# *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 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 October 14 Eclipse over the U.S. recorded with VLF software

Nathan Towne's SID monitor detected an interesting bump in response to the annular eclipse. (`https://myplace.frontier.com/~nathan56/sidmon/sidmon.html`) "My location is west central New Mexico about 125 km from the center of the eclipse path. It happens that the eclipse path crosses the signal path from NLK in Washington state at an acute angle and near the center of the signal path, allowing for a significant duration of the path in the shadow of the moon. The signal peaked at 16:27 UT. The peak was simultaneous with a C3.5 x-ray burst, but modest intensity bursts invariably depress the intensity of NLK at my location - not increase it. So the observed peak cannot have been due to the burst, and presumably was due to more night-time-like ionospheric conditions during the passage of the shadow."

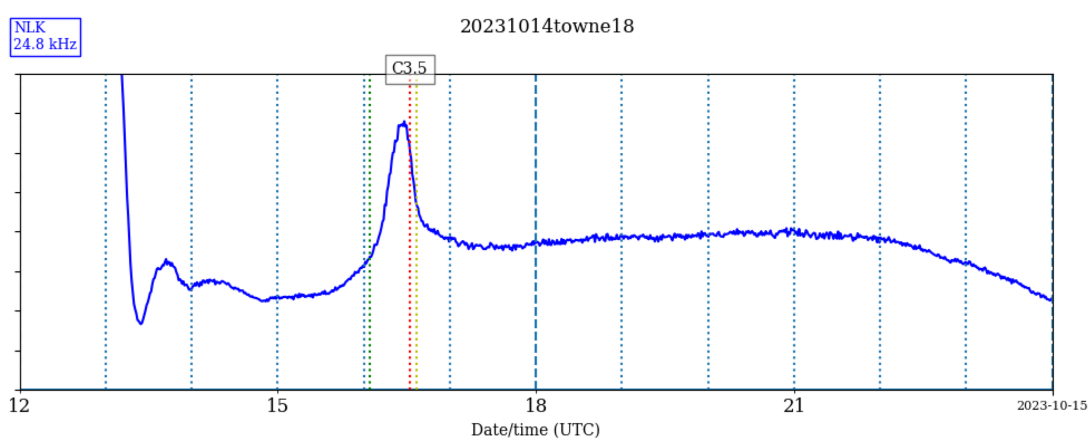


Figure 1: Solar eclipse shows a gentle rise and fall from the NLK transmitter, which is unlike a solar flare (see Figure 4).

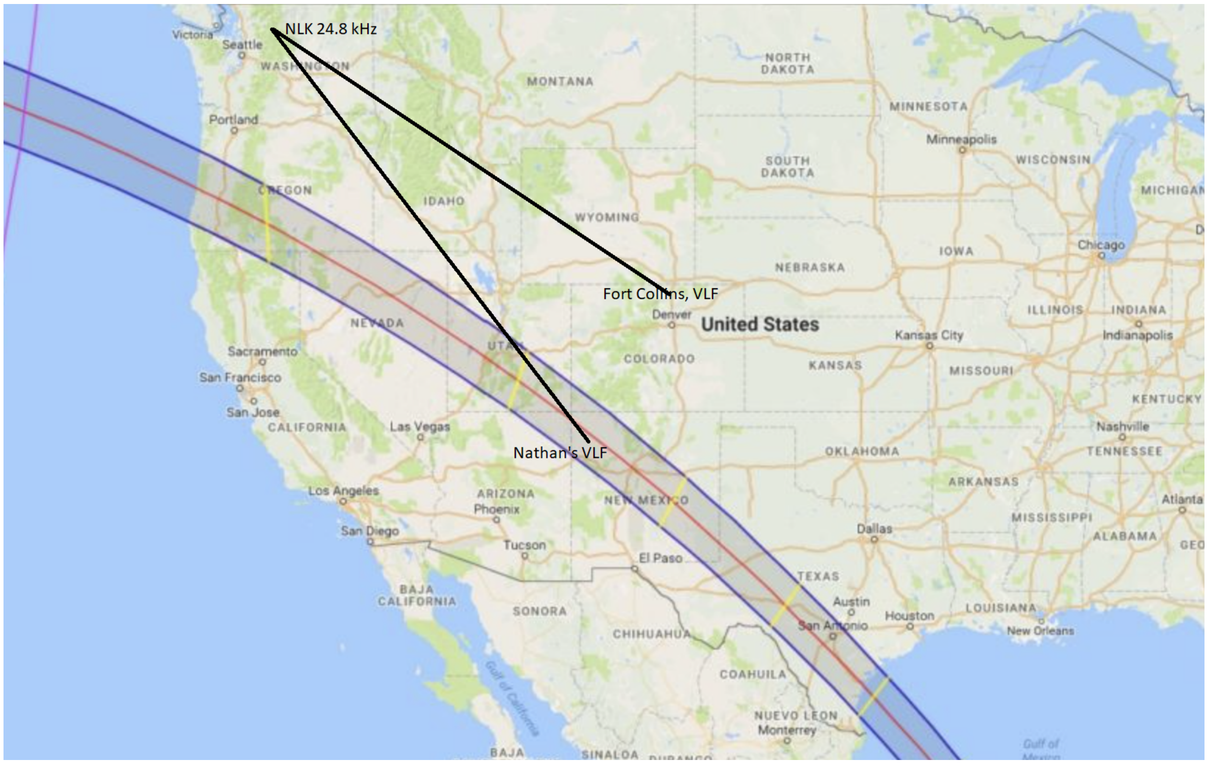


Figure 2: These VLF recordings provide insights into the dynamic nature of the solar eclipse when the path of the eclipse crosses close to one of the VLF transmitter's wave guides in the ionosphere (NLK in Washington State).

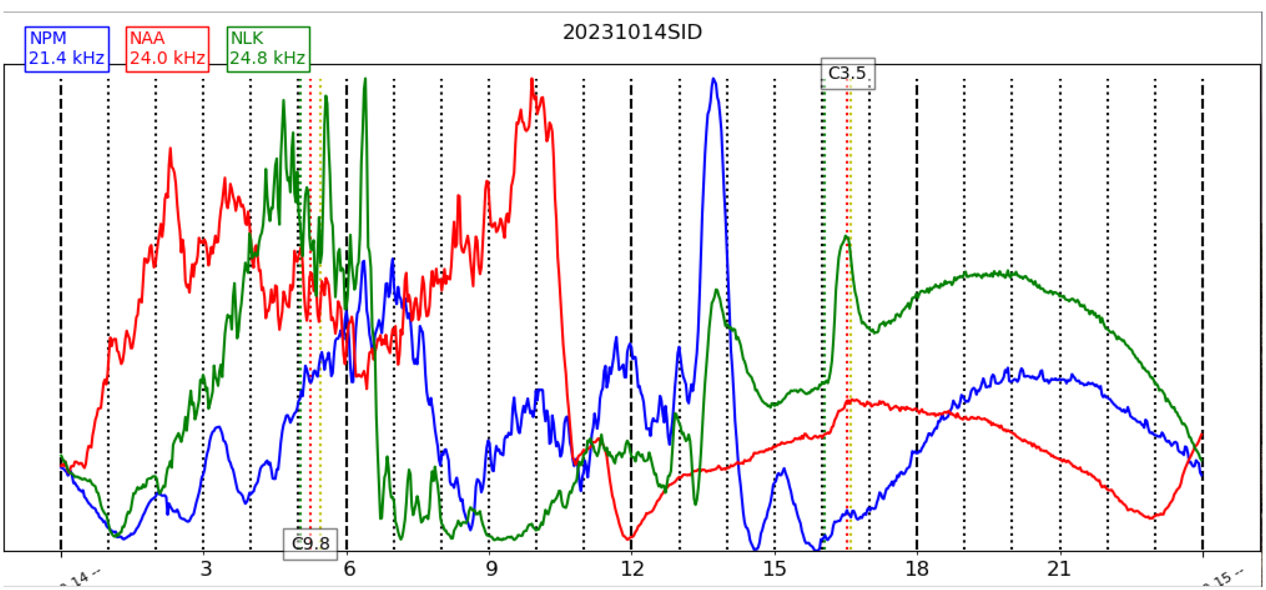


Figure 3: From Fort Collins, Colorado, we see a signature similar to NLK as in Nathan's plot (Figure 1). In Fort Collins, Colorado, the eclipse covered 85 percent of the sun.

# 2 Sudden Ionospheric Disturbance (SID) Report

## 2.1 SID Records

October 2023 (Figure 4): There was only one M class flare captured here in Fort Collins, Colorado, this month, on 7th of October. Compare the flare 'sharks' tail with the eclipse response (Figure 3).

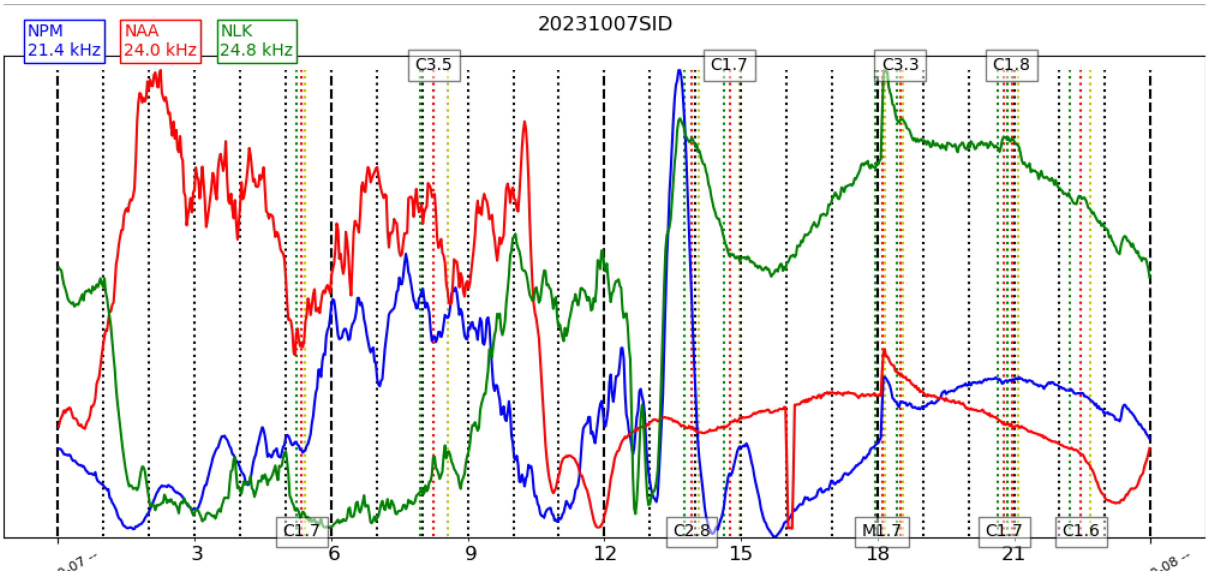


Figure 4: VLF recording from Fort Collins, CO.

## 2.2 SID Observers

In October 2023 we had 13 AAVSO SID observers who submitted VLF data, as listed in Table 1.

Table 1: 202310 VLF Observers

| Observer | Code | Stations |
|---|---|---|
| R Battaiola | A96 | HWU |
| J Wallace | A97 | NAA |
| L Loudet | A118 | DHO GQD |
| J Godet | A119 | GBZ GQD ICV |
| F Adamson | A122 | NWC |
| J Karlovsky | A131 | TBB |
| R Mrllak | A136 | GQD NSY |
| G Silvis | A141 | NAA NAU NPM |
| L Pina | A148 | NAA NLK |
| J Wendler | A150 | NAA |
| H Krumnow | A152 | DHO FTA GBZ |
| J DeVries | A153 | NLK |
| M Salo | A157 | NLK |

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.

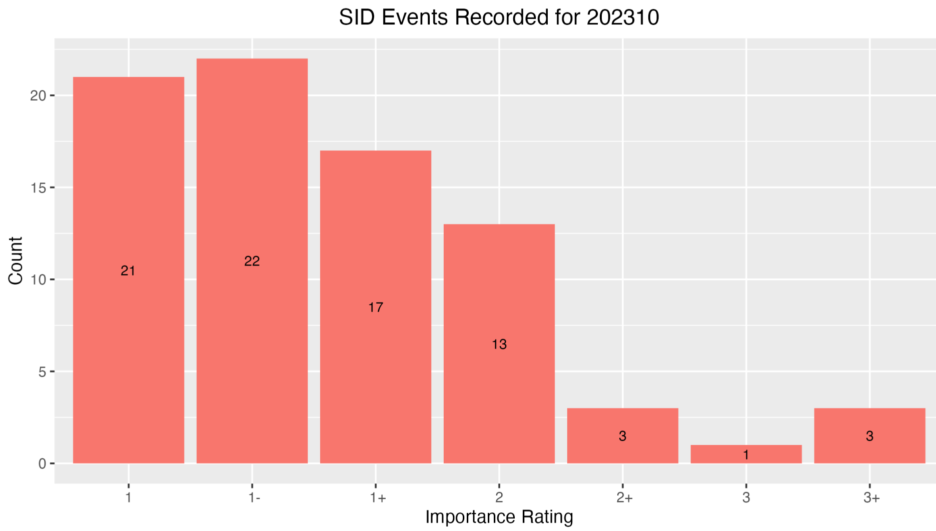


Figure 5: VLF SID Events.

### 2.3 Solar Flare Summary from GOES-16 Data

In October 2023, there were 213 GOES-16 XRA flares: 7 M-class, 190 C-class, and 16 B-class, far less intense flaring compared to last month (U.S. Dept. of Commerce–NOAA, 2022; see Figure 6).

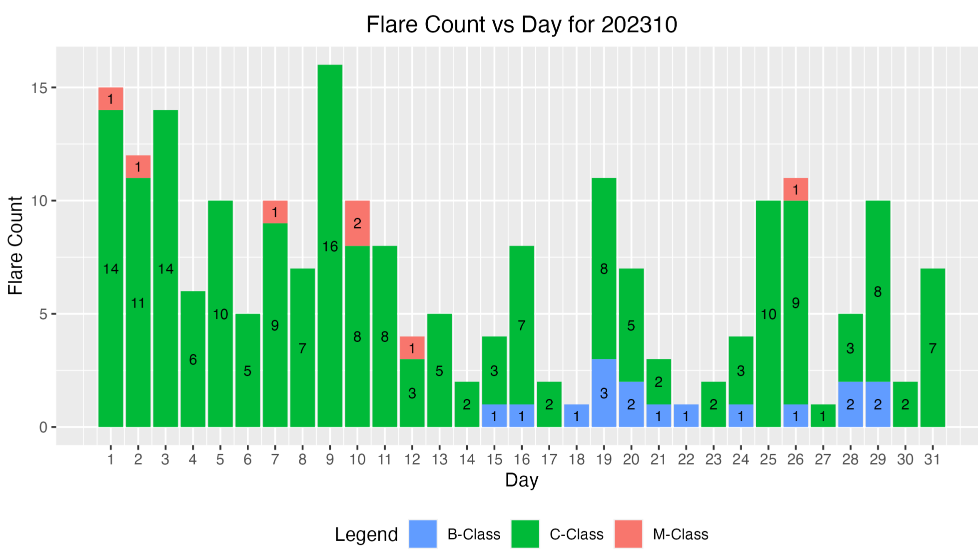


Figure 6: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2022).

# 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 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 October 2023. 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.

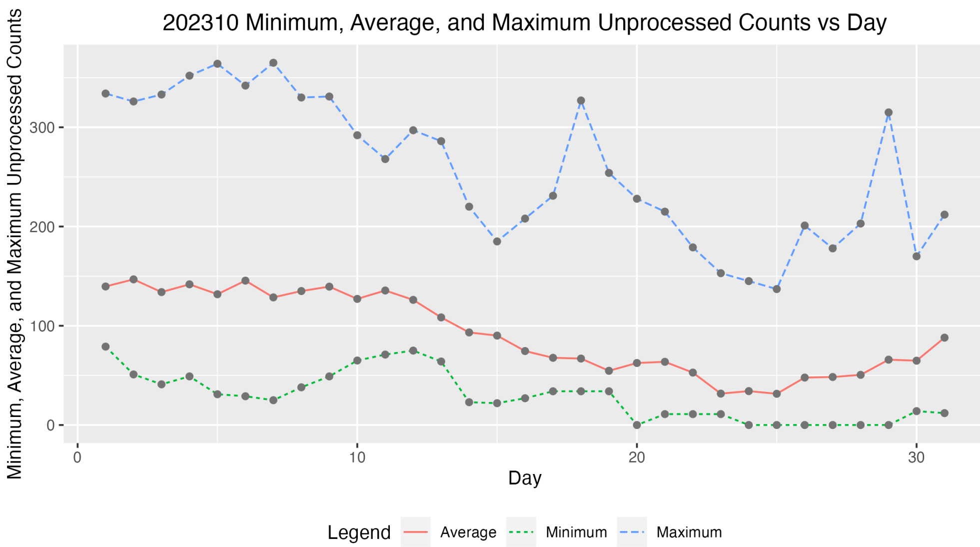


Figure 7: Raw Wolf number average, minimum and maximum by day of the month for all observers.

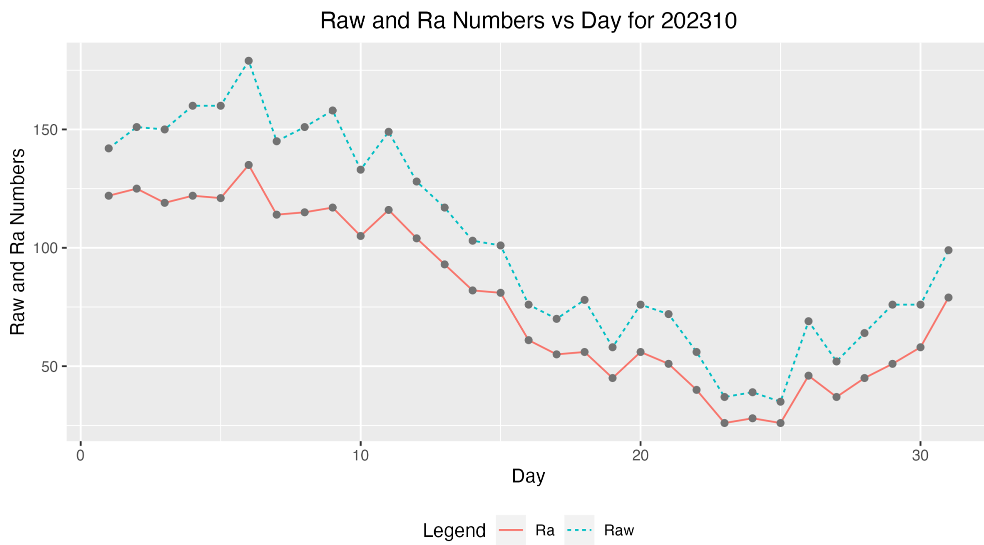


Figure 8: Raw Wolf average and $R_a$ numbers by day of the month for all observers.

### 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`). 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: 202310 American Relative Sunspot Numbers ($R_a$).

| Day | Number of Observers | Raw | $R_a$ |
|---|---|---|---|
| 1 | 43 | 142 | 122 |
| 2 | 40 | 151 | 125 |
| 3 | 38 | 150 | 119 |
| 4 | 33 | 160 | 122 |
| 5 | 36 | 160 | 121 |
| 6 | 38 | 179 | 135 |
| 7 | 38 | 145 | 114 |
| 8 | 35 | 151 | 115 |
| 9 | 37 | 158 | 117 |
| 10 | 38 | 133 | 105 |
| 11 | 32 | 149 | 116 |
| 12 | 29 | 128 | 104 |
| 13 | 32 | 117 | 93 |
| 14 | 35 | 103 | 82 |
| 15 | 38 | 101 | 81 |
| 16 | 33 | 76 | 61 |
| 17 | 30 | 70 | 55 |

Continued

Table 2: 202310 American Relative Sunspot Numbers ($R_a$).

| Day | Number of Observers | Raw | $R_a$ |
|---|---|---|---|
| 18 | 31 | 78 | 56 |
| 19 | 30 | 58 | 45 |
| 20 | 30 | 76 | 56 |
| 21 | 31 | 72 | 51 |
| 22 | 29 | 56 | 40 |
| 23 | 31 | 37 | 26 |
| 24 | 34 | 39 | 28 |
| 25 | 36 | 35 | 26 |
| 26 | 28 | 69 | 46 |
| 27 | 34 | 52 | 37 |
| 28 | 38 | 64 | 45 |
| 29 | 25 | 76 | 51 |
| 30 | 27 | 76 | 58 |
| 31 | 31 | 99 | 79 |
| Averages | 33.5 | 101.9 | 78.4 |

### 3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for October 2023, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (70), and total number of observations submitted (1056).

Table 3: 202310 Number of observations by observer.

| Observer Code | Number of Observations | Observer Name |
|---|---|---|
| AAX | 17 | Alexandre Amorim |
| AJV | 13 | J. Alonso |
| ARAG | 30 | Gema Araujo |
| ASA | 3 | Salvador Aguirre |
| ATE | 6 | Teofilo Arranz Heras |
| BATR | 2 | Roberto Battaiola |
| BKL | 16 | John A. Blackwell |
| BMF | 20 | Michael Boschat |
| BMIG | 24 | Michel Besson |
| BRAF | 1 | Raffaello Braga |
| BROB | 26 | Robert Brown |
| BXZ | 22 | Jose Alberto Berdejo |
| BZX | 23 | A. Gonzalo Vargas |
| CIOA | 1 | Ioannis Chouinavas |
| CKB | 25 | Brian Cudnik |
| CLDB | 15 | Laurent Cambon |

Continued

Table 3: 202310 Number of observations by observer.

| Observer Code | Number of Observations | Observer Name |
|---|---|---|
| CMAB | 14 | Maurizio Cervoni |
| CNT | 31 | Dean Chantiles |
| CVJ | 9 | Jose Carvajal |
| DARB | 8 | Aritra Das |
| DGIA | 16 | Giuseppe di Tommasco |
| DJOB | 11 | Jorge del Rosario |
| DJSA | 9 | Jeff DeVries |
| DJVA | 18 | Jacques van Delft |
| DMIB | 24 | Michel Deconinck |
| DUBF | 20 | Franky Dubois |
| EGMA | 5 | Georgios Epitropou |
| EHOA | 16 | Howard Eskildsen |
| ERB | 12 | Bob Eramia |
| FALB | 23 | Allen Frohardt |
| FLET | 22 | Tom Fleming |
| GIGA | 26 | Igor Grageda Mendez |
| HALB | 14 | Brian Halls |
| HKY | 13 | Kim Hay |
| HOWR | 24 | Rodney Howe |
| HSR | 14 | Serge Hoste |
| IEWA | 18 | Ernest W. Iverson |
| ILUB | 9 | Luigi Iapichino |
| JGE | 3 | Gerardo Jimenez Lopez |
| JSI | 2 | Simon Jenner |
| KAND | 25 | Kandilli Observatory |
| KAPJ | 13 | John Kaplan |
| KNJS | 29 | James & Shirley Knight |
| KTOC | 12 | Tom Karnuta |
| LKR | 15 | Kristine Larsen |
| LVY | 22 | David Levy |
| MARC | 6 | Arnaud Mengus |
| MARE | 12 | Enrico Mariani |
| MCE | 23 | Etsuiku Mochizuki |
| MJAF | 27 | Juan Antonio Moreno Quesada |
| MJHA | 25 | John McCammon |
| MLL | 8 | Jay Miller |
| MMI | 31 | Michael Moeller |
| MSS | 4 | Sandy Mesics |
| MWMB | 8 | William McShan |
| MWU | 20 | Walter Maluf |
| ONJ | 8 | John O'Neill |
| PLUD | 16 | Ludovic Perbet |
| RJV | 12 | Javier Ruiz Fernandez |

Continued

Table 3: 202310 Number of observations by observer.

| Observer Code | Number of Observations | Observer Name |
|---|---|---|
| SDOH | 31 | Solar Dynamics Obs - HMI |
| SNE | 4 | Neil Simmons |
| SQN | 10 | Lance Shaw |
| SRIE | 5 | Rick St. Hilaire |
| TDE | 22 | David Teske |
| TNIA | 7 | Nick Tonkin |
| TPJB | 3 | Patrick Thibault |
| URBP | 16 | Piotr Urbanski |
| VIDD | 12 | Dan Vidican |
| WND | 5 | Denis Wallian |
| WWM | 20 | William M. Wilson |
| Totals | 1056 | 70 |

## 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.

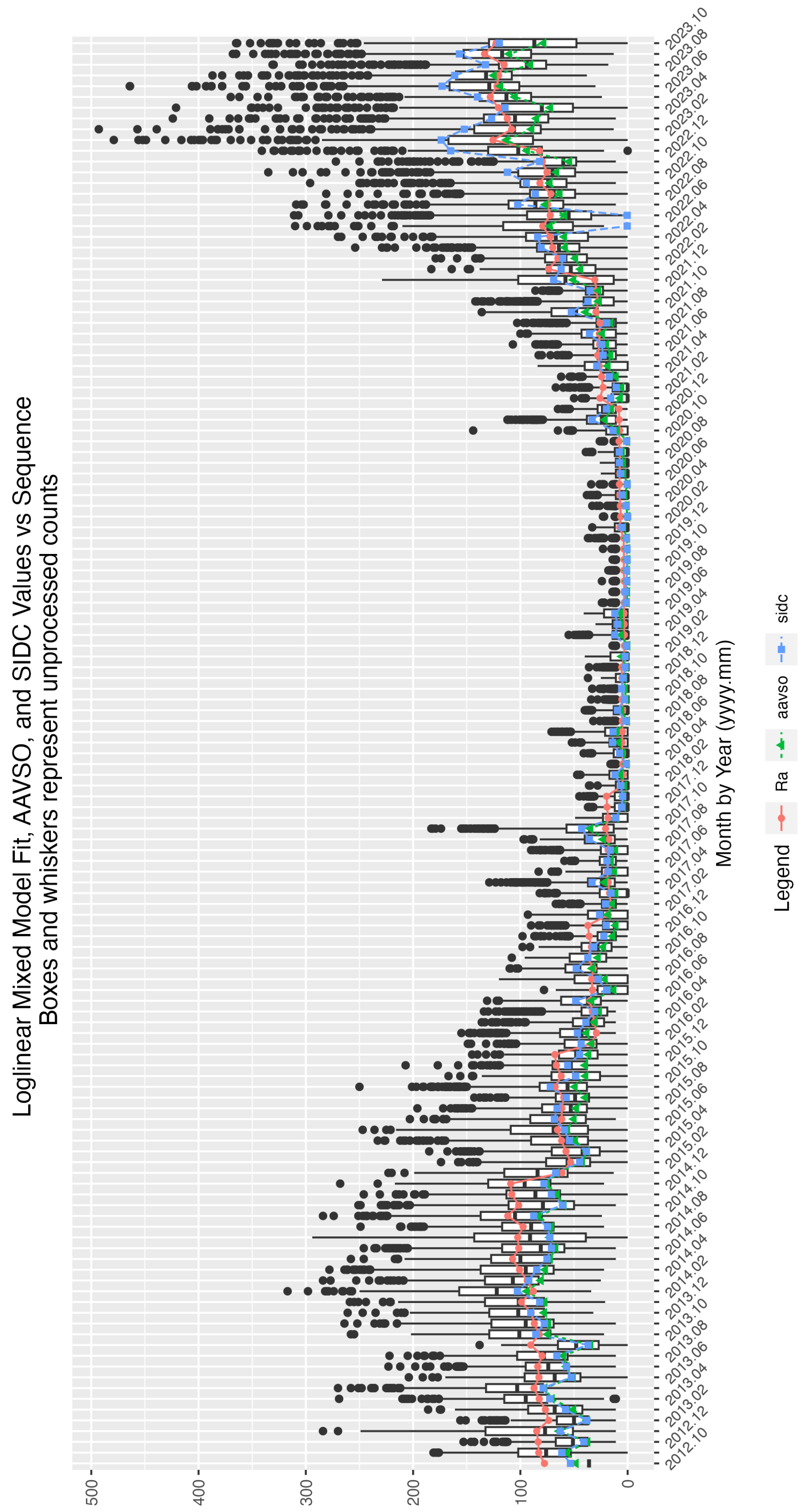


Figure 9: GLMM fitted data for $R_a$. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels.

# 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: Gonzalo's son Arturo and grand-daughter Valentina observing the annular eclipse through a replica of an antique telescope built by Gonzalo Vargas (BZX) (left). Image of the eclipse, from Cochabamba, Bolivia (right).

# 5 References


Nathan Towne's SID monitor,
`https://myplace.frontier.com/~nathan56/sidmon/sidmon.html`

Radio images of the eclipse taken at the Long Wavelength Array at OVRO,
*(LWA-OVRO) near Bishop, California:*
`https://www.astro.caltech.edu/news/a-solar-radio-eclipse-ring-of-fire`

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