Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

Rodney Howe, Editor, Chair
c/o AAVSO, 49 Bay State Rd
Cambridge, MA 02138 USA

Web: http://www.aavso.org/solar-bulletin
Email: solar@aavso.org
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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 Looking at the sun with infrared H, J band photometer - SSP-4

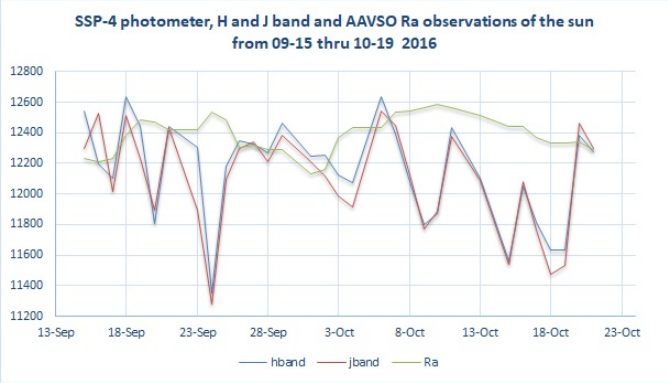

Figure 1: (left) A month of H and J band data collected with the SSP-4 photometer from Optec. (right) Myself lining up the Lunt 60 mm tilt-etalon solar scope with the SSP-4 photometer at the eyepiece.

Information about the SSP-4: (`http://www.optecinc.com`) The J band covers approximately 1300 nm and the H band at 1600 nm in the near infrared which may distinguish plasma motion of the solar disc if we can discriminate against the telluric contamination of the Earths atmosphere (`https://en.wikipedia.org/wiki/Telluric_contamination`). The SSP-4 uses an InGaAs diode the size of the reticle (roughly covering the IR frequencies from 1000 to 1800 nm), and the H band covers the spectral Fe I line at 1565 nm (Penn, M. J., 2008). So, what we may be seeing are fluctuations in Fe I emissions of IR very close to the surface of the sun. Notice how these H and J data compare to the visual observers Ra index of observations during this somewhat active time in 2016 (check the graph on the last page for these months) .

Penn, M. J., 2008: (`https://www.semanticscholar.org/paper/Infrared-Solar-Physics-Penn/e2d269a5eafe0a22694f17bf27c3eeb4155a4d62`)

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

September 2019 (Figure 2): There were no SID events recorded here in Fort Collins, Colorado for the month of September. (Please note the y-axis values in these SID graphs are non-dimensional.)

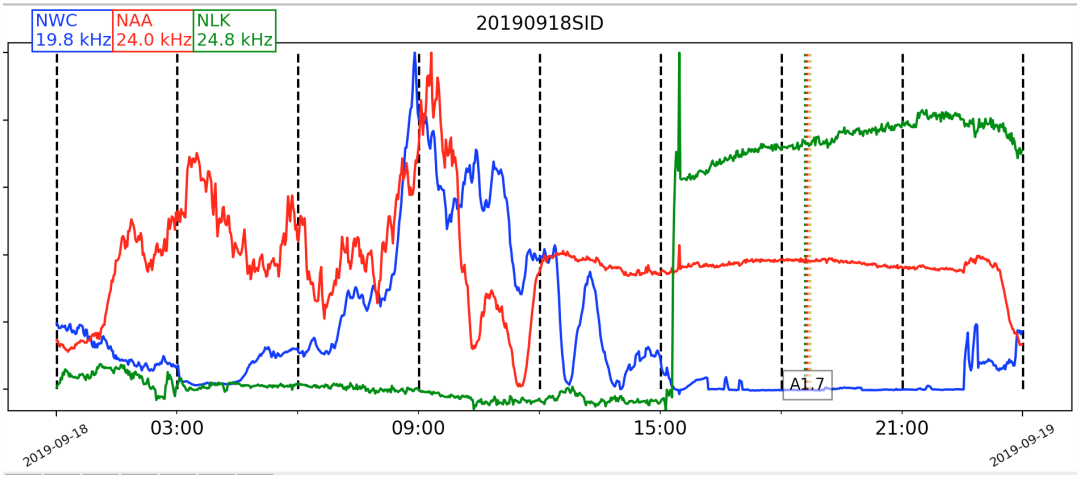

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In September 2019 we had 16 AAVSO SID observers who submitted VLF data as listed in Table 1. There were no observers who recorded SID events this month, which matched to GOES-15 XRA and FLA events.

Table 1: 201909 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	NWC
G Meyers	A124	NPM
S Oatney	A125	NML NLK NAA
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
R Rogge	A143	GQD
K Menzies	A146	NAA
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.

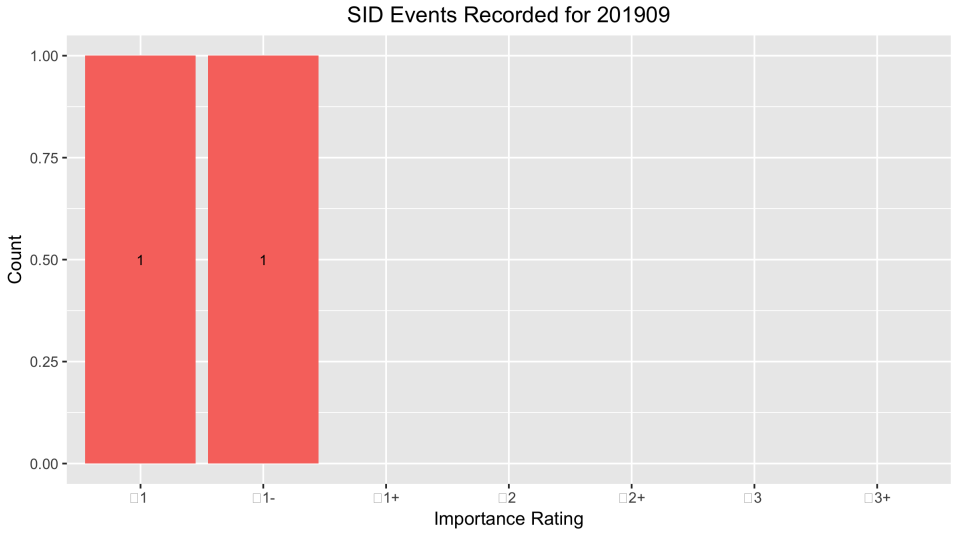

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-15 Data

In September 2019, there were two A class flares recorded from GOES-15. Even less flaring this month compared to last. There were 28 days this month with no GOES-15 reports of flares. (see Figure 4).

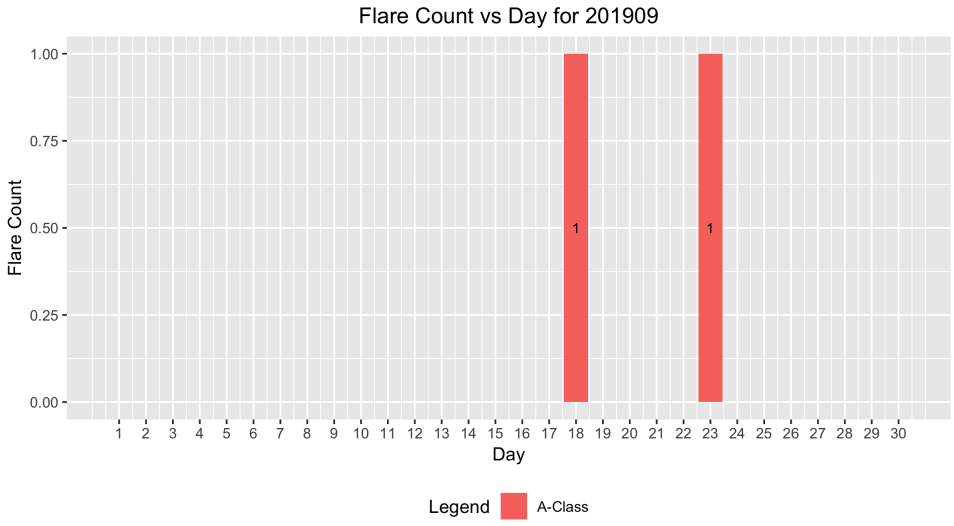

Figure 4: GOES - 15 XRA flares

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 September 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.

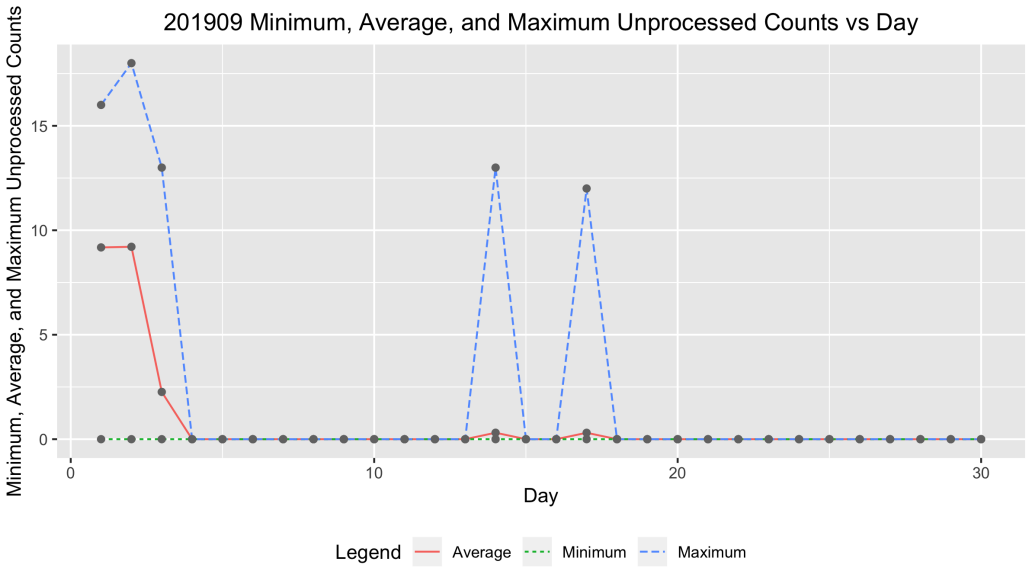

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

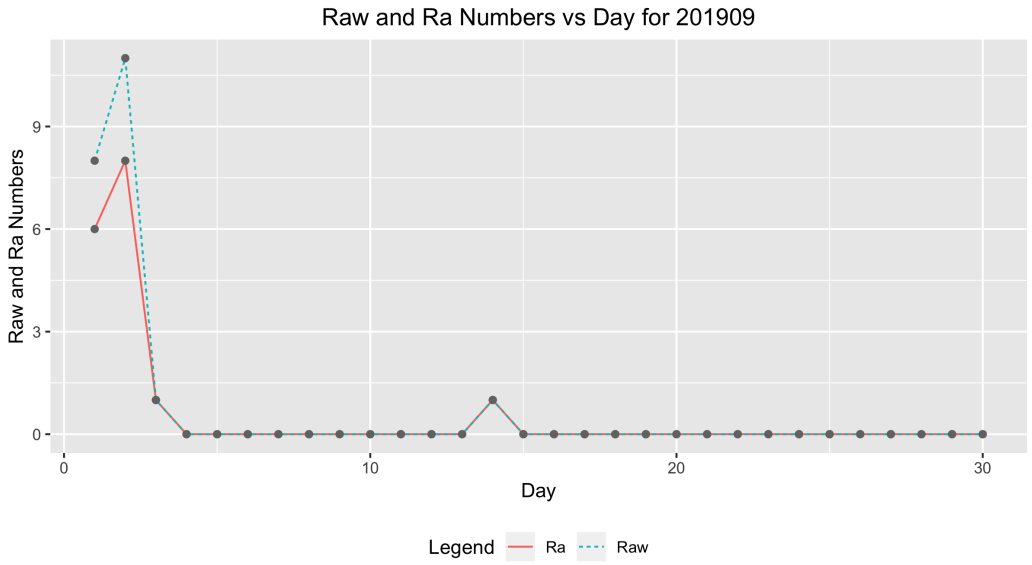

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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: 201909 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	39	8	6
2	43	11	8
3	42	1	1
4	38	0	0
5	38	0	0
6	40	0	0
7	47	0	0
8	46	0	0
9	43	0	0
10	40	0	0
11	38	0	0
12	45	0	0
13	38	0	0
14	42	1	1

Continued

Table 2: 201909 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	42	0	0
16	34	0	0
17	39	0	0
18	43	0	0
19	45	0	0
20	41	0	0
21	36	0	0
22	36	0	0
23	39	0	0
24	32	0	0
25	37	0	0
26	38	0	0
27	42	0	0
28	43	0	0
29	45	0	0
30	41	0	0
Averages	40.4	0.7	0.5

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for September 2019, 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 1212.

Table 3: 201909 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
AAX	13	Alexandre Amorim
AJV	23	J. Alonso
ARAG	30	Gema Araujo
ASA	24	Salvador Aguirre
ATE	26	Teofilo Arranz Heras
BARH	13	Howard Barnes
BERJ	29	Jose Alberto Berdejo
BMF	26	Michael Boschat
BRAF	26	Raffaello Braga
BROB	28	Robert Brown
BSAB	24	Santanu Basu
CHAG	28	German Morales Chavez
CKB	23	Brian Cudnik

Continued

Table 3: 201909 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
CNT	24	Dean Chantiles
CVJ	19	Jose Carvajal
DEMF	9	Frank Dempsey
DIVA	20	Ivo Demeulenaere
DJOB	19	Jorge del Rosario
DMIB	28	Michel Deconinck
DUBF	23	Franky Dubois
EHOA	7	Howard Eskildsen
ERB	18	Bob Eramia
FERJ	14	Javier Ruiz Fernandez
FLET	28	Tom Fleming
FLF	4	Fredirico Luiz Funari
FUJK	23	K. Fujimori
HAYK	21	Kim Hay
HMQ	19	Mark Harris
HOWR	28	Rodney Howe
HRUT	21	Timothy Hrutkay
JENS	5	Simon Jenner
JGE	5	Gerardo Jimenez Lopez
KAND	29	Kandilli Observatory
KAPJ	14	John Kaplan
KNJS	30	James & Shirley Knight
KROL	26	Larry Krozel
LEVM	18	Monty Leventhal
LGEC	7	Georgios Lekkas
LKR	10	Kristine Larsen
LRRA	3	Robert Little
MARC	15	Arnaud Mengus
MCE	24	Etsuiku Mochizuki
MILJ	15	Jay Miller
MJAF	22	Juan Antonio Moreno Quesada
MJHA	30	John McCammon
MUDG	11	George Mudry
MWU	19	Walter Maluf
OAAA	23	Al Sadeem Astronomy Observatory
ONJ	21	John O'Neill
SDOH	30	Solar Dynamics Obs - HMI
SNE	4	Neil Simmons
SONA	17	Andries Son
STAB	28	Brian Gordon-States
SUZM	24	Miyoshi Suzuki
TESD	30	David Teske
TST	22	Steven Toothman

Continued

Table 3: 201909 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
URBP	24	Piotr Urbanski
VARG	29	A. Gonzalo Vargas
VIDD	10	Daniel Vidican
WILW	29	William M. Wilson
Totals	1212	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 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

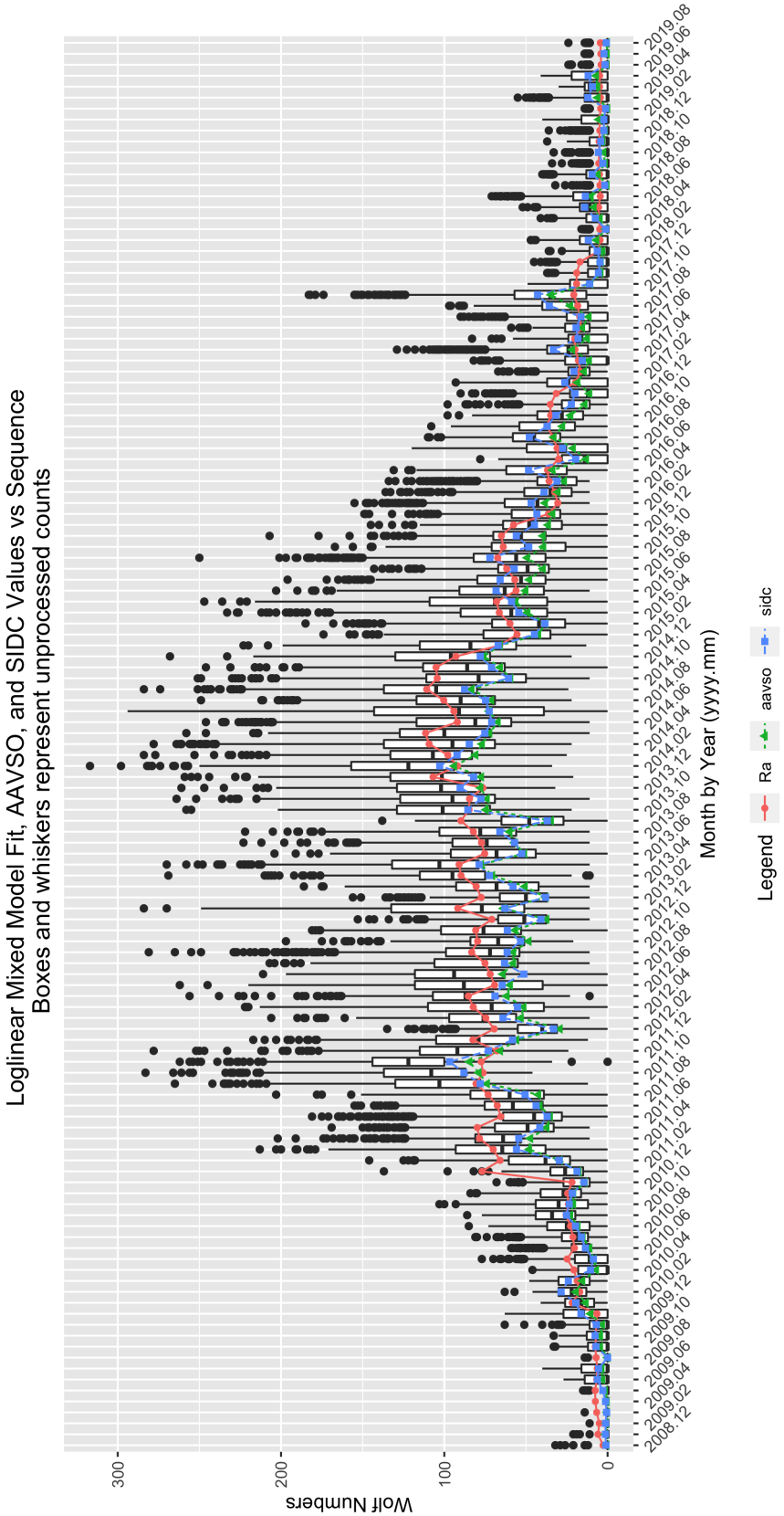

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels