for April 21 (right).

5 References

U.S. Dept. of Commerce–NOAA, Space Weather Prediction Center, 2022. *GOES-16 XRA data.* `ftp://ftp.swpc.noaa.gov/pub/indices/events/`