# *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. Section 1 gives contributions by our members. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

## 1 Sunspot progression over two days for October 26 and 27.

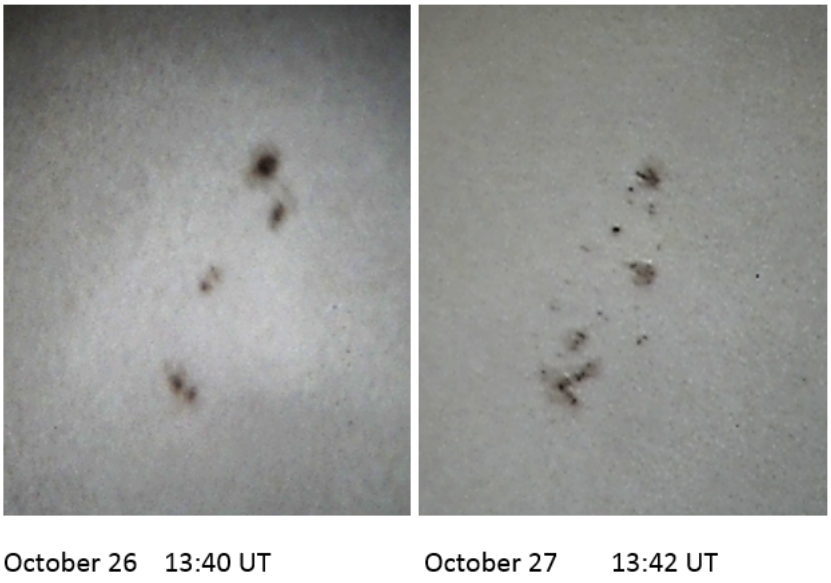


Figure 1: NOAA designation of the AR2778 sunspot progressions over two days.

The start of cycle 25 this month shows 3 group formations and a large number of sunspots. Here we have a two-day progression of a D-class (large group area) AR2778 for the 26 and 27th of October. Photos by Gonzalo Vargas (VARG) of Cochabamba, Bolivia.

# 2 Sudden Ionospheric Disturbance (SID) Report

## 2.1 SID Records

October 2020 (Figure 2): Here is the first SID Event for many years of solar minimum recorded by Roberto Battaiolia (A96).

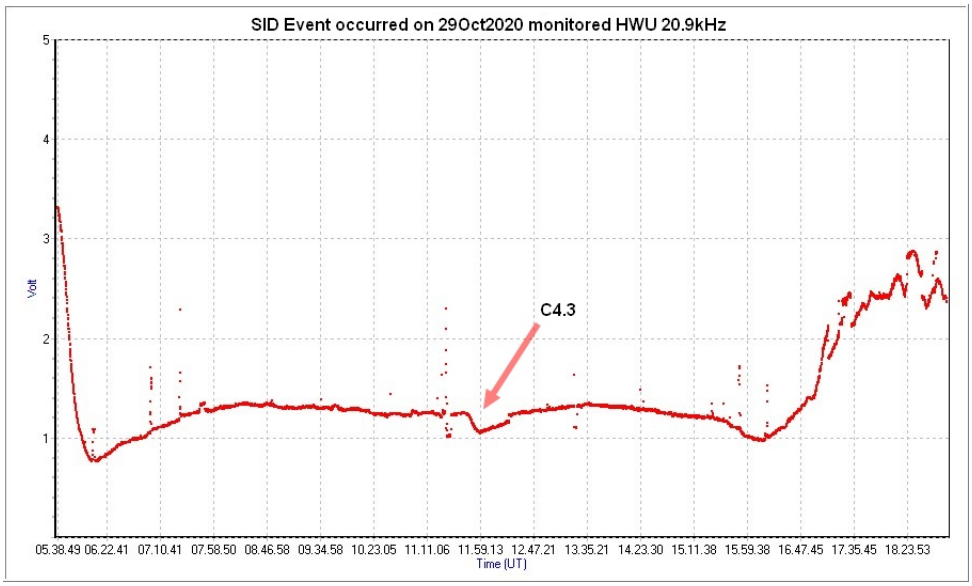


Figure 2: VLF recording from Milan, Italy by Roberto Battaiolia.

## 2.2 SID Observers

In October 2020 we had 13 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202010 VLF Observers

| Observer | Code | Stations |
|---|---|---|
| R Battaiola | A96 | HWU |
| J Wallace | A97 | NAA |
| L Loudet | A118 | DHO GBZ |
| J Godet | A119 | GBZ |
| B Terrill | A120 | NWC |
| F Adamson | A122 | NWC |
| S Oatney | A125 | NML NLK NAA |
| J Karlovsky | A131 | NSY ICV |
| S Aguirre | A138 | NPM |
| G Silvis | A141 | NAA NML |
| R Rogge | A143 | GQD |
| A Maevsky | A151 | GQD |
| H Krumnow | A152 | HWU GQD DHO |

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.

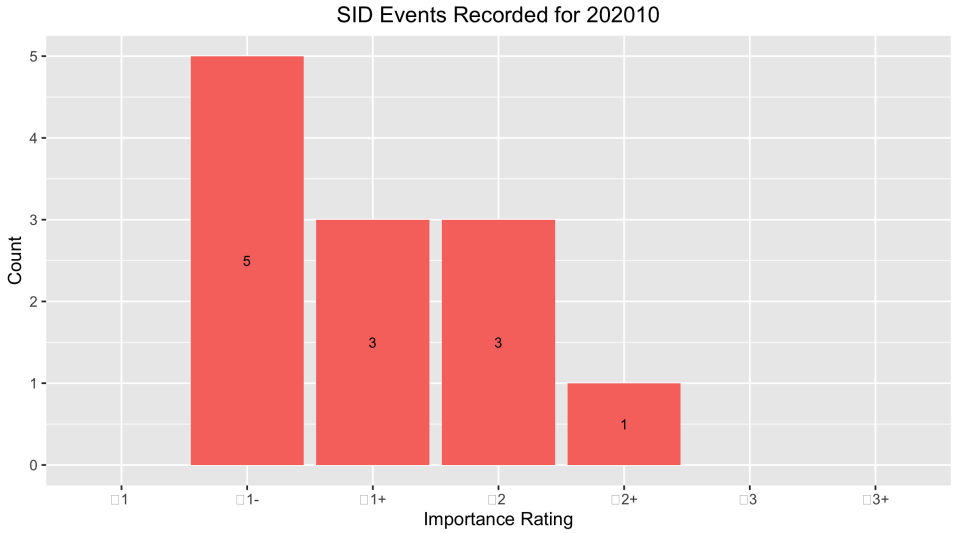


Figure 3: VLF SID Events.

## 2.3 Solar Flare Summary from GOES-16 Data

In October 2020, There were 96 XRA flares recorded by GOES-16; two A-class, 80 B-class and 14 C-class flares for October 2020. A large increase in flaring this month compared to last month. There were 15 days this month with no GOES-16 reports of flares (see Figure 4).

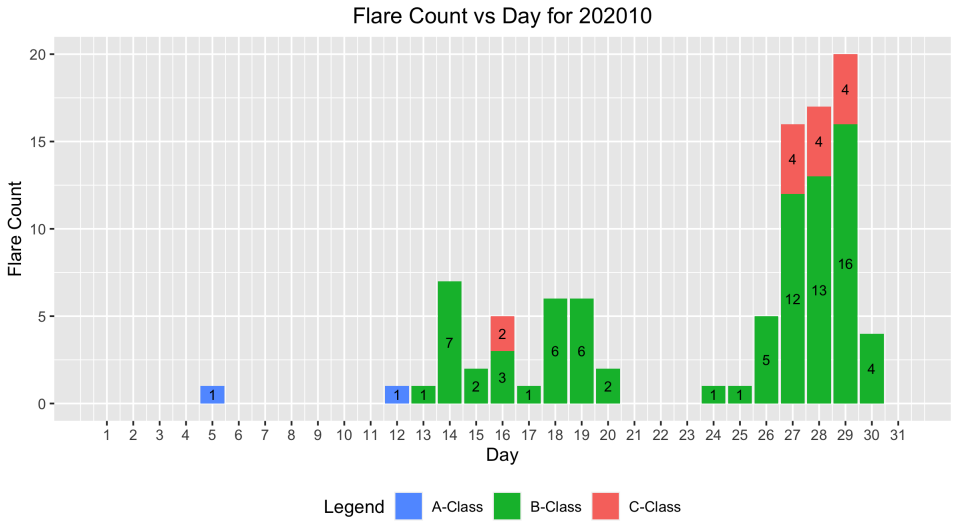


Figure 4: GOES-16 XRA flares

# 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 an 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 October 2020. 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.

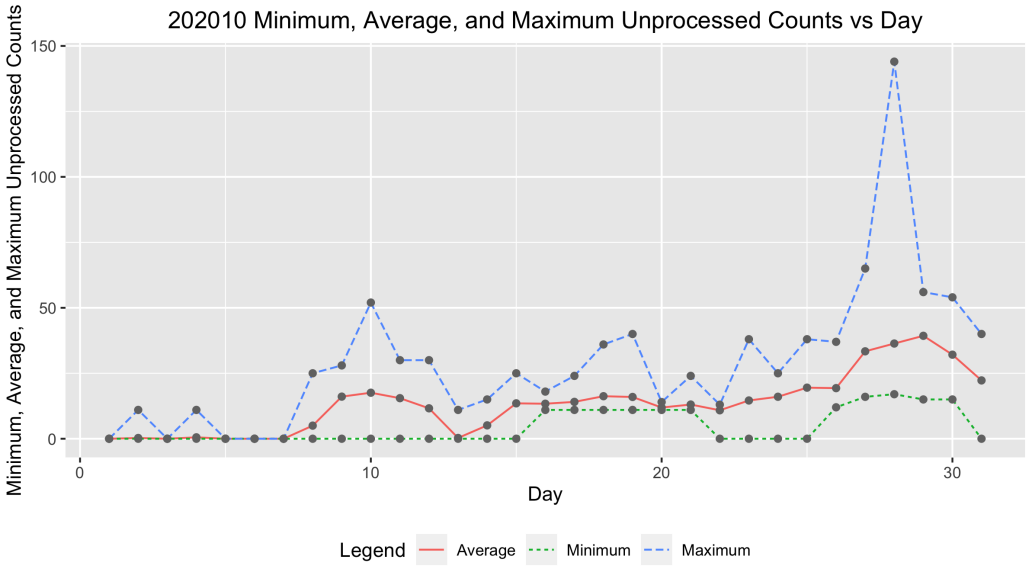


Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

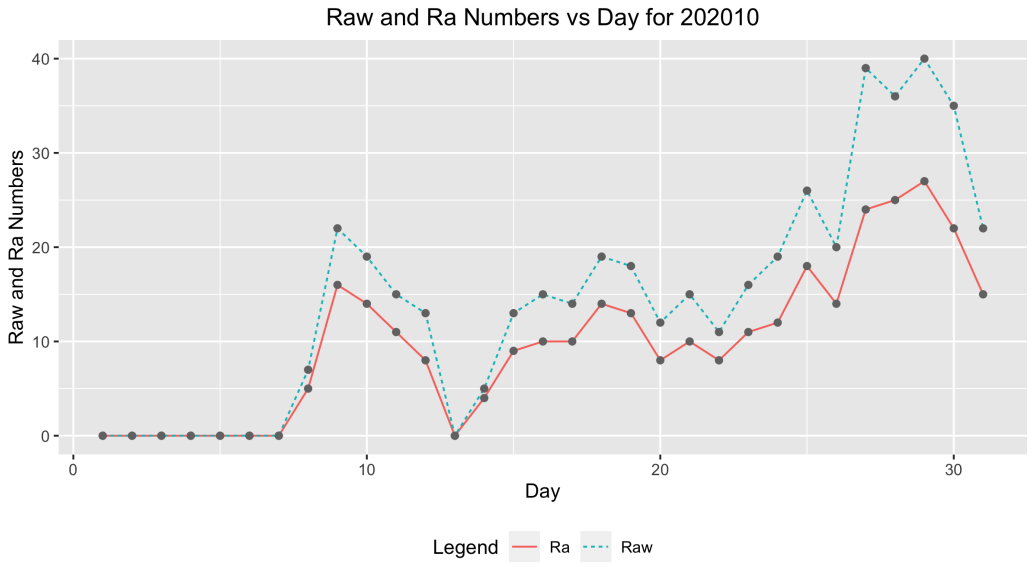


Figure 6: Raw Wolf average and $R_a$ numbers by day of the month for all observers.

### 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 6, 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: 202010 American Relative Sunspot Numbers ($R_a$).

| Day | Number of Observers | Raw | $R_a$ |
|---|---|---|---|
| 1 | 47 | 0 | 0 |
| 2 | 39 | 0 | 0 |
| 3 | 38 | 0 | 0 |
| 4 | 41 | 0 | 0 |
| 5 | 39 | 0 | 0 |
| 6 | 38 | 0 | 0 |
| 7 | 41 | 0 | 0 |
| 8 | 36 | 7 | 5 |
| 9 | 39 | 22 | 16 |
| 10 | 42 | 19 | 14 |
| 11 | 43 | 15 | 11 |
| 12 | 39 | 13 | 8 |
| 13 | 38 | 0 | 0 |
| 14 | 39 | 5 | 4 |

Continued

Table 2: 202010 American Relative Sunspot Numbers ($R_a$).

| Day | Number of Observers | Raw | $R_a$ |
|---|---|---|---|
| 15 | 35 | 13 | 9 |
| 16 | 41 | 15 | 10 |
| 17 | 40 | 14 | 10 |
| 18 | 38 | 19 | 14 |
| 19 | 39 | 18 | 13 |
| 20 | 33 | 12 | 8 |
| 21 | 34 | 15 | 10 |
| 22 | 37 | 11 | 8 |
| 23 | 33 | 16 | 11 |
| 24 | 36 | 19 | 12 |
| 25 | 28 | 26 | 18 |
| 26 | 40 | 20 | 14 |
| 27 | 29 | 39 | 24 |
| 28 | 37 | 36 | 25 |
| 29 | 36 | 40 | 27 |
| 30 | 41 | 35 | 22 |
| 31 | 45 | 22 | 15 |
| Averages | 38.1 | 14.5 | 9.9 |

### 3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for October 2020, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (69), and total number of observations submitted (1181).

Table 3: 202010 Number of observations by observer.

| Observer Code | Number of Observations | Observer Name |
|---|---|---|
| AAX | 24 | Alexandre Amorim |
| AJV | 19 | J. Alonso |
| ARAG | 30 | Gema Araujo |
| ASA | 24 | Salvador Aguirre |
| ATE | 28 | Teofilo Arranz Heras |
| BARH | 12 | Howard Barnes |
| BATR | 7 | Roberto Battaiola |
| BERJ | 29 | Jose Alberto Berdejo |
| BLAJ | 12 | John A. Blackwell |
| BMF | 22 | Michael Boschat |
| BRAF | 16 | Raffaello Braga |
| BROB | 30 | Robert Brown |
| CHAG | 30 | German Morales Chavez |

Continued

Table 3: 202010 Number of observations by observer.

| Observer Code | Number of Observations | Observer Name |
|---|---|---|
| CIOA | 7 | Ioannis Chouinavas |
| CKB | 23 | Brian Cudnik |
| CNT | 29 | Dean Chantiles |
| CVJ | 12 | Jose Carvajal |
| DEMF | 13 | Frank Dempsey |
| DIVA | 9 | Ivo Demeulenaere |
| DJOB | 15 | Jorge del Rosario |
| DMIB | 27 | Michel Deconinck |
| DROB | 1 | Bob Dudley |
| DUBF | 26 | Franky Dubois |
| EHOA | 16 | Howard Eskildsen |
| ERB | 17 | Bob Eramia |
| FERJ | 14 | Javier Ruiz Fernandez |
| FLET | 26 | Tom Fleming |
| FTAA | 7 | Tadeusz Figiel |
| FUJK | 18 | K. Fujimori |
| GIGA | 31 | Igor Grageda Mendez |
| HALB | 7 | Brian Halls |
| HAYK | 19 | Kim Hay |
| HMQ | 20 | Mark Harris |
| HOWR | 21 | Rodney Howe |
| IEWA | 23 | Ernest W. Iverson |
| JDAC | 1 | David Jackson |
| JENS | 2 | Simon Jenner |
| JGE | 10 | Gerardo Jimenez Lopez |
| KAND | 14 | Kandilli Observatory |
| KAPJ | 19 | John Kaplan |
| KNJS | 31 | James & Shirley Knight |
| LEVM | 14 | Monty Leventhal |
| LGEC | 7 | Georgios Lekkas |
| LKR | 5 | Kristine Larsen |
| LRRA | 13 | Robert Little |
| MARC | 9 | Arnaud Mengus |
| MCE | 22 | Etsuiku Mochizuki |
| MGAR | 5 | Gary Myers |
| MILJ | 18 | Jay Miller |
| MJAF | 30 | Juan Antonio Moreno Quesada |
| MJHA | 28 | John McCammon |
| MUDG | 7 | George Mudry |
| MWU | 24 | Walter Maluf |
| OAAA | 27 | Al Sadeem Astronomy Observatory |
| ONJ | 18 | John O'Neill |
| PEKT | 9 | Riza Pektas |

Continued

Table 3: 202010 Number of observations by observer.

| Observer Code | Number of Observations | Observer Name |
|---|---|---|
| SDOH | 31 | Solar Dynamics Obs - HMI |
| SJAH | 2 | Jim Soos |
| SNE | 9 | Neil Simmons |
| SONA | 5 | Andries Son |
| STAB | 24 | Brian Gordon-States |
| SUZM | 22 | Miyoshi Suzuki |
| TESD | 25 | David Teske |
| TPJB | 1 | Patrick Thibault |
| TST | 18 | Steven Toothman |
| URBP | 15 | Piotr Urbanski |
| VARG | 30 | A. Gonzalo Vargas |
| WGI | 1 | Guido Wollenhaupt |
| WILW | 21 | William M. Wilson |
| Totals | 1181 | 69 |

### 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 7 shows the monthly GLMM $R_a$ numbers for a rolling eleven-year (132 months) 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 confidence band uses the large sample approximation based on the Gaussian distribution. 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.

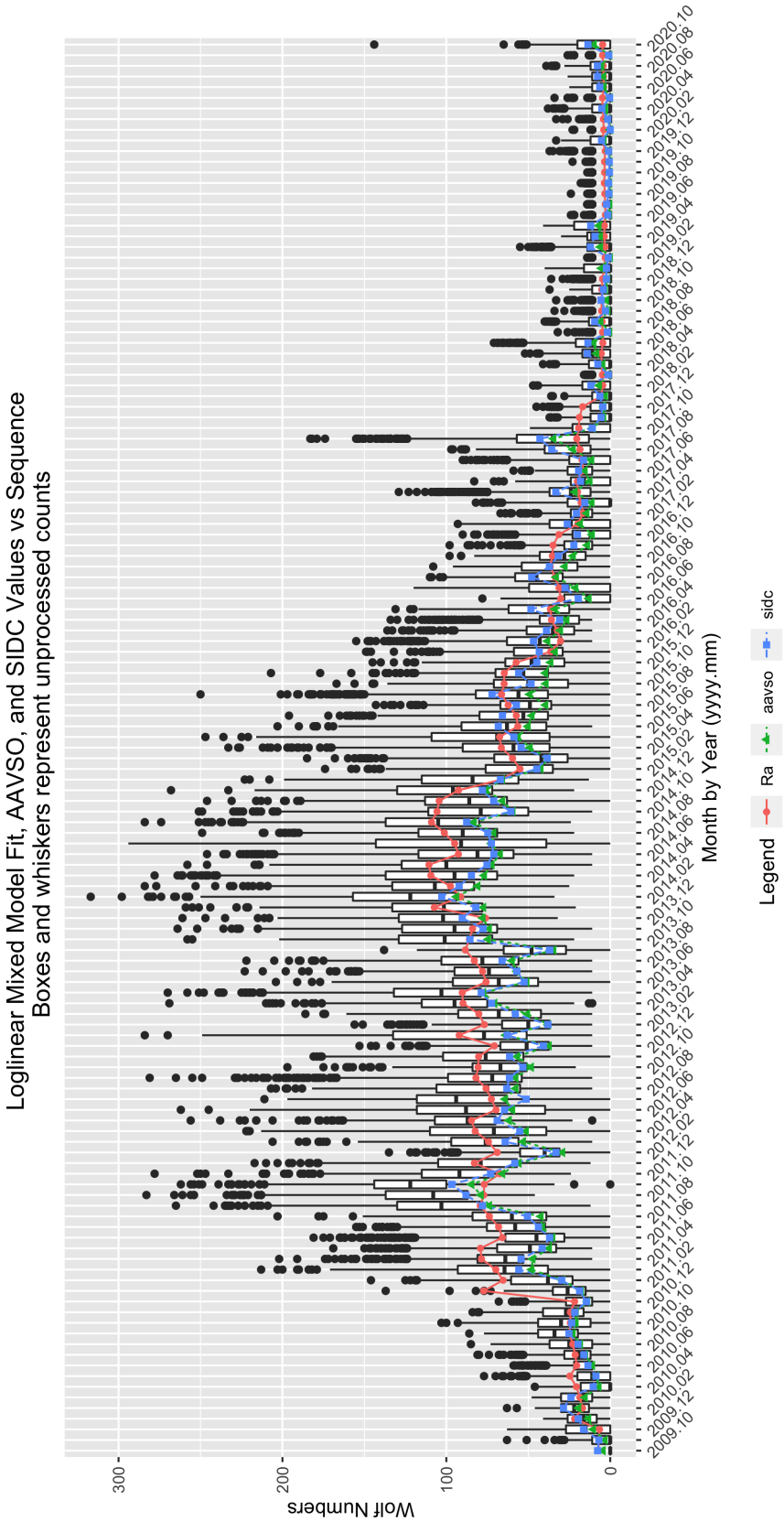


Figure 7: GLMM fitted data for $R_a$. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

# 4 Endnotes

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


Figure 8: I know that sometimes you like to add my sun's work in your bulletin, be sure that I appreciate that! Here I join the October AR2776 development. Michel Deconinck. (`https://astro.aquarellia.com`)