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 Finding the best model to fit the solar cycles

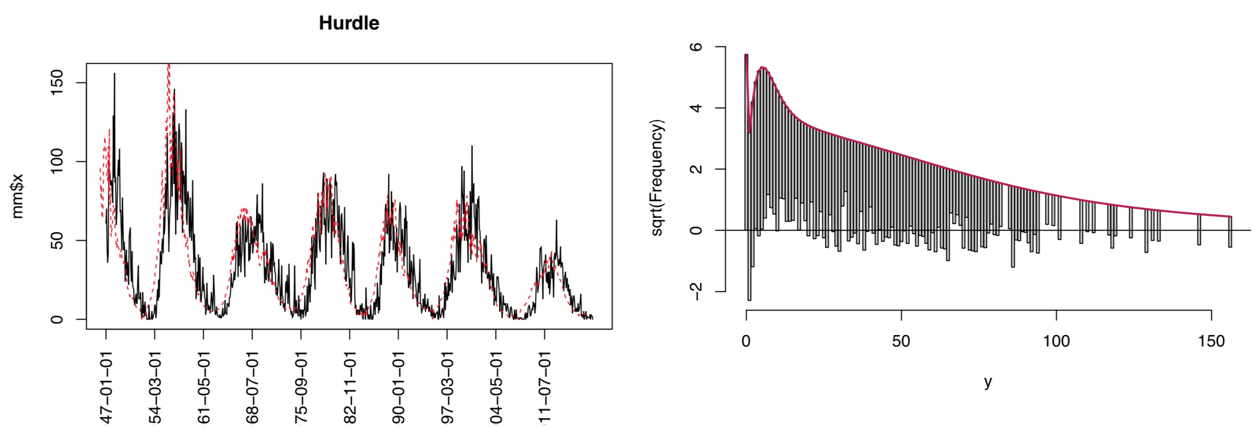

Figure 1, left: A Hurdle model with a negative binomial distribution forms a good fit to the last 7 solar cycles.

Figure 1, right: A negative binomial distribution and the Hurdle model in R (modeling by Mark Heiple) for sunspot distribution of all AAVSO solar cycle observations from 1947–2019, showing the density of sunspots (x-axis is sunspot counts; y-axis is the square root of the frequency or number of counts) (right). (Hurdle models, with example graphs, are described in detail in other publications, including at https://data.library.virginia.edu/getting-started-with-hurdle-models/). There are AAVSO monthly data posted on the AAVSO web site going back to 1947: https://www.aavso.org/sites/default/files/solar/NOAAfiles/NOAAmonthly.csv.

Fitted and original data is plotted, with the Rootogram function showing goodness of fit (red line)—underpredicting small count values and overpredicting larger counts (Figure 1).

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

Figure 2: The most active day in June was the 1st of the month, where there was one B-class flare recorded by GOES-15 XRA. However, nothing shows a SID event here in Fort Collins, Colorado. (Please note the y-axis values in these SID graphs are non-dimensional.)

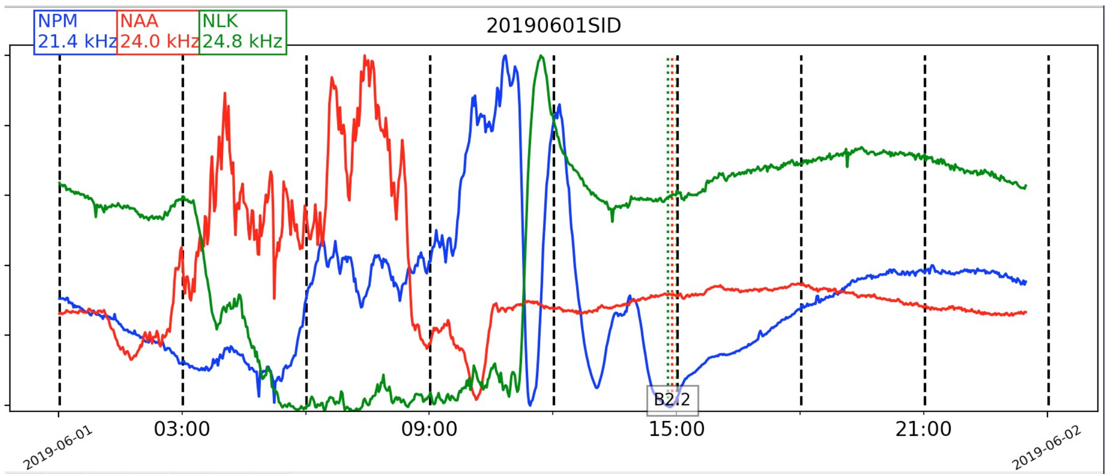

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In June 2019, 15 AAVSO SID observers submitted VLF data as listed in Table 1. Some observers recorded SID events this month, which matched to GOES-15 XRA and FLA events.

Table 1: 201905 VLF Observers

Observer	Code	Stations
S Hansen	A59	NAA
A McWilliams	A94	NML
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
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
G Silvis	A141	HWU NAU
R Rogge	A143	GQD
R Russel	A147	NPM
L Ferreira	A149	NWC

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.

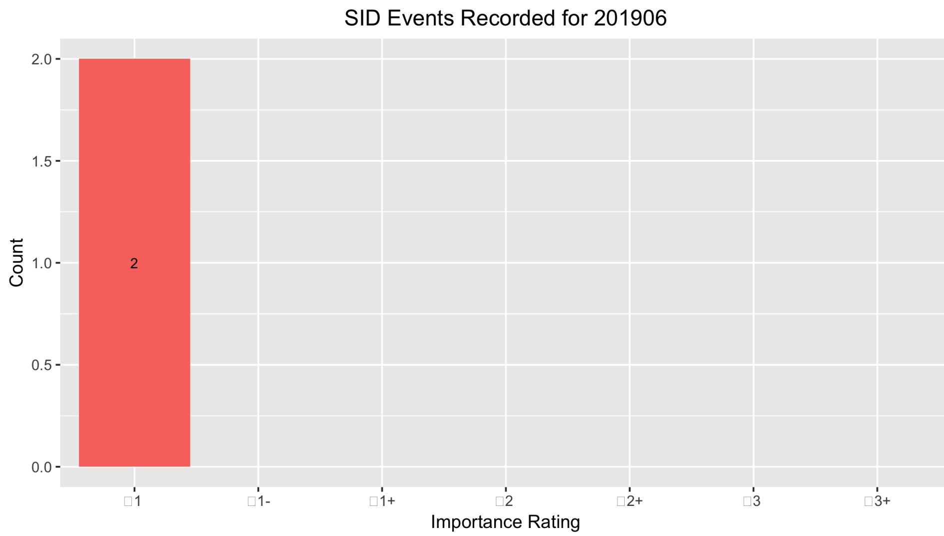

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-15 Data

In June 2019, there were three A-class and 1 B-class flares recorded from GOES-15. There were 25 days this month with no GOES-15 reports of flares (Figure 4); far less flaring compared to last month.

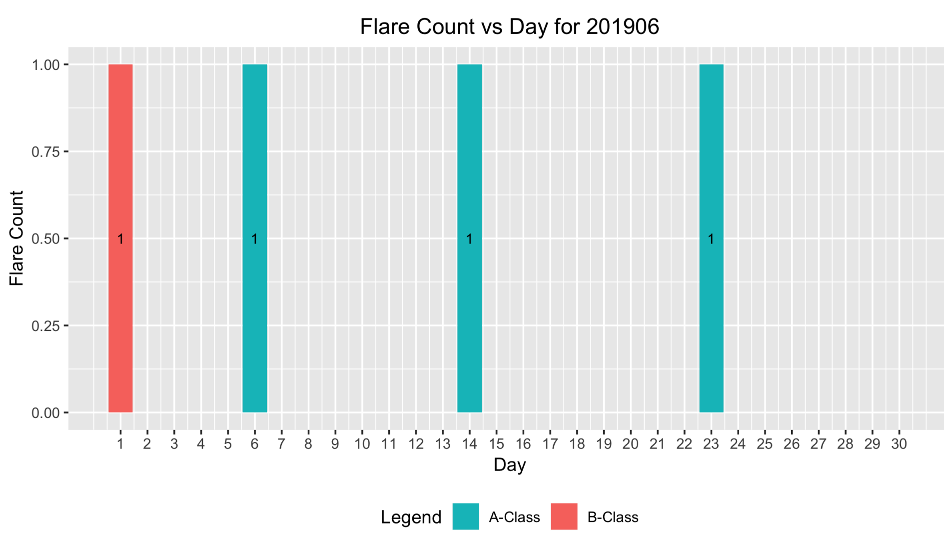

Figure 4: GOES-15 XRA flares

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 a 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 June 2019. 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.

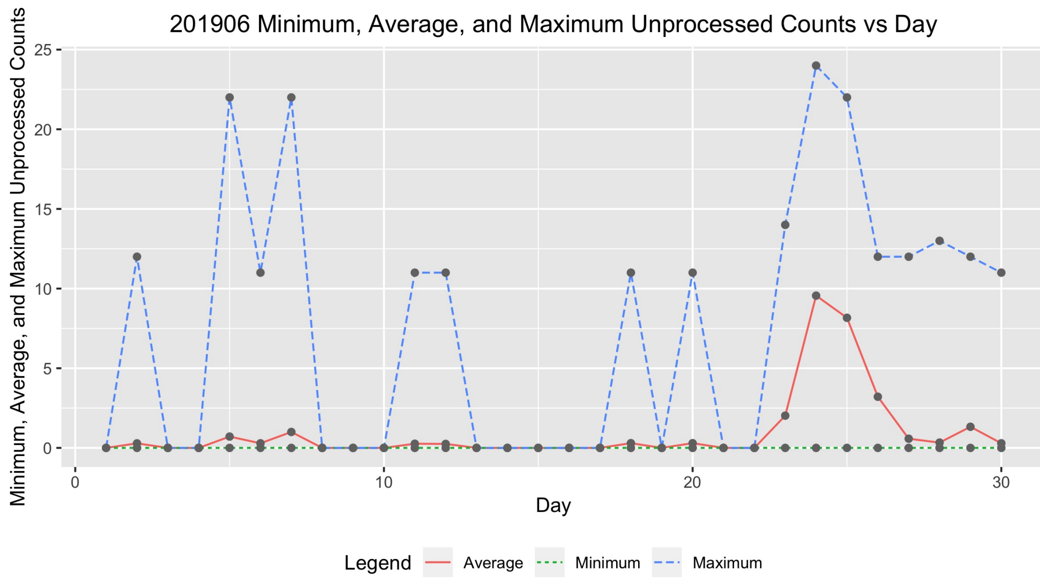

Figure 5: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

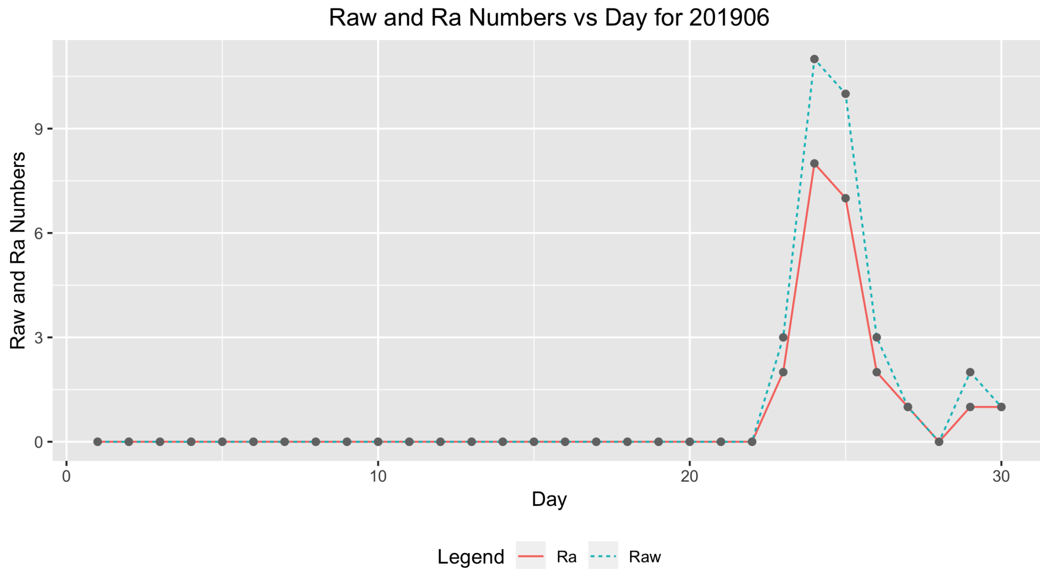

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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, and fixed effects, such as seeing condition. The raw Wolf averages and calculated R_a are shown in Figure 6. Table 2 shows the Day of the observation (column 1), the Number of Observers (column 2), the raw Wolf number (column 3), and the Shapley correction (R_a) (column 4).

Table 2: 201906 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	48	0	0
2	42	0	0
3	39	0	0
4	38	0	0
5	31	0	0
6	38	0	0
7	34	0	0
8	44	0	0
9	35	0	0
10	36	0	0
11	42	0	0
12	44	0	0
13	37	0	0
14	41	0	0

Continued

Table 2: 201906 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	39	0	0
16	38	0	0
17	41	0	0
18	37	0	0
19	38	0	0
20	37	0	0
21	39	0	0
22	43	0	0
23	41	3	2
24	43	11	8
25	42	10	7
26	38	3	2
27	40	1	1
28	39	0	0
29	43	2	1
30	38	1	1
Averages	39.5	1	0.7

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations submitted for June 2019 (column 2), and the Observer Name (column 3). The final rows of the table give the total number of observers who submitted sunspot counts and the total number of observations submitted. The total number of observers is 60 and the total number of observations is 1,185.

Table 3: 201906 Number of Observations by Observer.

Observer Code	Number of Observations	Observer Name
AAX	22	Alexandre Amorim
AJV	15	J. Alonso
ARAG	30	Gema Araujo
ASA	26	Salvador Aguirre
ATE	19	Teofilo Arranz Heras
BARH	16	Howard Barnes
BATR	8	Roberto Battaiola
BERJ	28	Jose Alberto Berdejo
BMF	19	Michael Boschat
BRAF	22	Raffaello Braga
BROB	29	Robert Brown
BSAB	26	Santanu Basu
CHAG	26	German Chavez Morales

Continued

Table 3: 201906 Number of Observations by Observer.

Observer Code	Number of Observations	Observer Name
CKB	24	Brian Cudnik
CNT	11	Dean Chantiles
DEMF	2	Frank Dempsey
DIVA	25	Ivo Demeulenaere
DJOB	10	Jorge del Rosario
DMIB	22	Michel Deconinck
DROB	15	Bob Dudley
DUBF	30	Franky Dubois
EHOA	6	Howard Eskildsen
ERB	20	Bob Eramia
FERJ	19	Javier Ruiz Fernandez
FLET	25	Tom Fleming
FLF	10	Fredirico Luiz Funari
FUJK	19	K. Fujimori
HAYK	21	Kim Hay
HMQ	4	Mark Harris
HOWR	23	Rodney Howe
HRUT	29	Timothy Hrutkay
JDAC	13	David Jackson
JENS	4	Simon Jenner
JGE	3	Gerardo Jiménez López
KAND	26	Kandilli Observatory
KAPJ	27	John Kaplan
KNJS	30	James & Shirley Knight
KROL	15	Larry Krozel
LEVM	19	Monty Leventhal
LKR	6	Kristine Larsen
LRRA	18	Robert Little
MARC	19	Arnaud Mengus
MCE	19	Etsuiku Mochizuki
MILJ	20	Jay Miller
MJHA	27	John McCammon
MUDG	15	George Mudry
MWU	23	Walter Maluf
OAAA	29	Al Sadeem Astronomy Observatory
ONJ	19	John O’Neill
SDOH	30	Solar Dynamics Observatory- HMI
SMNA	7	Michael Stephanou
SNE	9	Neil Simmons
STAB	30	Brian Gordon-States
SUZM	23	Miyoshi Suzuki
TESD	29	David Teske
TST	25	Steven Toothman

Continued

Table 3: 201906 Number of Observations by Observer.

Observer Code	Number of Observations	Observer Name
URBP	30	Piotr Urbanski
VARG	30	A. Gonzalo Vargas
VIDD	12	Daniel Vidican
WILW	27	William M. Wilson
Totals	1,185	60

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 (Section 3). 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 a paper, *A Generalized Linear Mixed Model for Enumerated Sunspots,* (GLMM05) on http://www.spesi.org/?page id=65 of the sunspot counts research page.

The monthly GLMM R_a numbers are provided for the 24th solar cycle to date (Figure 7). 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 25th through the 75th quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25th quartile, and 1.5 times the IQR above the 75th quartile. The black dots below and above the whiskers are traditionally considered outliers, but with GLMM modeling, they are observations that are accounted for by the GLMM model.

4 Endnotes

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

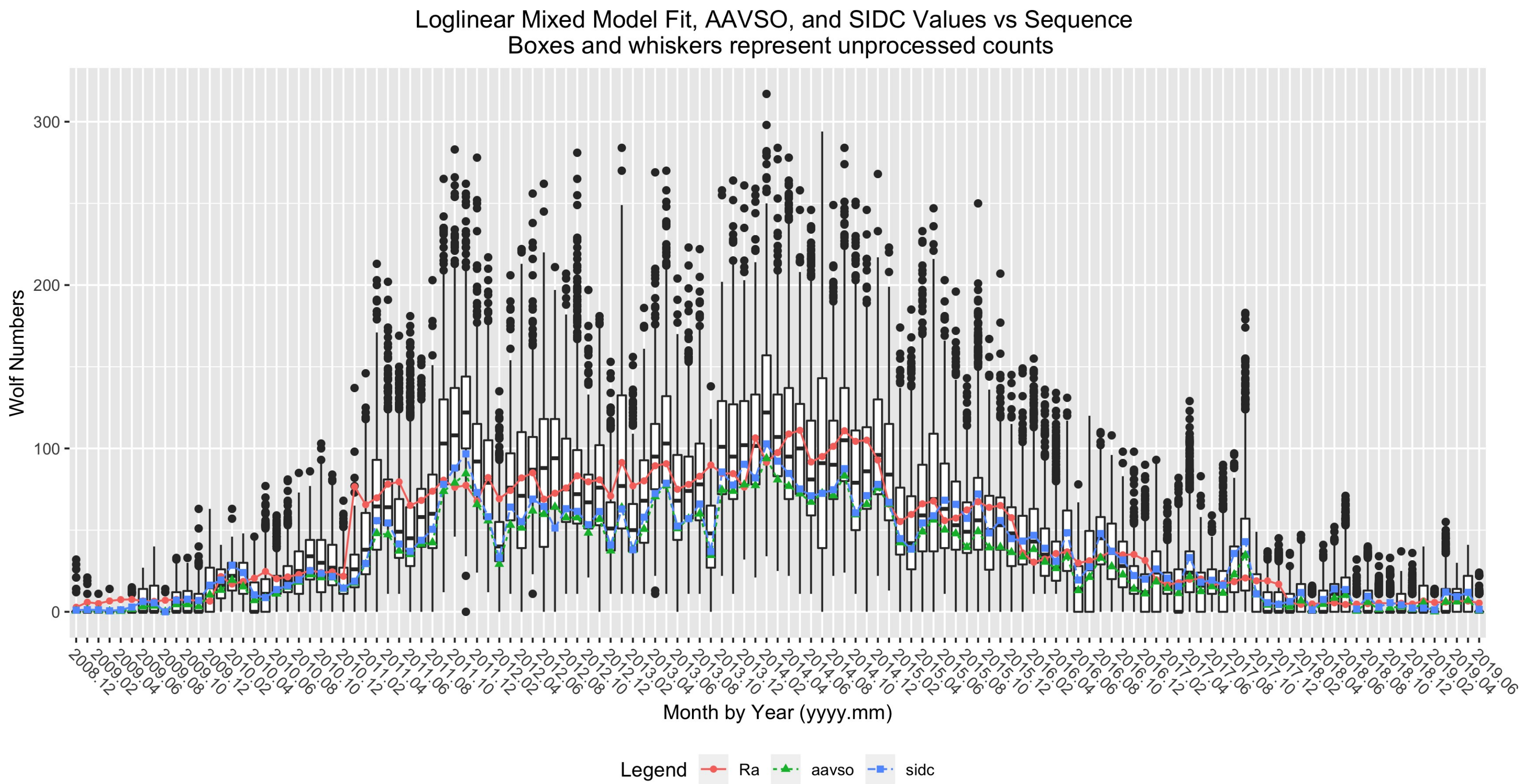

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels.