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. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Compare SILSO(SIDC) sunspot counts (ISN) with AAVSO R_a sunspot counts

The SIDC ISN numbers are always higher than the AAVSO R_a numbers by an average of about 1.414 times the AAVSO sunspot counts (see Figure 7). This is because SILSO uses the Lorcano observatory as a referent to all their observers' group and sunspot counts. SILSO's ISN construction is here: `https://wwwbis.sidc.be/silso/newdataset`. The AAVSO has no reference observatory, and uses all the observer submissions for the AAVSO R_a index using the Shapley method with k-factors: `http://iopscience.iop.org/article/10.1086/126109/pdf`.

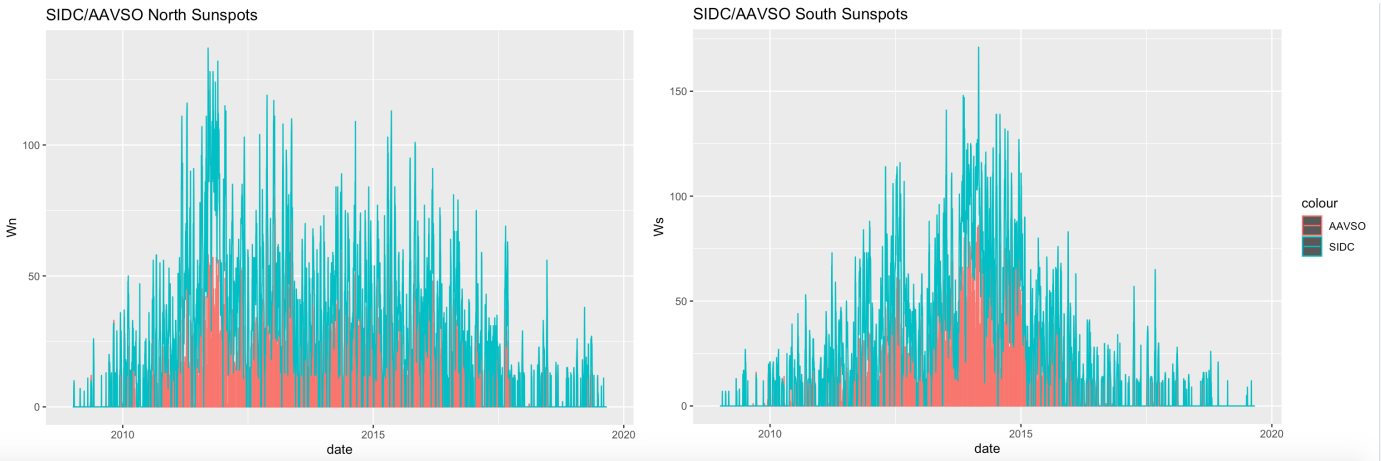

Figure 1: Red are the AAVSO R_a sunspot counts, and Cyan are the SIDC ISN sunspot counts for Cycle 24 over the last decade. Note the y-axis differences between the north and south sunspot counts.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

December 2021 (Figure 2): a moderate SID Event from a M1.6 flare recorded here at Fort Collins, Colorado with the peak at 16:00 UT; seen best from the NAA and NLK transmitters at Cutler, Maine and Jim Creek, Washington, respectively.

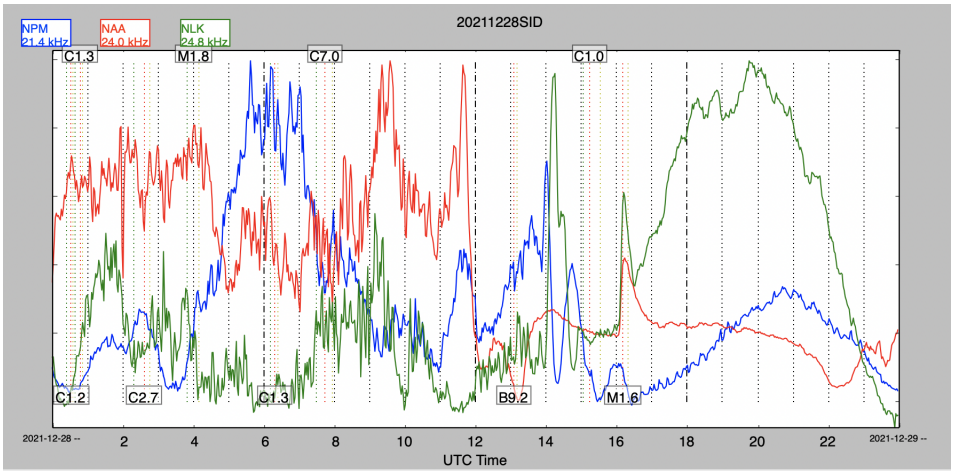

Figure 2: VLF recording on the 28th of December.

2.2 SID Observers

In December 2021, 15 AAVSO SID observers submitted VLF data as listed in Table 1.

Table 1: 202112 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD
B Terrill	A120	NWC
F Adamson	A122	NWC
G Perry	A126	DHO
J Karlovsky	A131	FTA
R Green	A134	NWC
G Silvis	A141	NAA NLK
K Menzies	A146	NAA
L Pina	A148	NAA NLK
J Wendler	A150	NAA
H Krumnow	A152	FTA GBZ
J DeVries	A153	NLK

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.

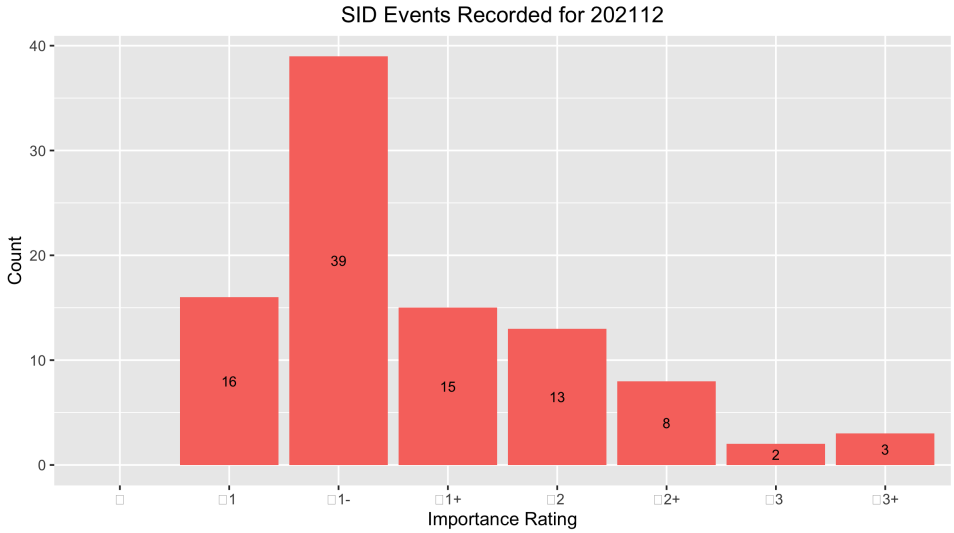

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In December 2021, there were 282 GOES-16 XRA flares for December 2021: 8 M-Class, 171 C-Class and 103 B-Class flares. More flaring this month compared to last (see Figure 4).

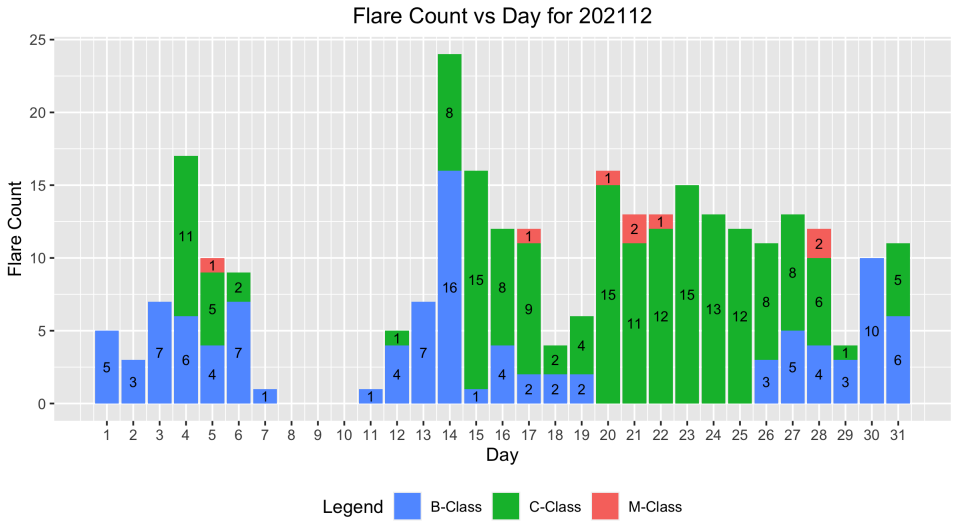

Figure 4: GOES-16 XRA flares.

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 December 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.

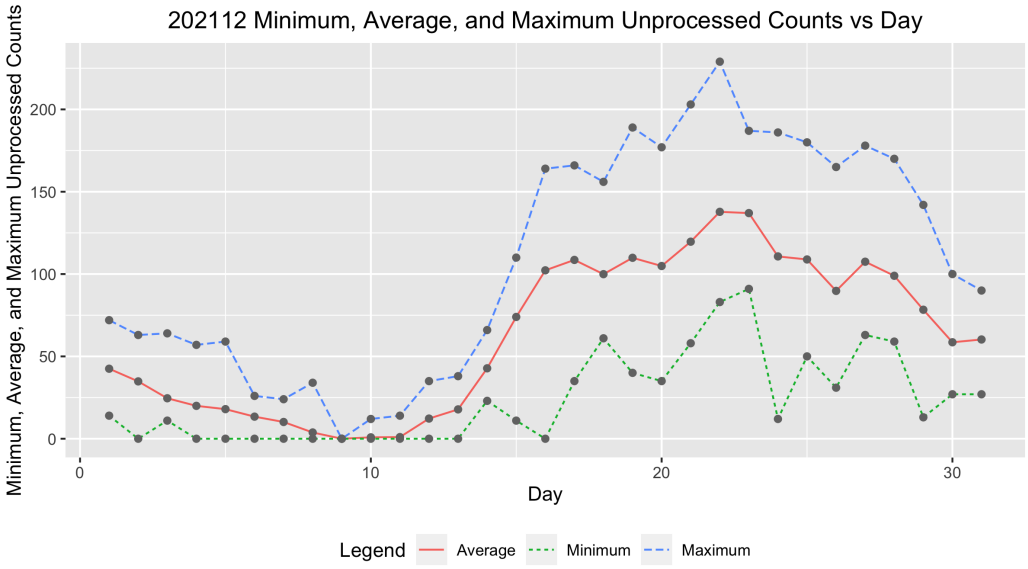

Figure 5: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

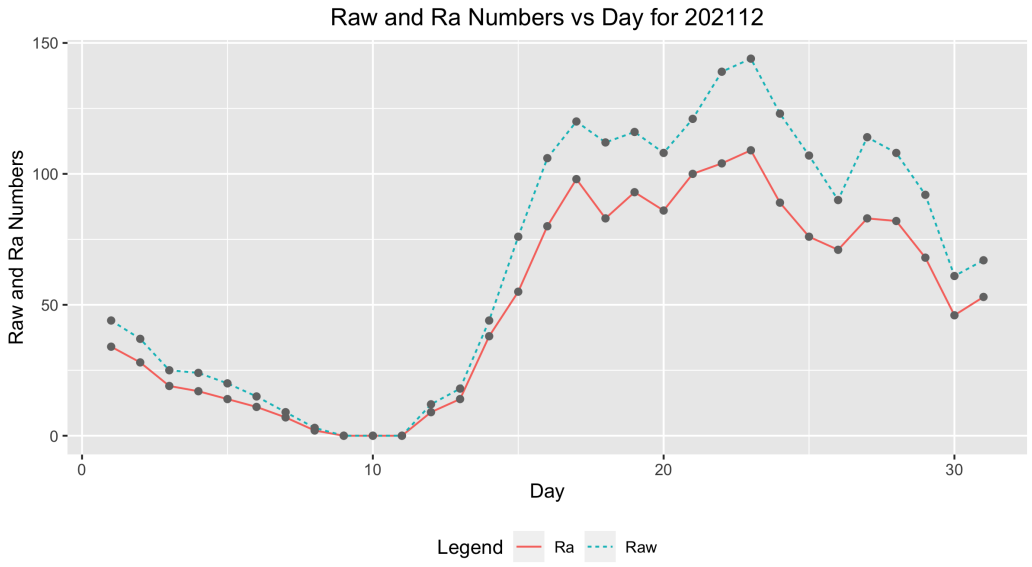

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202112 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	35	44	34
2	34	37	28
3	35	25	19
4	31	24	17
5	30	20	14
6	29	15	11
7	29	9	7
8	30	3	2
9	27	0	0
10	27	0	0
11	37	0	0
12	37	12	9
13	33	18	14
14	35	44	38

Continued

Table 2: 202112 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	29	76	55
16	30	106	80
17	34	120	98
18	33	112	83
19	34	116	93
20	36	108	86
21	41	121	100
22	39	139	104
23	30	144	109
24	28	123	89
25	23	107	76
26	32	90	71
27	28	114	83
28	30	108	82
29	30	92	68
30	31	61	46
31	30	67	53
Averages	31.8	66.3	50.6

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 2021, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (73), and total number of observations submitted (987).

Table 3: 202112 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	26	Alexandre Amorim
AJV	19	J. Alonso
ARAG	29	Gema Araujo
ASA	5	Salvador Aguirre
ATE	23	Teofilo Arranz Heras
BARH	4	Howard Barnes
BATR	7	Roberto Battaiola
BMF	23	Michael Boschat
BMIG	13	Michel Besson
BRAF	7	Raffaello Braga
BROB	14	Robert Brown
BXZ	12	Jose Alberto Berdejo
BZX	17	A. Gonzalo Vargas

Continued

Table 3: 202112 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CKB	12	Brian Cudnik
CMOD	5	Moise Carlo
CNT	21	Dean Chantiles
CPAD	3	Panagiotis Chatzistamatiou
CVJ	3	Jose Carvajal
DARB	19	Aritra Das
DFR	6	Frank Dempsey
DJOB	9	Jorge del Rosario
DMIB	19	Michel Deconinck
DROB	4	Bob Dudley
DUBF	15	Franky Dubois
EHOA	16	Howard Eskildsen
ERB	4	Bob Eramia
FERA	8	Eric Fabrigat
FLET	24	Tom Fleming
GIGA	20	Igor Grageda Mendez
HALB	2	Brian Halls
HKY	12	Kim Hay
HOWR	17	Rodney Howe
HRUT	20	Timothy Hrutkay
IEWA	19	Ernest W. Iverson
ILUB	6	Luigi Lapichino
JDAC	6	David Jackson
JGE	7	Gerardo Jimenez Lopez
KAMB	31	Amoli Kakkar
KAND	10	Kandilli Observatory
KAPJ	10	John Kaplan
KNJS	31	James & Shirley Knight
KZAD	10	Zachary Knoles
LEVM	12	Monty Leventhal
LKR	3	Kristine Larsen
LRRA	15	Robert Little
MARC	6	Arnaud Mengus
MCE	24	Etsuiku Mochizuki
MJAF	27	Juan Antonio Moreno Quesada
MJHA	31	John McCammon
MLL	12	Jay Miller
MMAY	31	Max Surlaroute
MMI	31	Michael Moeller
MUDG	6	George Mudry
MWU	23	Walter Maluf
OAAA	24	Al Sadeem Astronomy Obs.
ONJ	4	John O'Neill

Continued

Table 3: 202112 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
PEKT	9	Riza Pektas
PLUD	14	Ludovic Perbet
RFDA	15	Filipp Romanov
RJV	17	Javier Ruiz Fernandez
SATH	4	Andries Son
SDOH	31	Solar Dynamics Obs - HMI
SNE	2	Neil Simmons
SQN	9	Lance Shaw
SRIE	5	Rick St. Hilaire
TDE	19	David Teske
TPJB	4	Patrick Thibault
TST	13	Steven Toothman
URBP	4	Piotr Urbanski
VIDD	4	Dan Vidican
VRUA	4	Ruben Verboven
WGI	2	Guido Wollenhaupt
WWM	14	William M. Wilson
Totals	987	73

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; 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 24$^{\text{th}}$ 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$^{\text{th}}$ through the 75$^{\text{th}}$ quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25$^{\text{th}}$ quartile, and 1.5 times the IQR above the 75$^{\text{th}}$ 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.

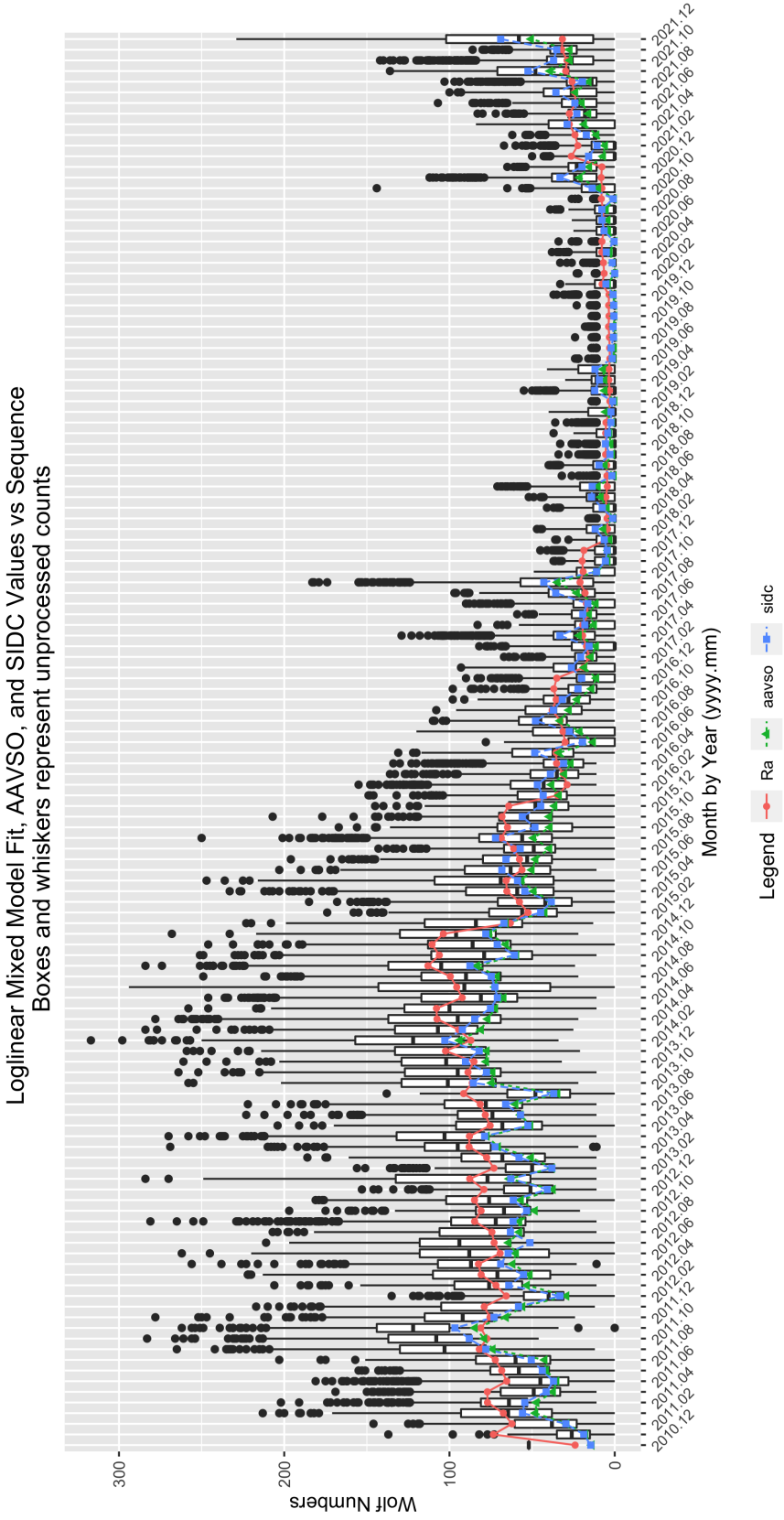

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

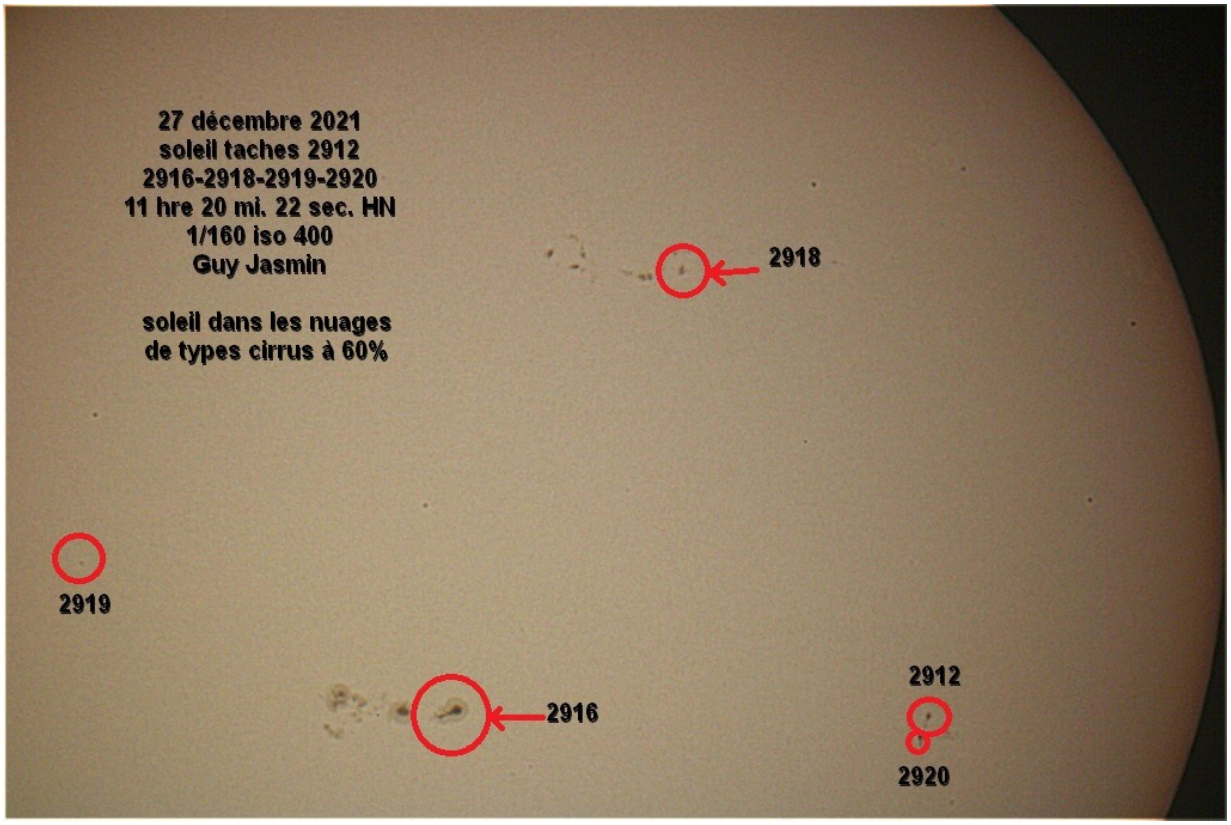

Figure 8: Photograph following the trajectory of the spots on the sun, by Guy Jasmin, December 27, 2021.

Figure 9: From AAVSO solar observer Filipp Romanov (observer code RFDA): "Sun with large number of sunspots on December 21, 2021 (04:30 UTC), on the Winter Solstice. This image is result of stacking of 100 frames from video taken (in my small homeland: Yuzhno-Morskoy, near Nakhodka, Russia) by mobile phone camera through eyepiece of 60mm refractor with solar filter. My observations of the Sun in my presentation (`https://www.youtube.com/watch?v=oFRVp0-Sm7A`) 'Free popularization of astronomy in Russia by an amateur astronomer' at the CAP 2021 Virtual conference."

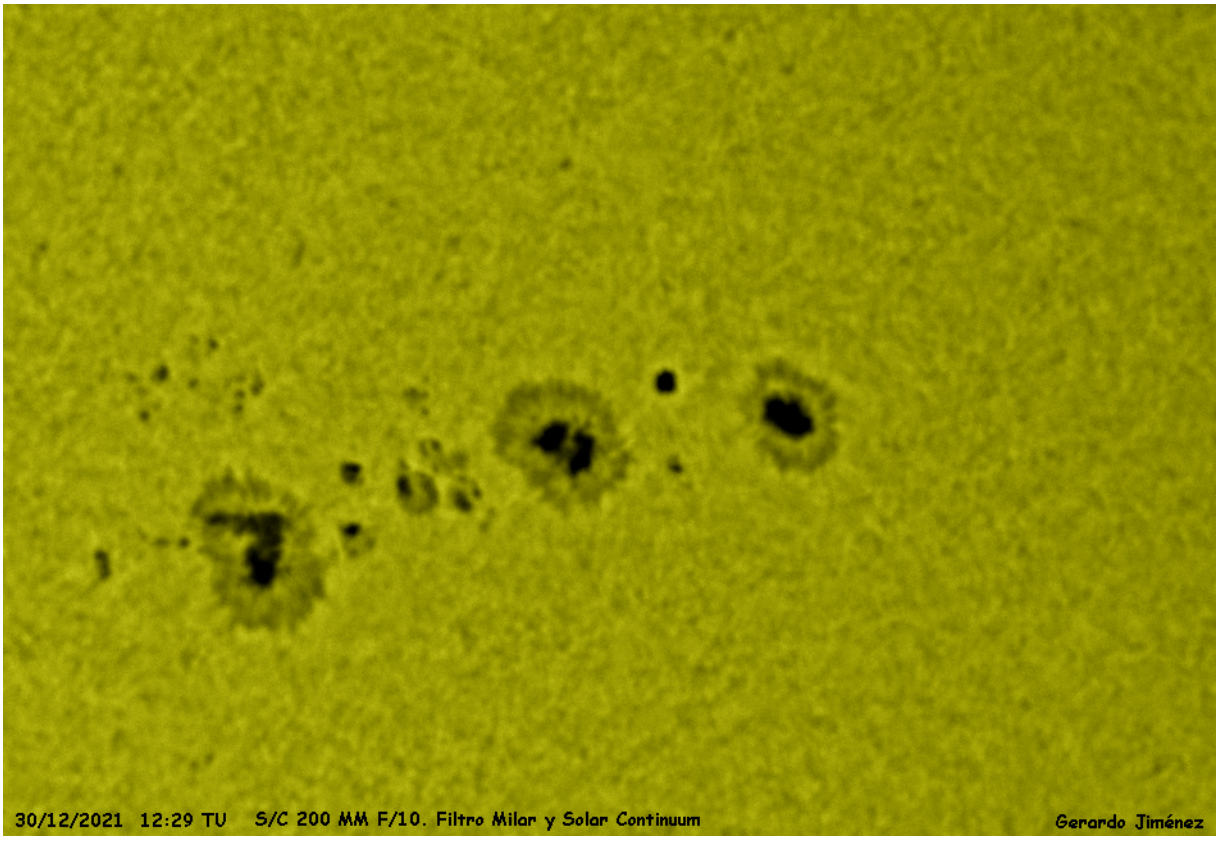

Figure 10: From AAVSO solar observer Gerardo Jimenez Lopez (JGE), Avila, Spain, using a Meade S/C 200 mm F/10 LX200 with an Equatorial mount, a Mylar Filter and Solar Continuum Filter; ASI ZWO 290 MM 60, tracking photo segments in video, processed with PiPP, Autostakker and Registax 6.