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 does the Total Electron Count (TEC) affect the VLF signals over the South Atlantic Magnetic Anomaly (SAMA)?

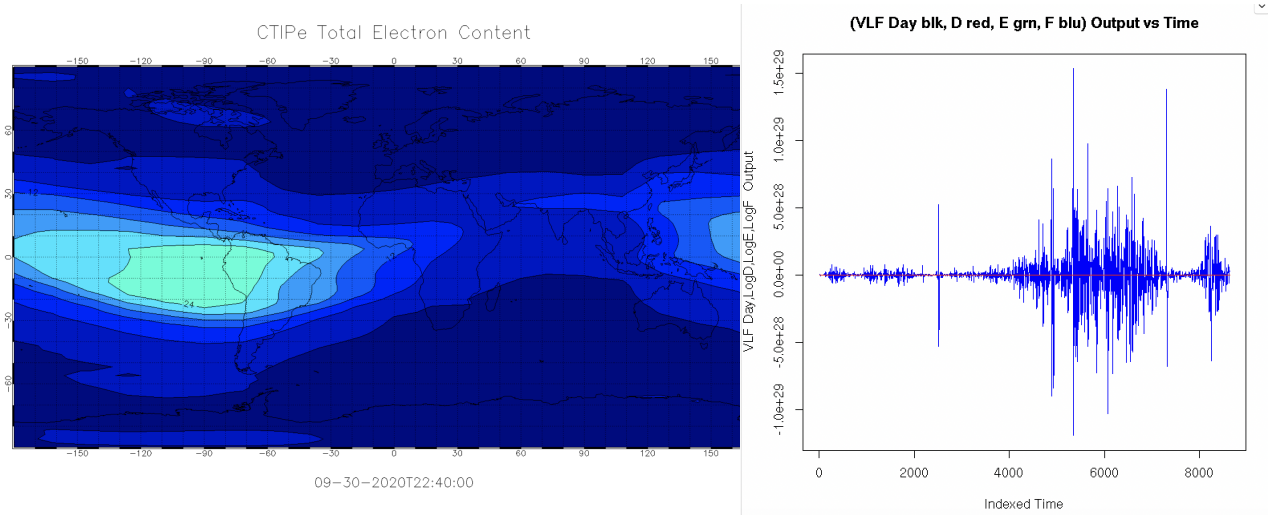

Figure 1: (left) CTIPE from NOAA shows the TEC crosses westward over the Atlantic during the day time where the Van Allen belt precipitates electrons into the ionosphere, (right) the VLF model shows the estimates of a daytime TEC which affects the F layer (blue) of the ionosphere causing a disruption of the VLF daytime signals from Naval transmitters.

VLF observers who live in South America have been trying for years to record consistent Naval transmissions from distant stations. It seems the TEC drifts from Africa to South America over the SAMA on a daily basis because of the Earth's weak magnetic field under the Atlantic Ocean. The weak magnetic field causes electron precipitation to occur from the Van Allen belt, especially when there is a strong solar wind. Looking at the VLF day-time signal, right graph, when SID events occur during the day, shows a strong influence of TEC in the ionosphere. (`https://www.swpc.noaa.gov/products/ctipe-total-electron-content-forecast`). Further reading on the SAMA: (`https://en.wikipedia.org/wiki/South_Atlantic_Anomaly`)

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

September 2020 (Figure 2): There were no SID Events recorded here in Fort Collins, Colorado, even for the most active day, on the 21 of September. (Please note the y-axis values in these SID graphs are non-dimensional.)

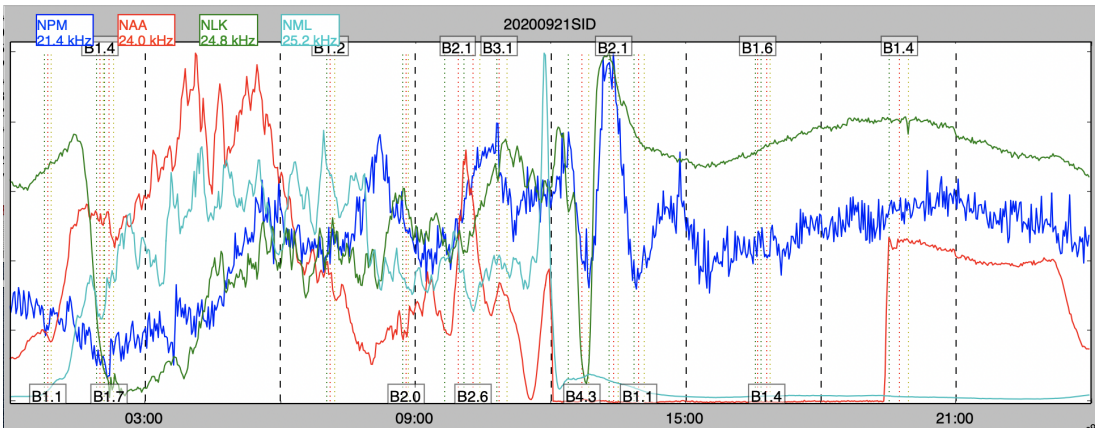

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In September 2020 we had 11 AAVSO SID observers who submitted VLF data as listed in Table 1. There was one C.1 class SID Event observation recorded on the 25th of September by our folks in Europe which matched to GOES-16 XRA event.

Table 1: 202009 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO GBZ
J Godet	A119	GBZ
F Adamson	A122	NWC
S Aguirre	A138	NPM
R Rogge	A143	GQD
K Menzies	A146	NAA
R Russel	A147	NPM
L Pina	A148	NML
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.

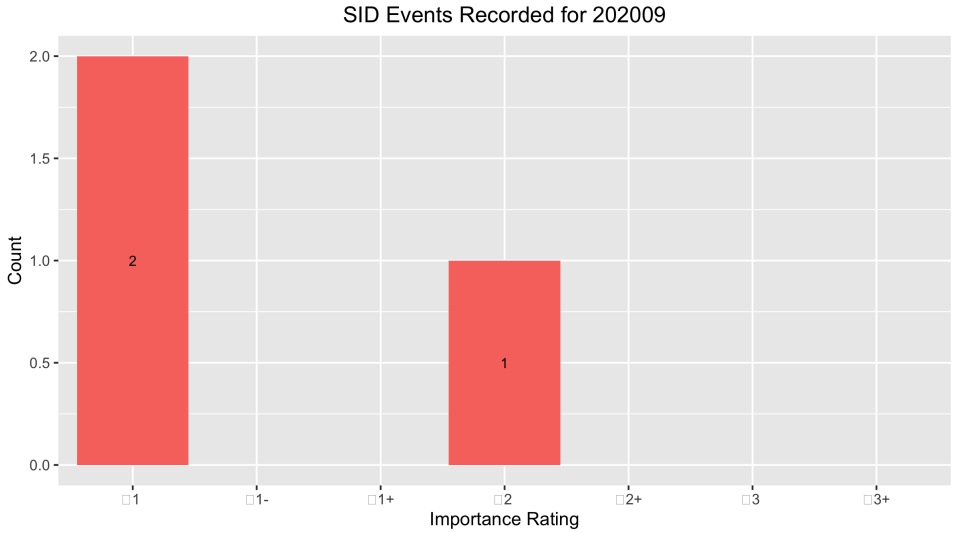

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In September 2020, There were 20 GOES-16 XRA flares this month, 19 B-class and one C-class flare for September 2020. Far more flaring compared to last month. There were 25 days this month with no GOES-16 reports of flares (see Figure 4).

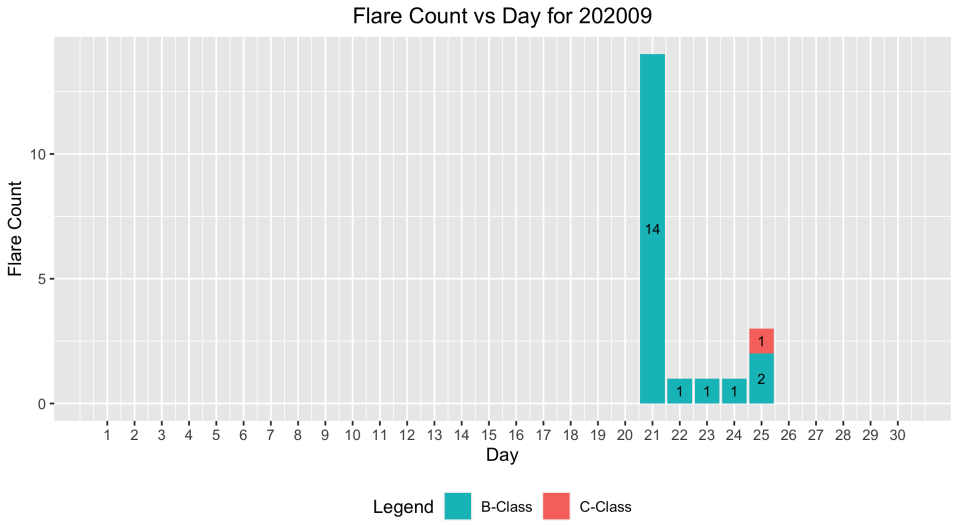

Figure 4: GOES-16 XRA flares

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 September 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.

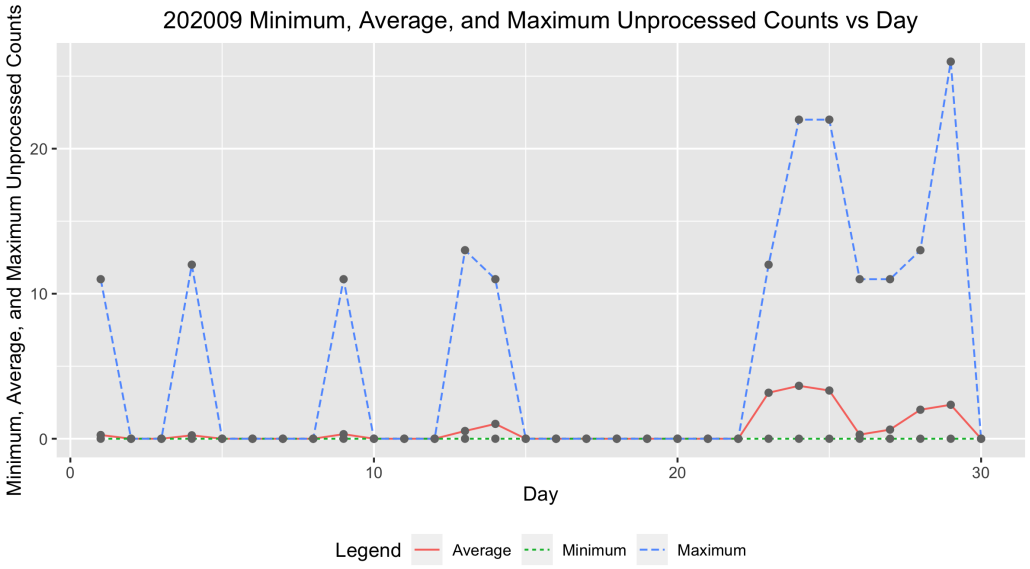

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

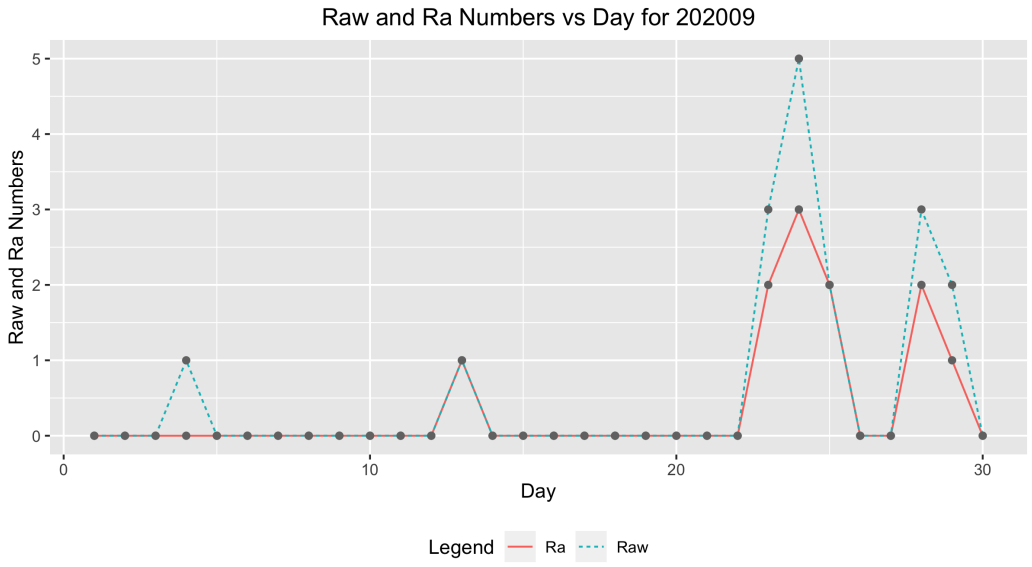

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202009 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	43	0	0
2	49	0	0
3	46	0	0
4	51	1	0
5	50	0	0
6	53	0	0
7	44	0	0
8	43	0	0
9	35	0	0
10	40	0	0
11	45	0	0
12	43	0	0
13	45	1	1
14	43	0	0

Continued

Table 2: 202009 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	51	0	0
16	44	0	0
17	40	0	0
18	42	0	0
19	45	0	0
20	45	0	0
21	43	0	0
22	41	0	0
23	35	3	2
24	37	5	3
25	37	2	2
26	39	0	0
27	35	0	0
28	37	3	2
29	41	2	1
30	46	0	0
Averages	42.9	0.6	0.4

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for September 2020, and the Observer Name (column 3). The final rows of the table give the total number of observers who submitted sunspot counts (68), and the total number of observations submitted (1288).

Table 3: 202009 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	14	Alexandre Amorim
AJV	16	J. Alonso
ARAG	30	Gema Araujo
ASA	28	Salvador Aguirre
ATE	29	Teofilo Arranz Heras
BARH	11	Howard Barnes
BATR	11	Roberto Battaiola
BERJ	28	Jose Alberto Berdejo
BLAJ	22	John A. Blackwell
BMF	24	Michael Boschat
BRAF	21	Raffaello Braga
BROB	24	Robert Brown
CHAG	26	German Morales Chavez

Continued

Table 3: 202009 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CIOA	20	Ioannis Chouinavas
CKB	19	Brian Cudnik
CNT	29	Dean Chantiles
CVJ	17	Jose Carvajal
DEMF	10	Frank Dempsey
DIVA	20	Ivo Demeulenaere
DJOB	17	Jorge del Rosario
DMIB	28	Michel Deconinck
DROB	3	Bob Dudley
DUBF	27	Franky Dubois
EHOA	11	Howard Eskildsen
ERB	19	Bob Eramia
FERJ	12	Javier Ruiz Fernandez
FLET	22	Tom Fleming
FUJK	20	K. Fujimori
GIGA	27	Igor Grgeda Mndez
HALB	15	Brian Halls
HAYK	23	Kim Hay
HMQ	22	Mark Harris
HOWR	22	Rodney Howe
IEWA	21	Earnest. W. Iverson
JENS	11	Simon Jenner
JGE	3	Gerardo Jimenez Lopez
KAND	14	Kandilli Observatory
KAPJ	15	John Kaplan
KNJS	30	James & Shirley Knight
LEVM	19	Monty Leventhal
LGEC	12	Georgios Lekkas
LKR	2	Kristine Larsen
LRRA	14	Robert Little
MARC	12	Arnaud Mengus
MARE	7	Enrico Mariani
MCE	20	Etsuiku Mochizuki
MILJ	19	Jay Miller
MJAF	26	Juan Antonio Moreno Quesada
MJHA	28	John McCammon
MUDG	11	George Mudry
MWU	26	Walter Maluf
OAAA	25	Al Sadeem Astronomy Observatory
ONJ	19	John O'Neill
PEKT	14	Riza Pektas
RLM	1	Mat Raymonde
SDOH	30	Solar Dynamics Obs - HMI

Continued

Table 3: 202009 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SJAH	22	Jim Soos
SNE	11	Neil Simmons
SONA	20	Andries Son
STAB	30	Brian Gordon-States
SUZM	23	Miyoshi Suzuki
TESD	24	David Teske
TST	25	Steven Toothman
URBP	24	Piotr Urbanski
VARG	30	A. Gonzalo Vargas
VIDD	9	Daniel Vidican
WGI	2	Guido Wollenhaupt
WILW	22	William M. Wilson
Totals	1288	68

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.

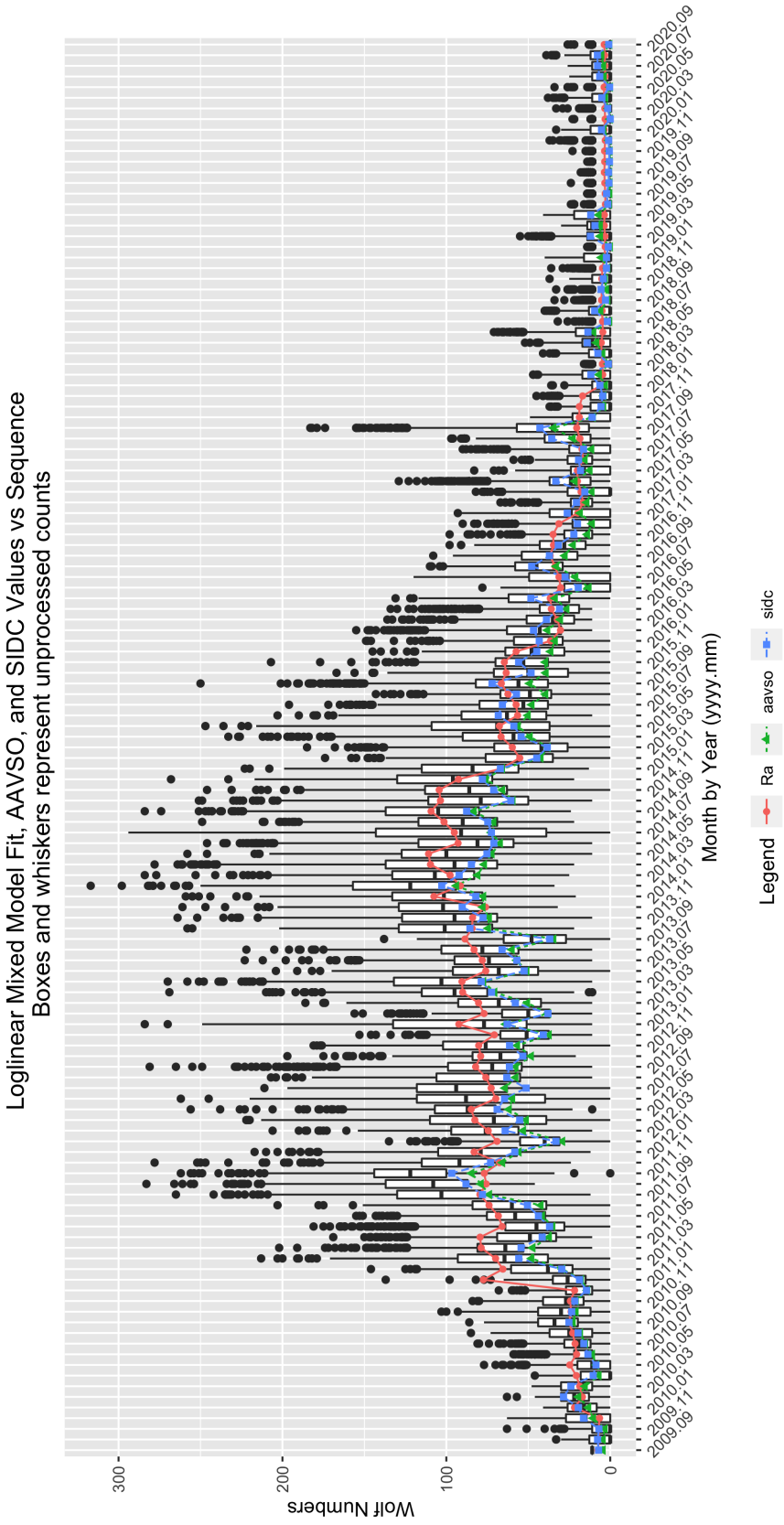

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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