Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

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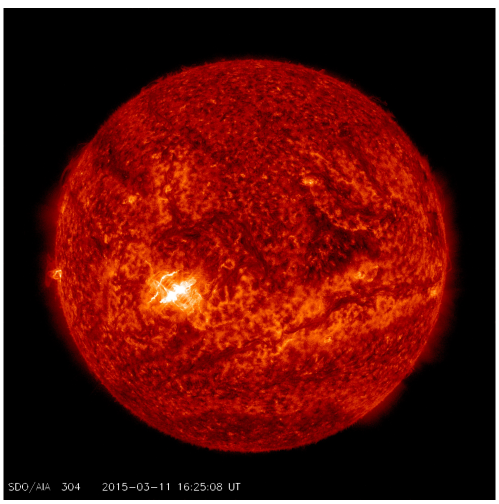
The Solar Bulletin of the AAVSO is a summary of each month's solar activity recorded by visual solar observers' counts of group and sunspots, and the VLF radio recordings of SID Events in the ionosphere. Section 1 gives contributions by our members. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 How a X2 class flare affected the magnetic aa index on Earth and SDO satellite data on March 15, 2015.



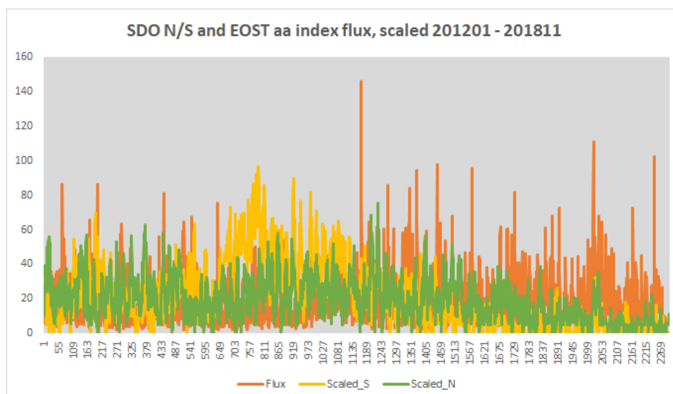


Figure 1: These EOST magnetic aa flux data go back to 1868! (`http://isgi.unistra.fr`) That spike in mid graph (right panel) was from the X-flare of March 11, 2015 (left image) when a CME propelled into space by the explosion hit Earth's magnetic field on Sunday March 15, 2015, and from then on the north and south SDO hemisphere data cross over (lower values), and the aa index observations here on Earth had higher values than the SDO Wolf numbers for each solar hemisphere. (These are scaled data and so are normalized to the be visible on the graph.)

For further reading on the X2 flare go to spaceweather.com: (`http://spaceweather.com/archive.php?view=1&day=15&month=03&year=2015`) and SDO data from Jan Alvestad (SDOH) (`https://www.solen.info/solar/`)

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

December 2018 (Figure 2): There was one B class flare on the 5th of December recorded here Fort Collins, CO. However, these weak B class flares do not affect the D Layer (daytime) ionosphere and no SID event was detected.

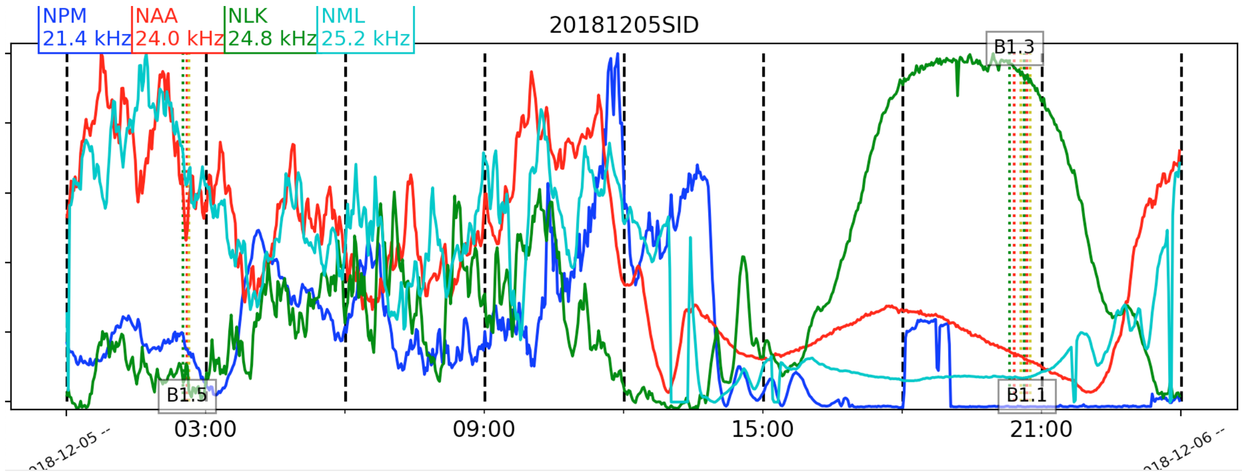


Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In December 2018 we had 17 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 201812 VLF Observers

Observer	Code	Stations
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	NAA
G Meyers	A124	NPM
S Oatney	A125	NML NLK NAA
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
G Silvis	A141	NLK
I Ryumshin	A142	GQD DHO
R Rogge	A143	GQD
K Menzies	A146	NAA
R Russel	A147	NPM

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.

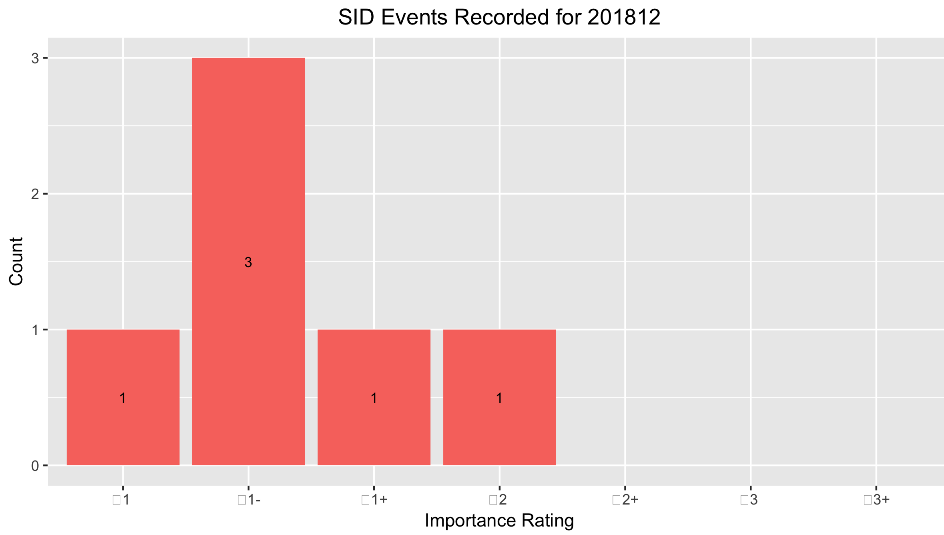


Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-15 Data

In December 2018, there were 13 solar flares measured by GOES-15: Five A class and 8 B class flares. More flaring this month compared to last month. There were 22 days this month with no GOES-15 reports of flares. (see Figure 4).

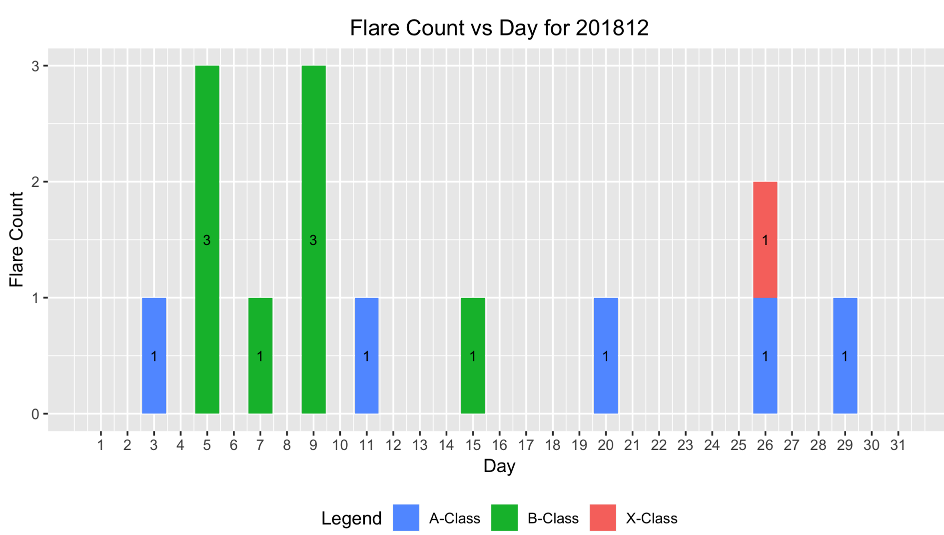


Figure 4: GOES - 15 XRA flares

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 December 2018. These counts are reported by the day of the month, and are either from data not scrubbed or corrected data.

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.

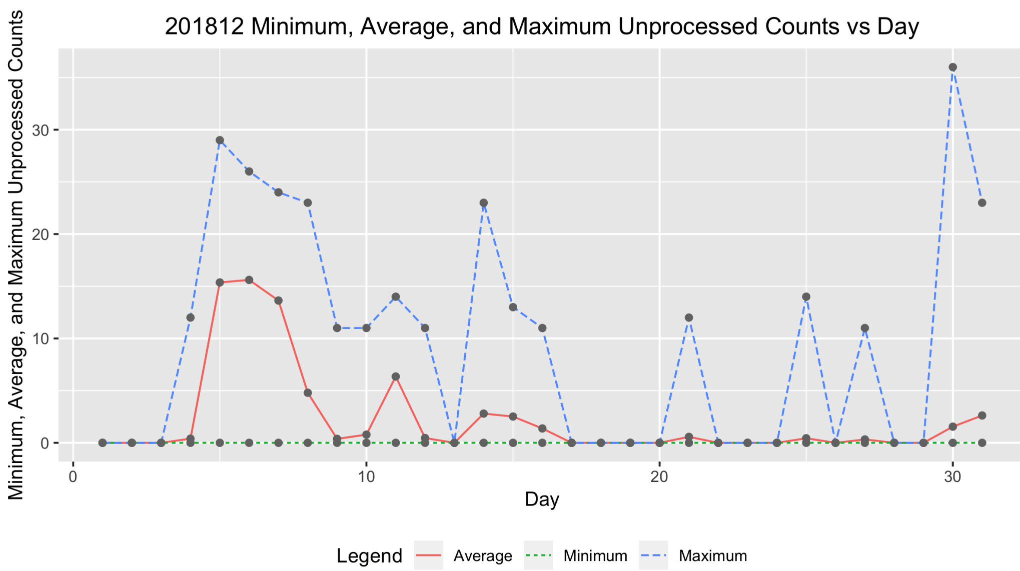


Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

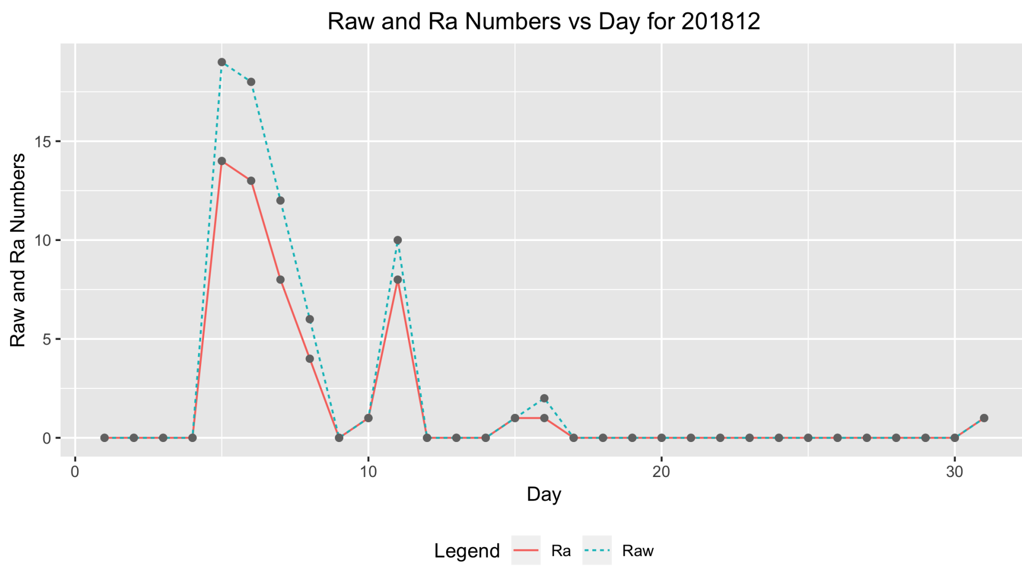


Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 seen in Figure 6 and Table 2 shows the Day (column 1) of the observation, the Number of Observations is in column 2, the raw Wolf number is in column 3, and the Shapley correction (R_a) is in column 4.

Table 2: 201812 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	30	0	0
2	32	0	0
3	30	0	0
4	30	0	0
5	30	19	14
6	23	18	13
7	30	12	8
8	34	6	4
9	29	0	0
10	28	1	1
11	34	10	8
12	24	0	0
13	24	0	0
14	25	0	0
15	29	1	1

Continued

Table 2: 201812 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	32	2	1
17	33	0	0
18	27	0	0
19	29	0	0
20	25	0	0
21	21	0	0
22	32	0	0
23	28	0	0
24	32	0	0
25	32	0	0
26	28	0	0
27	34	0	0
28	31	0	0
29	39	0	0
30	31	0	0
31	34	1	1
Averages	29.7	2.3	1.6

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 2018, 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 64 and the total number of observations is 920.

Table 3: 201812 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
AAX	24	Alexandre Amorim
AJV	20	J. Alonso
ARAG	24	Gema Araujo
ASA	25	Salvador Aguirre
ATE	20	Teofilo Arranz Heras
BARH	12	Howard Barnes
BATR	4	Roberto Battaiola
BERJ	23	Jose Alberto Berdejo
BLAJ	2	John A. Blackwell
BMF	24	Michael Boschat
BRAD	23	David Branchett
BRAF	10	Raffaello Braga
BROB	16	Robert Brown
BSAB	27	Santanu Basu

Continued

Table 3: 201812 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
CHAG	22	German Morales Chavez
CIOA	6	Ioannis Chouinavas
CKB	16	Brian Cudnik
CNT	18	Dean Chantiles
CVJ	5	Jose Carvajal
DEMF	3	Frank Dempsey
DIVA	15	Ivo Demeulenaere
DJOB	9	Jorge del Rosario
DMIB	21	Michel Deconinck
DROB	2	Bob Dudley
DUBF	22	Franky Dubois
EHOA	20	Howard Eskildsen
ERB	7	Bob Eramia
FERJ	17	Javier Ruiz Fernandez
FLET	18	Tom Fleming
FLF	11	Fredirico Luiz Funari
FTAA	1	Tadeusz Figiel
FUJK	22	K. Fujimori
HAYK	9	Kim Hay
HMQ	6	Mark Harris
HOWR	21	Rodney Howe
JDAC	8	David Jackson
JGE	6	Gerardo Jimenez Lopez
KAND	13	Kandilli Observatory
KAPJ	7	John Kaplan
KNJS	31	James & Shirley Knight
KROL	23	Larry Krozel
LEVM	22	Monty Leventhal
LKR	1	Kristine Larsen
MARE	8	Enrico Mariani
MCE	24	Etsuiku Mochizuki
MILJ	11	Jay Miller
MJAF	30	Juan Antonio Moreno Quesada
MJHA	29	John McCammon
MUDG	4	George Mudry
MWU	20	Walter Maluf
OATS	1	Susan Oatney
ONJ	1	John O'Neill
RLM	6	Mat Raymonde
SDOH	31	Solar Dynamics Obs - HMI
SNE	3	Neil Simmons
STAB	18	Brian Gordon-States
SUZM	22	Miyoshi Suzuki

Continued

Table 3: 201812 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
TESD	19	David Teske
TPJB	1	Patrick Thibault
TST	2	Steven Toothman
URBP	9	Piotr Urbanski
VARG	28	A. Gonzalo Vargas
VIDD	4	Daniel Vidican
WILW	13	William M. Wilson
Totals	920	64

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 a paper (GLMM05) on http://www.spesi.org/?page_id=65 of the sunspot counts research page. The paper title is *A Generalized Linear Mixed Model for Enumerated Sunspots*.

Figure 7 shows the monthly GLMM R_a numbers for the 24th solar cycle to date. 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.

4 Endnotes

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

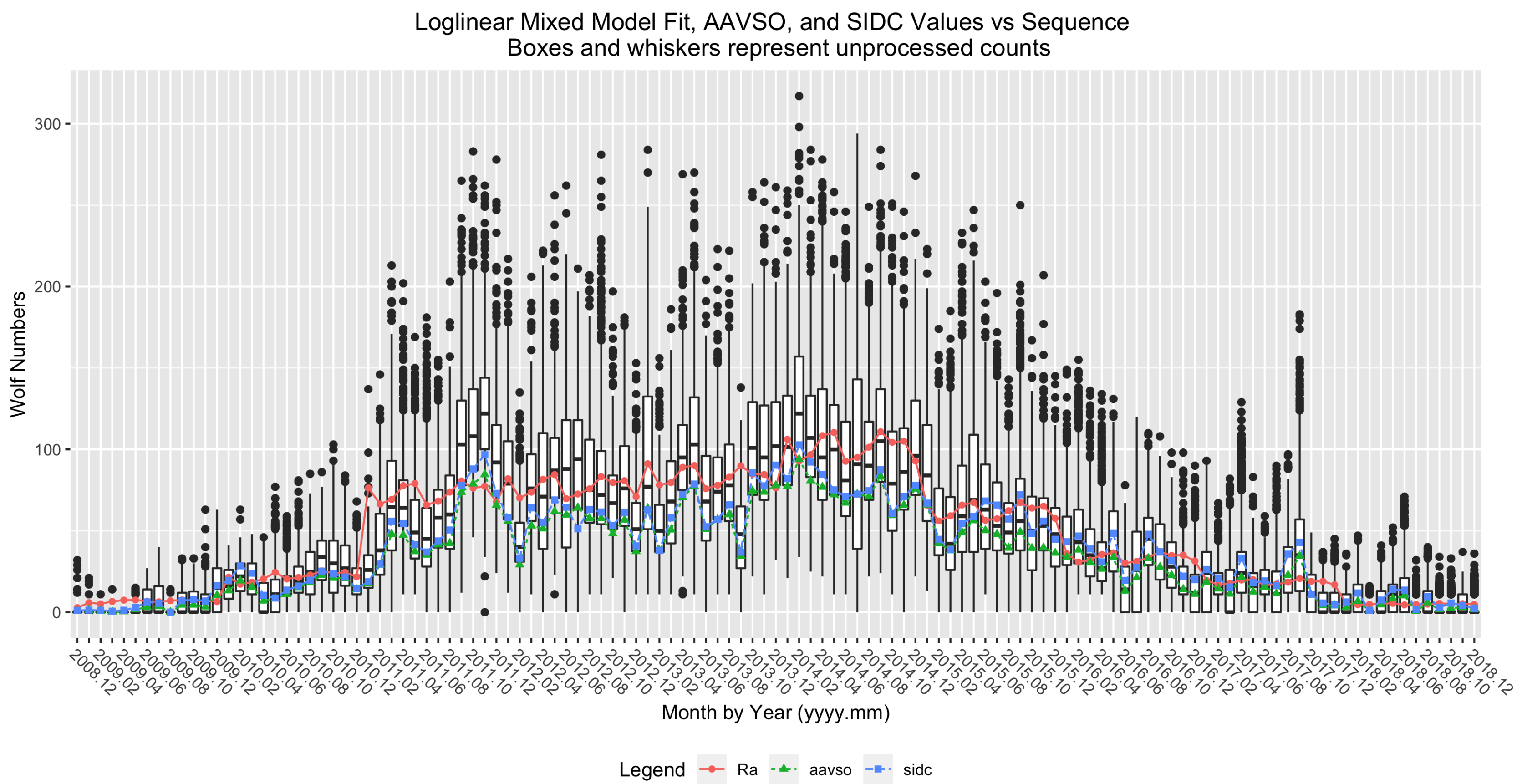


Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels