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 Forecasting models for predicting Cycle 25

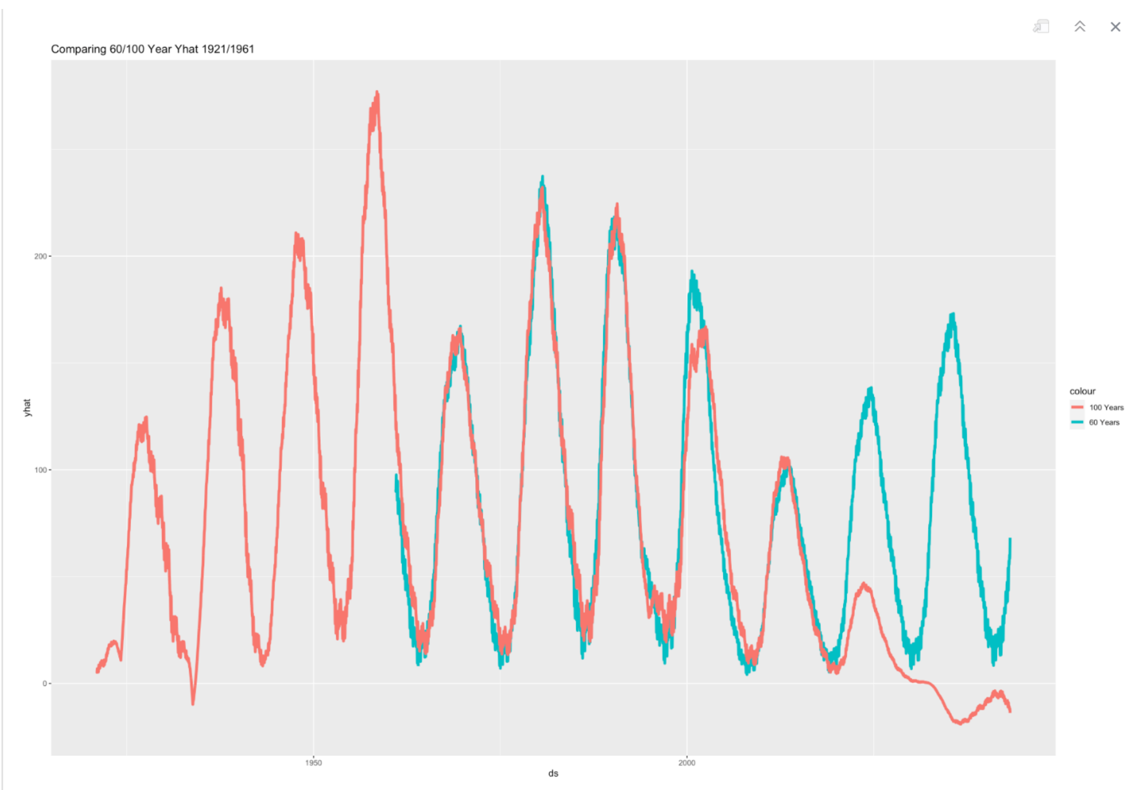
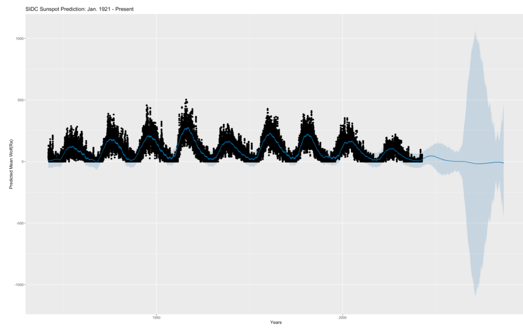


Figure 1: Graph of 100 years covering the Grand Solar Maximum.

Two different projections for up-coming solar cycle 25; one says the cycle will be weak (red), the other says the cycle will be strong (green).
If the solar science models use the past solar International Sunspot Number (ISN) cycles from SIDC `http://www.sidc.be/silso/datafiles`, to predict the future cycle 25, then which time-

series window of the past should be used? For example, if you go back 100 years the projection will show a weak cycle. If you go back 60 years then cycle 25 will be a strong cycle.



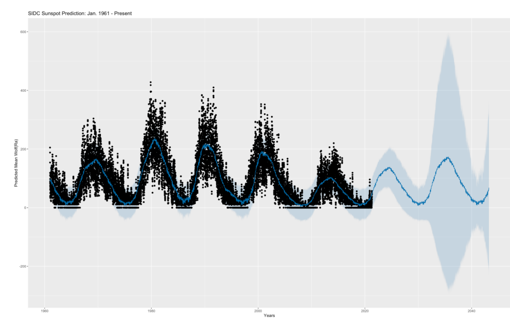


Figure 2: Left shows 100 years of ISN Wolf numbers, right shows 60 years of ISN Wolf numbers.

These graphs are created from the Prophet library in the R language. (`https://cran.r-project.org`). The three above graphs were made for this Solar Bulletin, May 2021, from AAVSO solar observer, David Jackson (observer code JDAC).

For further reading on another model: Andres Munoz-Jaramillo, 2012, Calibrating 100 Years of Polar Faculae Measurements: Implications for the evolution of the Heliospheric magnetic field. https://iopscience.iop.org/article/10.1088/0004-637X/753/2/146/pdf.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

May 2021 (Figure 3): two M class flares on the 22nd. A very active day, recorded here in Fort Collins, Colorado.

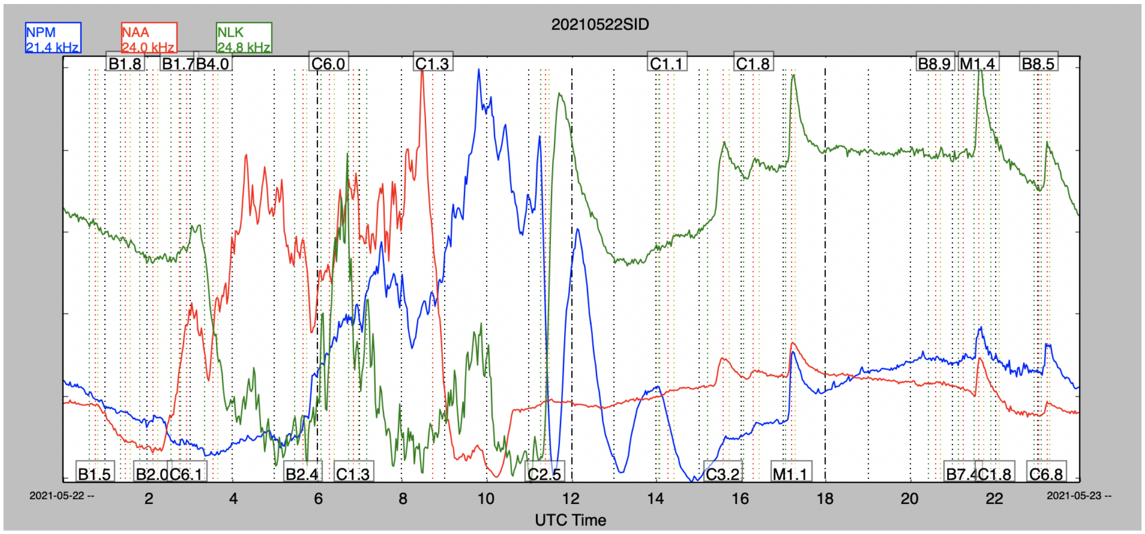


Figure 3: VLF recording on the 22nd of May from Fort Collins, Colorado

2.2 SID Observers

In May 2021 we had 13 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202105 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
R Green	A134	NWC
S Aguirre	A138	NPM
K Menzies	A146	NAA
R Russel	A147	NPM
L Pina	A148	NML
J Wendler	A150	NAA
H Krumnow	A152	HWU GQD DHO

Figure 4 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.

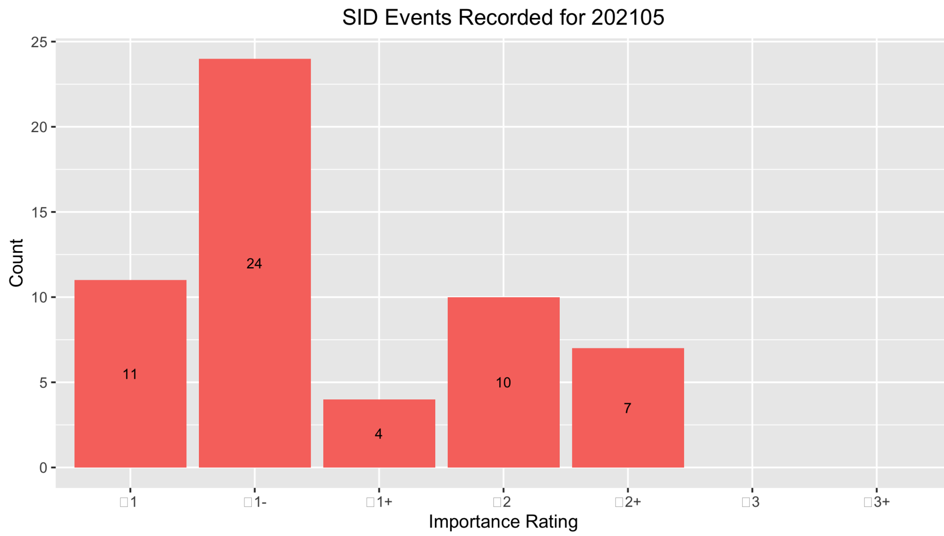


Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In May 2021, there were 243 flares for May 2021: 202 B-class flares, 37 C-class and 4 M-class flares. More flares this month compared to last month. (see Figure 5).

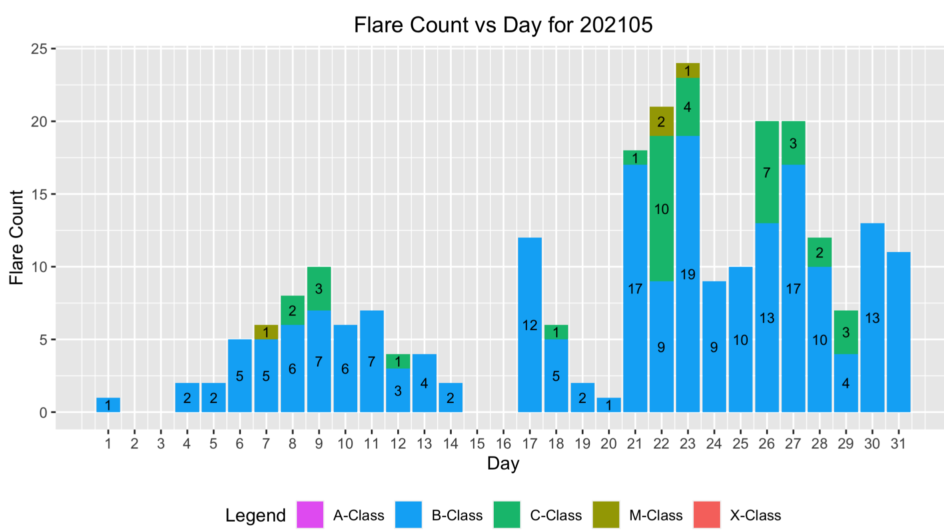


Figure 5: GOES-16 XRA flares

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 May 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 6.

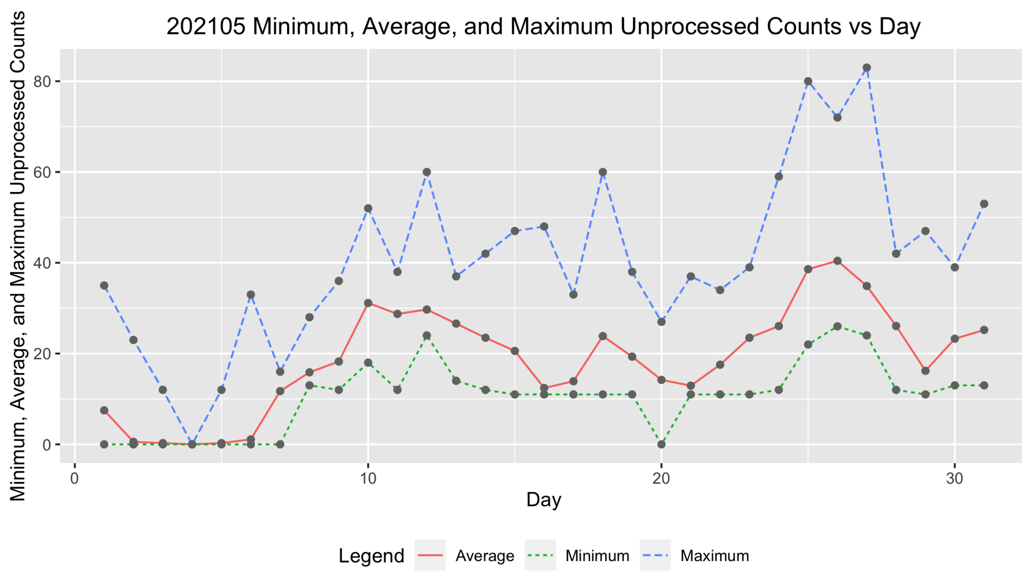


Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

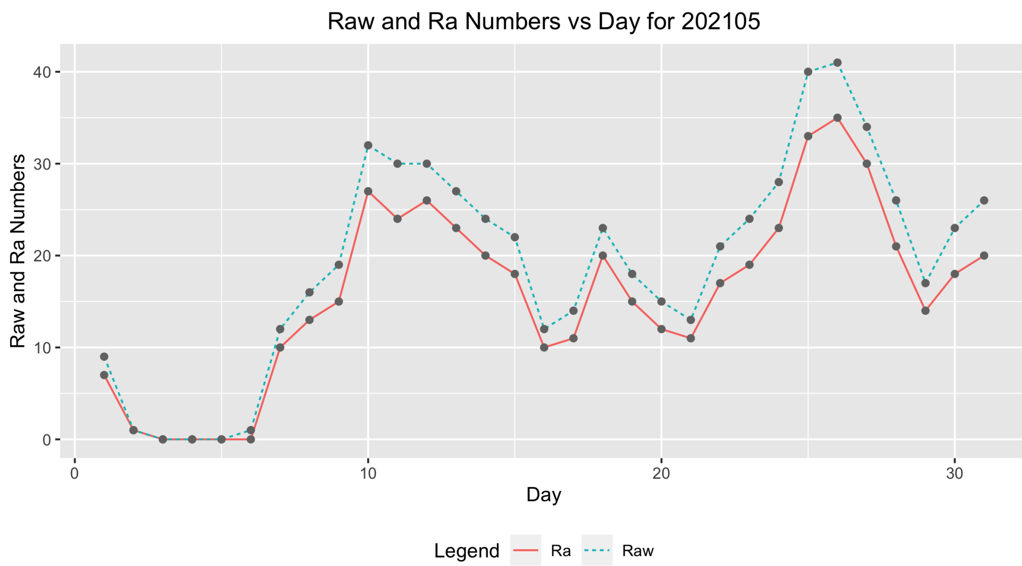


Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 7, 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: 202105 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	48	9	7
2	42	1	1
3	43	0	0
4	41	0	0
5	43	0	0
6	42	1	0
7	44	12	10
8	46	16	13
9	48	19	15
10	49	32	27
11	45	30	24
12	47	30	26
13	50	27	23
14	52	24	20

Continued

Table 2: 202105 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	46	22	18
16	39	12	10
17	43	14	11
18	40	23	20
19	50	18	15
20	46	15	12
21	41	13	11
22	42	21	17
23	43	24	19
24	49	28	23
25	49	40	33
26	53	41	35
27	44	34	30
28	39	26	21
29	40	17	14
30	41	23	18
31	45	26	20
Averages	44.8	19.3	15.9

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for May 2021, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (72), and total number of observations submitted (1398).

Table 3: 202105 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	23	Alexandre Amorim
AJV	25	J. Alonso
ARAG	31	Gema Araujo
ASA	19	Salvador Aguirre
ATE	31	Teofilo Arranz Heras
BATR	12	Roberto Battaiola
BERJ	27	Jose Alberto Berdejo
BLAJ	8	John A. Blackwell
BMF	24	Michael Boschat
BRAF	22	Raffaello Braga
BROB	30	Robert Brown
CHAG	28	German Morales Chavez
CKB	26	Brian Cudnik

Continued

Table 3: 202105 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CMOD	4	Mois Carlo
CNT	23	Dean Chantiles
CVJ	4	Jose Carvajal
DARB	15	Aritra Das
DEMF	19	Frank Dempsey
DJOB	13	Jorge del Rosario
DMIB	23	Michel Deconinck
DROB	9	Bob Dudley
DUBF	31	Franky Dubois
EHOA	25	Howard Eskildsen
ERB	21	Bob Eramia
FDAE	3	David Fox
FERJ	21	Javier Ruiz Fernandez
FLET	18	Tom Fleming
GIGA	30	Igor Grageda Mendez
HALB	15	Brian Halls
HAYK	25	Kim Hay
HMQ	5	Mark Harris
HOWR	17	Rodney Howe
IEWA	20	Ernest W. Iverson
JDAC	12	David Jackson
JENJ	8	Jamey Jenkins
JENS	4	Simon Jenner
JGE	3	Gerardo Jimenez Lopez
KAMB	8	Amoli Kakkar
KAND	17	Kandilli Observatory
KAPJ	19	John Kaplan
KNJS	28	James & Shirley Knight
KZAD	31	Zachary Knoles
LEVM	21	Monty Leventhal
LGEC	5	Georgios Lekkas
LKR	10	Kristine Larsen
LRRA	24	Robert Little
MARC	15	Arnaud Mengus
MCE	19	Etsuiku Mochizuki
MILJ	18	Jay Miller
MJAF	29	Juan Antonio Moreno Quesada
MJHA	25	John McCammon
MMAY	31	Max Surlaroute
MMI	31	Michael Moeller
MUDG	18	George Mudry
MWU	28	Walter Maluf
OAAA	22	Al Sadeem Astronomy Obs.

Continued

Table 3: 202105 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
ONJ	25	John O'Neill
PEKT	8	Riza Pektas
RFDA	18	Filipp Romanov
SDOH	31	Solar Dynamics Obs - HMI
SNE	11	Neil Simmons
SONA	15	Andries Son
SQN	24	Lance Shaw
STAB	30	Brian Gordon-States
SUZM	17	Miyoshi Suzuki
TESD	27	David Teske
TST	19	Steven Toothman
URBP	22	Piotr Urbanski
VARG	31	A. Gonzalo Vargas
VIDD	13	Dan Vidican
WGI	6	Guido Wollenhaupt
WILW	28	William M. Wilson
Totals	1398	72

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 8 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.

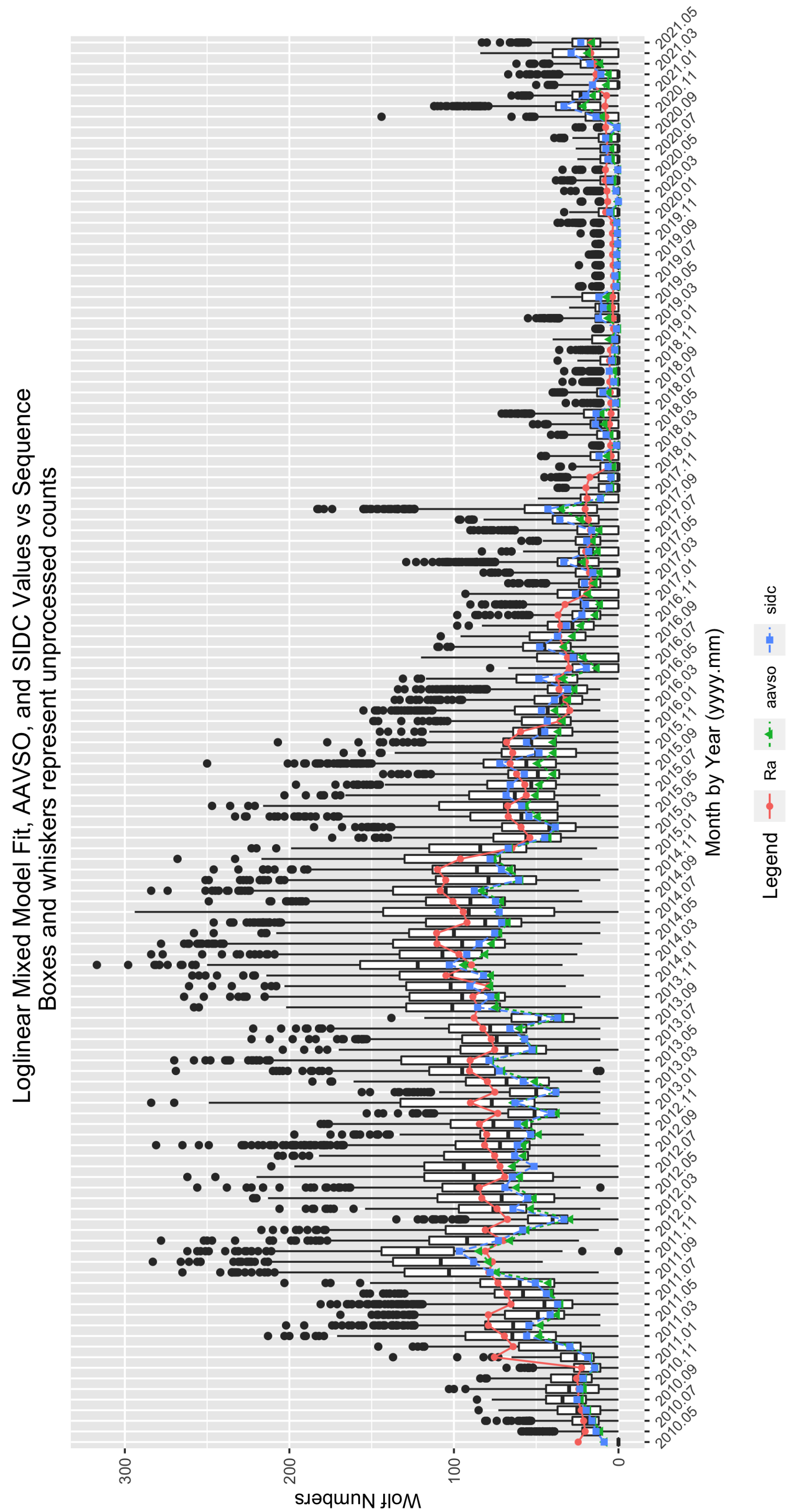


Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

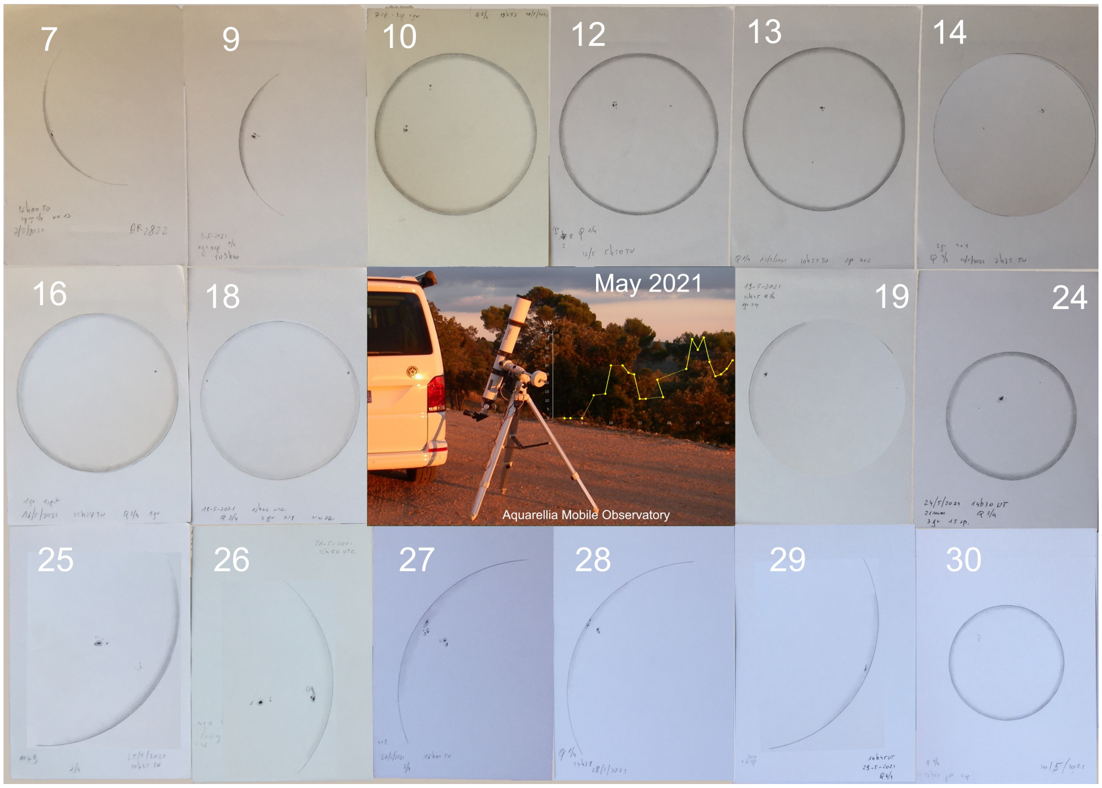


Figure 9: "To thank you for your Solar Bulletins and the heavy associated work, I attach here my May 2021 souvenir video." --Michel Deconinck (AAVSO observer DMIB). And thanks from us to Michel for this fun 'souvenir' video: https://www.youtube.com/watch?v=cEQFdpUwGQA (https://www.aquarellia.com).