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 Living during the Grand Solar Maximum

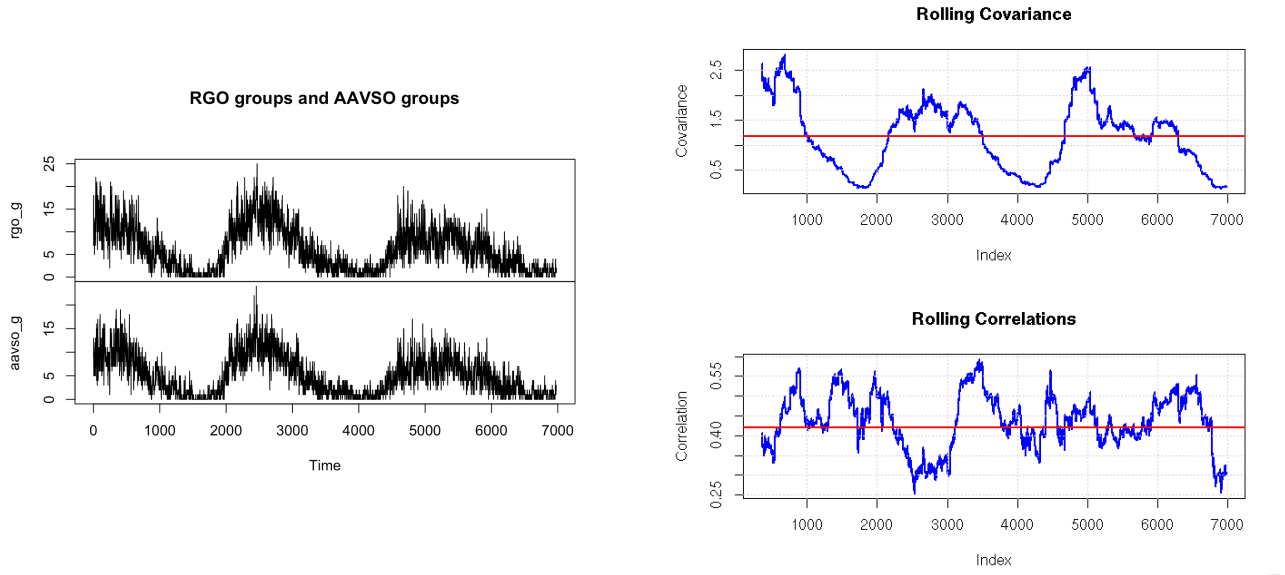

Figure 1: Left panel is a stacked view of both RGO and AAVSO group numbers. Right panel shows the rolling co-variance and correlations of these two group counts.

Above are group number counts from the Royal Greenwich Observatory (RGO) and the AAVSO from solar cycles 18, 19, 20, 1947 - 1977. The RGO data from Hoyt and Schatten: (`https://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-indices/sunspot-numbers/group/group-sunspot-standard-deviation_daily-values(dailysd)_depricate.txt`). Leif Svalgaard entered these RGO group numbers into the Vaquero GN database: (`https://www.researchgate.net/publication/308127781_A_Revised_Collection_of_Sunspot_Group_Numbers`). The AAVSO group number data come from the AAVSO Solar database recorded by Herbert Luft (LJ) and Thomas Cragg (CR) during these Grand Solar Maximum cycles.

Interesting, I think, that the right panel above, shows how the rolling co-variance matrices have Eigen values (general direction either positive or negative) that reflect the 3 solar cycles, however the rolling correlations show disparity during the peak cycle 19 with a large negative correlation and then a high positive rolling correlation in both data sets. This could be due to differences between the RGO group count estimates of Hoyt and Schatten (a higher number of group counts, y-axis on the left panel) vs. the AAVSO group count numbers during the Grand Maximum peak.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

March 2021 (Figure 2): There were 4 B-Class flares and one C-Class flare on the 9th of March, the one C-Class flare was during the terminator, as recorded here in Fort Collins, CO.

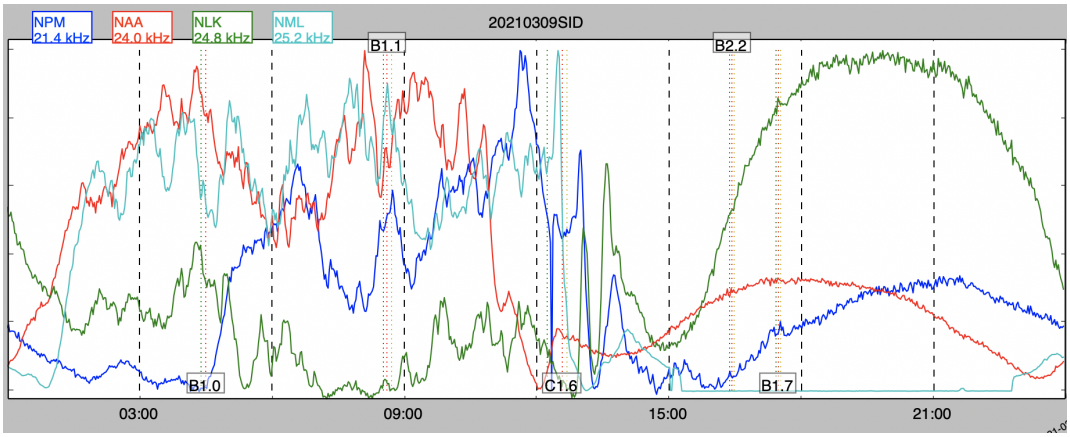

Figure 2: VLF recording from Fort Collins, Colorado.

2.2 SID Observers

In March 2021 we had 16 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202103 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
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
G Silvis	A141	NAA NML
R Rogge	A143	GQD
K Menzies	A146	NAA
R Russel	A147	NPM
L Pina	A148	NML
L Ferreira	A149	NWC
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.

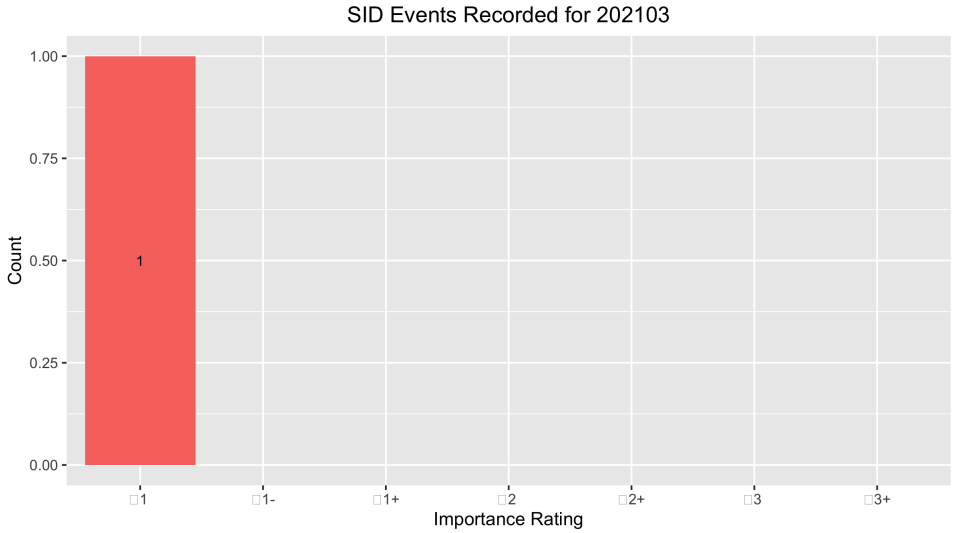

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In March 2021, there were 62 XRA flares for the month of March 2021, 60 B-Class and 2 C-class flares. About the same as last month. There were 10 days this month with no GOES-16 reports of flares (see Figure 4).

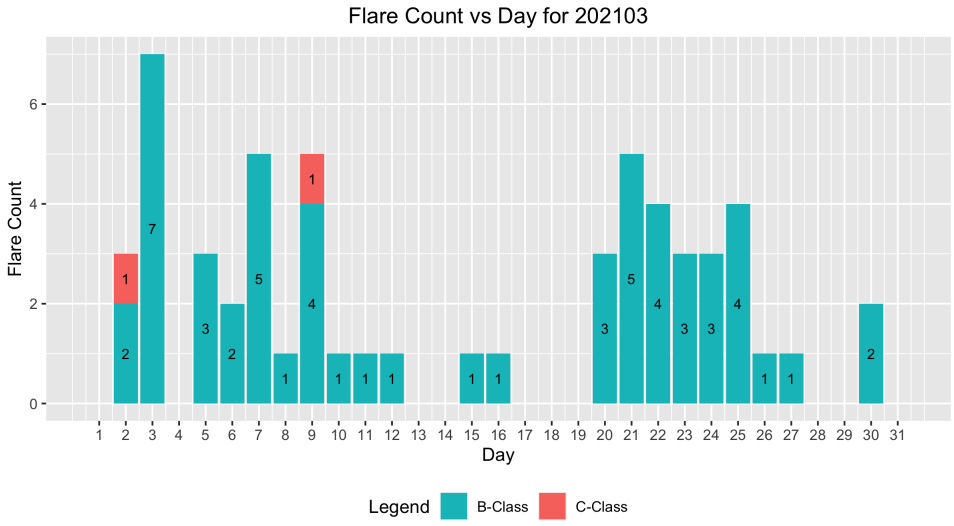

Figure 4: GOES-16 XRA flares

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 a Structured Query Language (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 March 2021. 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.

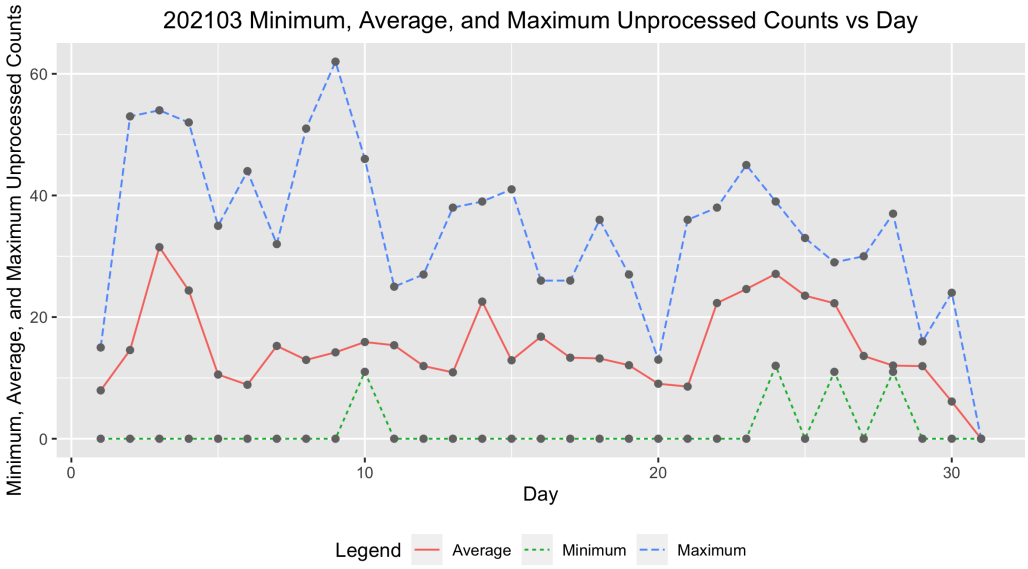

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

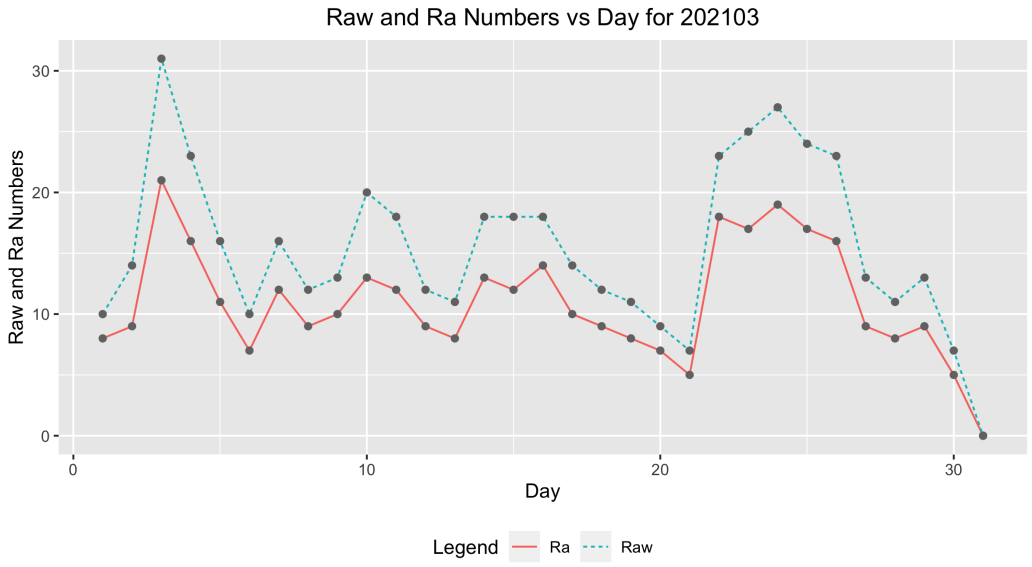

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202103 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	38	10	8
2	43	14	9
3	48	31	21
4	48	23	16
5	38	16	11
6	46	10	7
7	50	16	12
8	46	12	9
9	44	13	10
10	41	20	13
11	38	18	12
12	44	12	9
13	45	11	8
14	33	18	13

Continued

Table 2: 202103 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	38	18	12
16	36	18	14
17	37	14	10
18	35	12	9
19	45	11	8
20	49	9	7
21	40	7	5
22	39	23	18
23	41	25	17
24	41	27	19
25	44	24	17
26	40	23	16
27	41	13	9
28	35	11	8
29	48	13	9
30	43	7	5
31	44	0	0
Averages	41.9	15.5	11

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for March 2021, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (74), and total number of observations submitted (1321).

Table 3: 202103 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	25	Alexandre Amorim
AJV	17	J. Alonso
ARAG	31	Gema Araujo
ASA	27	Salvador Aguirre
ATE	30	Teofilo Arranz Heras
BARH	15	Howard Barnes
BATR	14	Roberto Battaiola
BERJ	26	Jose Alberto Berdejo
BLAJ	11	John A. Blackwell
BMF	25	Michael Boschat
BRAF	22	Raffaello Braga
BROB	24	Robert Brown
CHAG	27	German Morales Chavez

Continued

Table 3: 202103 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CIOA	14	Ioannis Chouinavas
CKB	22	Brian Cudnik
CMOD	4	Mois Carlo
CNT	28	Dean Chantiles
CVJ	6	Jose Carvajal
DARB	14	Aritra Das
DEMF	14	Frank Dempsey
DJOB	13	Jorge del Rosario
DMIB	27	Michel Deconinck
DUBF	26	Franky Dubois
EHOA	16	Howard Eskildsen
ERB	20	Bob Eramia
FDAE	9	David Fox
FERJ	19	Javier Ruiz Fernandez
FLET	24	Tom Fleming
FTAA	12	Tadeusz Figiel
GIGA	25	Igor Grageda Mendez
HALB	6	Brian Halls
HAYK	17	Kim Hay
HDAF	3	David Hollinberger
HMQ	14	Mark Harris
HOWR	18	Rodney Howe
IEWA	18	Ernest. W. Iverson
JDAC	9	David Jackson
JENJ	11	Jamey Jenkins
JENS	3	Simon Jenner
JGE	2	Gerardo Jimenez Lopez
KAND	16	Kandilli Observatory
KAPJ	16	John Kaplan
KNJS	30	James & Shirley Knight
LEVM	13	Monty Leventhal
LGEC	8	Georgios Lekkas
LKR	4	Kristine Larsen
LRRA	22	Robert Little
MARC	11	Arnaud Mengus
MCE	22	Etsuiku Mochizuki
MILJ	19	Jay Miller
MJAF	31	Juan Antonio Moreno Quesada
MJHA	26	John McCammon
MMAY	31	Max Surlaroute
MUDG	10	George Mudry
MWU	29	Walter Maluf
OAAA	24	Al Sadeem Astronomy Observatory

Continued

Table 3: 202103 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
ONJ	25	John O'Neill
PEKT	6	Riza Pektas
RFDA	22	Filipp Romanov
RMW	3	Michael Rapp
SDOH	31	Solar Dynamics Obs - HMI
SNE	12	Neil Simmons
SONA	16	Andries Son
SQN	13	Lance Shaw
STAB	28	Brian Gordon-States
SUZM	23	Miyoshi Suzuki
TESD	22	David Teske
TPJB	16	Patrick Thibault
TST	23	Steve Toothman
URBP	22	Piotr Urbanski
VARG	28	A. Gonzalo Vargas
VIDD	12	Daniel Vidican
WGI	5	Guido Wollenhaupt
WILW	14	William M. Wilson
Totals	1321	74

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. For more details, *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-month) 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 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 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.

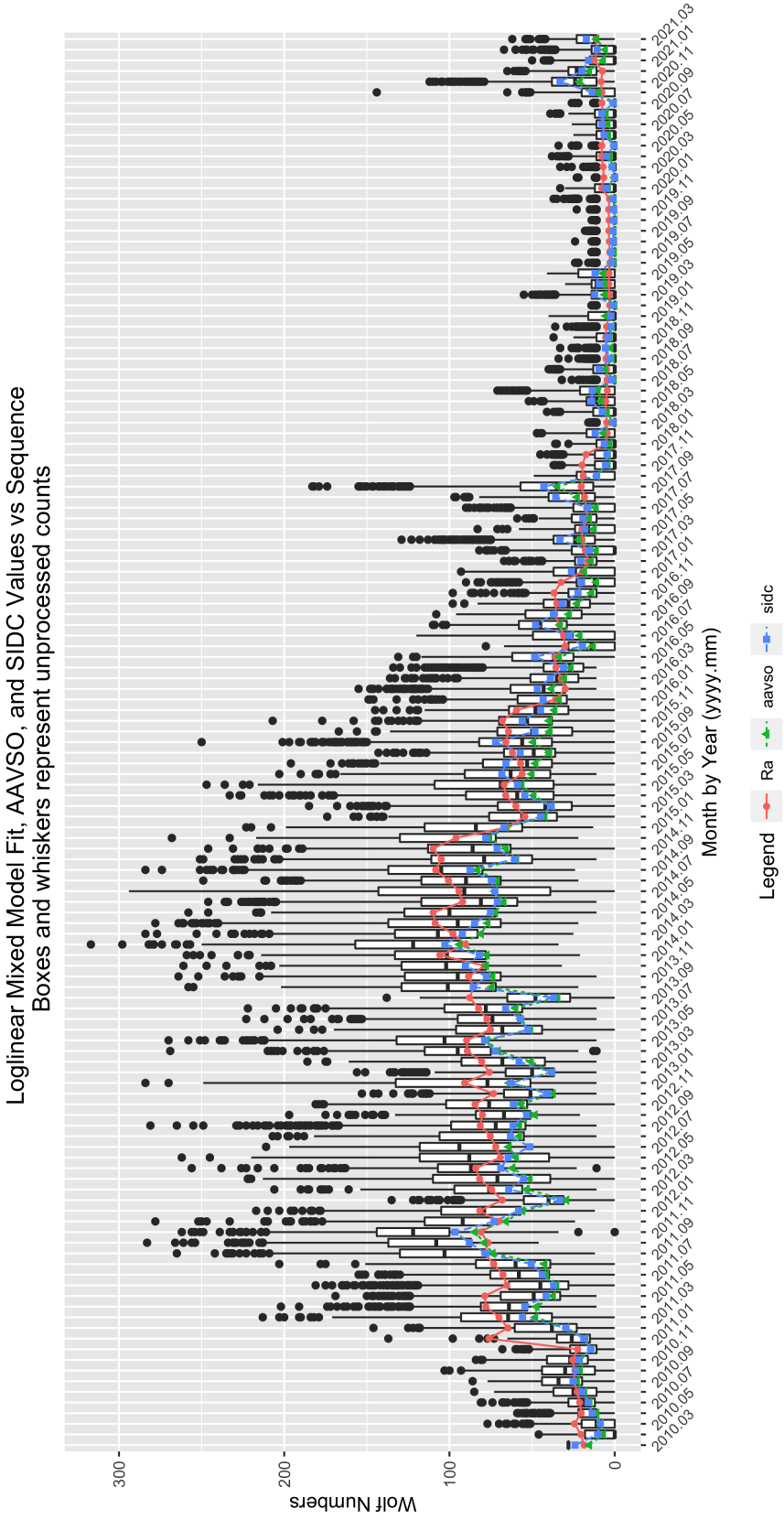

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

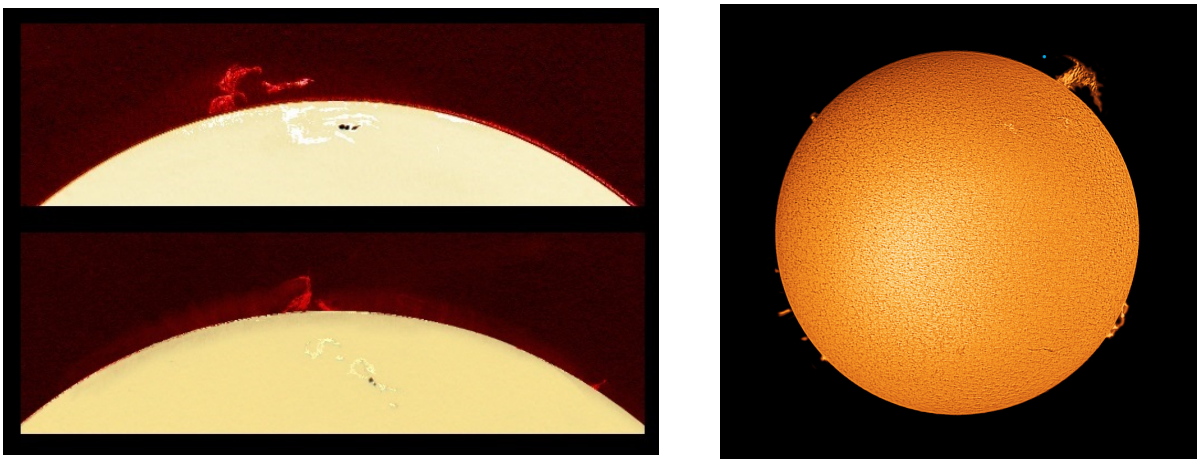

Figure 8: The left image shows two sketches by Michel Deconinck (AAVSO observer code DMIB), March 16 and 17, 2021, made directly through the eyepiece of his Bresser Refractor 152mm/f8 with objective filter for the white light (yellow inside) together with a mini LUNT 35mm for the prominence in H alpha (red outside) (Aquarellia Observatory `https://astro.aquarellia.com`) drawings by Michel Deconinck, Aquarellia Observatory. The right image is a stacked set of images of a prominence on March 21, 2021 from Jon Wallace, VLF observer A97.