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 May 6th and 10th sunspot groups.

Figure 1: The left panel shows a CCD image from Monty Leventhal (LEVM) for the 6th of May. Right panel shows a CCD image from German Morales Chavez (CHAG) for the 10th of May.

For the left panel: Monty Leventhal takes a picture for the two sunspot groups on the 6th of May where one of the groups is right on the limb of the sun. For the right panel: German Chavez shows on May 10th the two sunspot groups are in the center of the solar disk.

Below is a graph from David Jackson (JDAC). He is using a forecast model for Solar Cycle 25. These are the AAVSO daily data posted on the AAVSO web site going back to 1945. David uses a R routine library called Prophet (Bill Letham and Facebook) (`https://cran.r-project.org/web/packages/prophet/index.html`) to graph an estimate for the upcoming cycle 25:

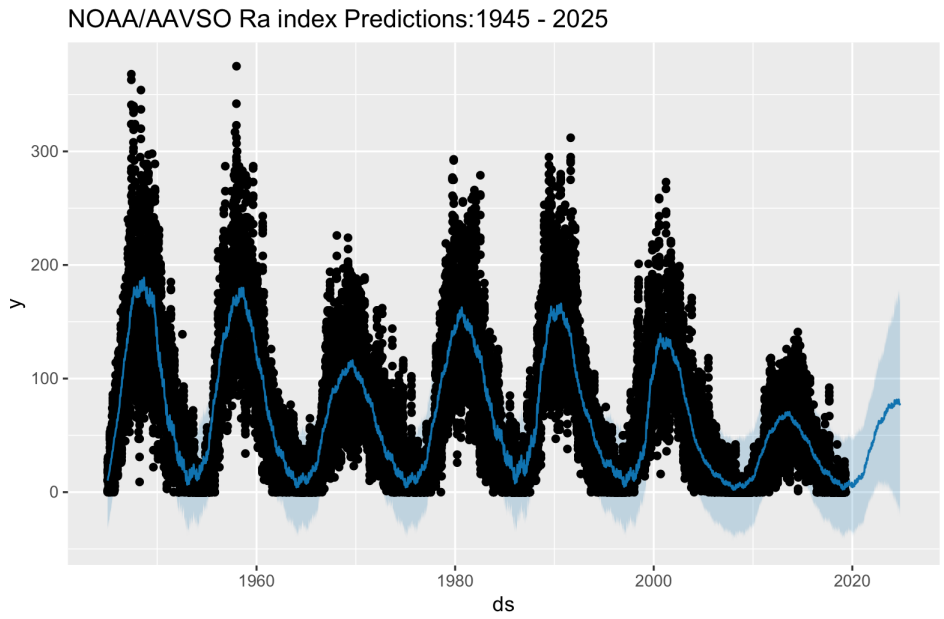

Figure 2: Estimate of AAVSO Ra index values for Cycle 25 in light blue.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

May 2019 (Figure 3): The most active day this month was the 6th of May where there were 17 flares recorded by GOES-15 XRA. Four of these flares show up from NLK as a SID events here in Fort Collins, Colorado. (Please note the y-axis values in these SID graphs are non-dimensional.)

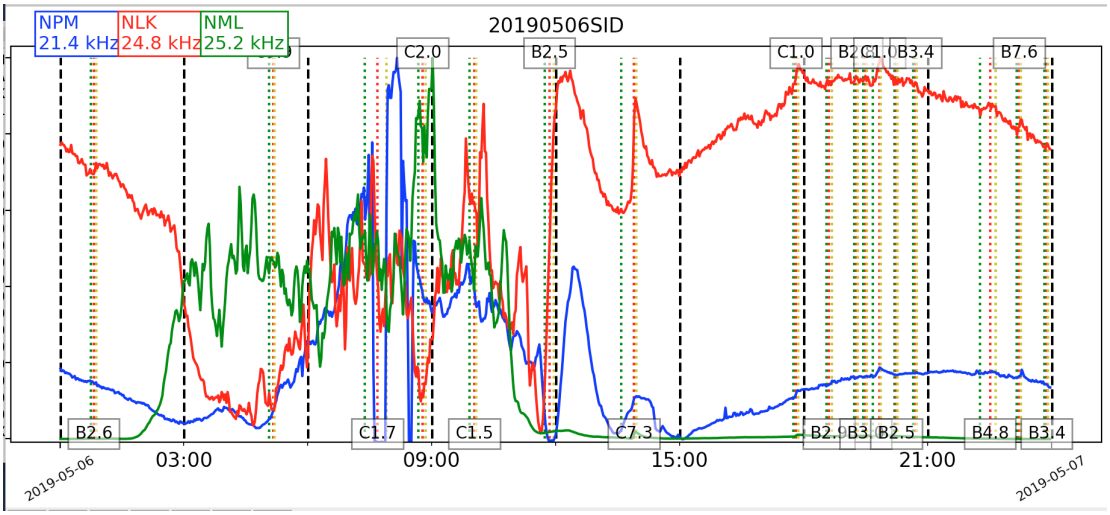

Figure 3: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In May 2019 we had 20 AAVSO SID observers who submitted VLF data as listed in Table 1. There were some observers who recorded SID events this month, which matched to GOES-15 XRA and FLA events.

Table 1: 201905 VLF Observers

Observer	Code	Stations
S Hansen	A59	NAA
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
R Mrllak	A136	NSY GQD
S Aguirre	A138	NPM
G Silvis	A141	HWU NAU
I Ryumshin	A142	GQD DHO
R Rogge	A143	GQD
R Russel	A147	NPM
G Wood	A150	NML
A Maevsky	A151	GQD

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-15 Data

In May 2019, there were two A class, 39 B class and 13 C class flares recorded from GOES-15 for May 2019. Far more flaring this month compared to last. There were 17 days this month with no GOES-15 reports of flares. (see Figure 5).

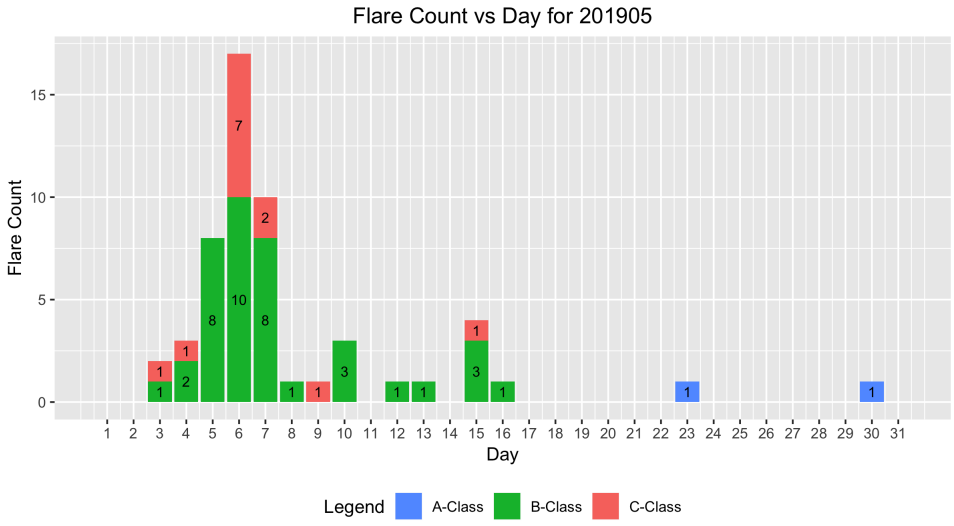

Figure 5: GOES - 15 XRA flares

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 May 2019. These counts are reported by the day of the month, and are either from data not scrubbed or corrected data. 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.

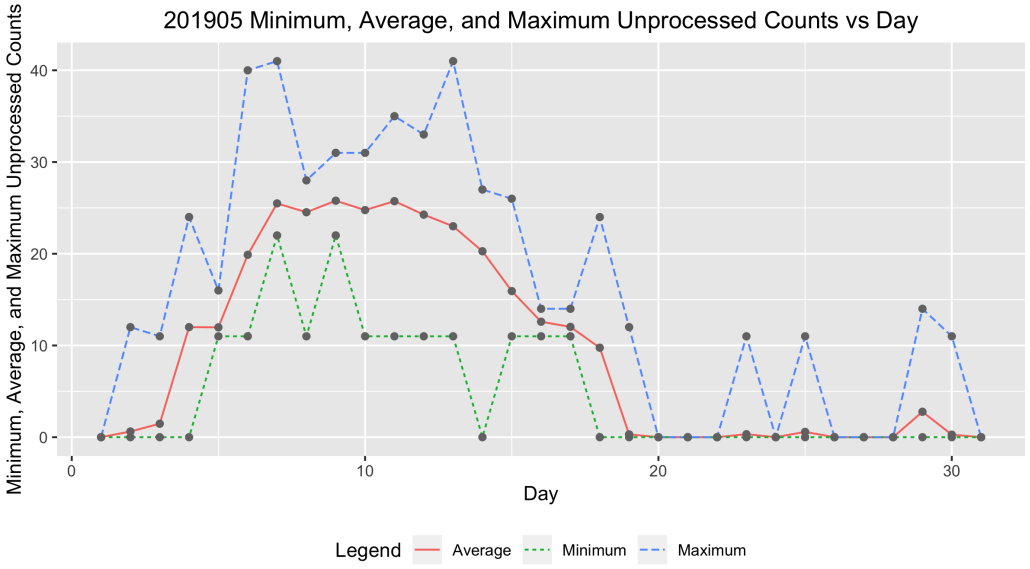

Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

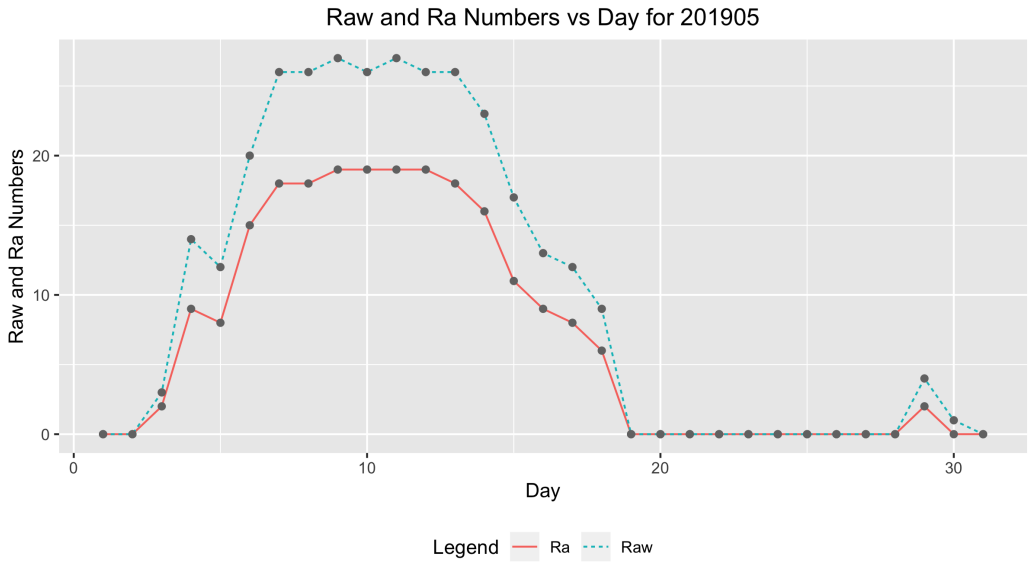

Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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 (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: 201905 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	36	0	0
2	37	0	0
3	30	3	2
4	34	14	9
5	41	12	8
6	45	20	15
7	41	26	18
8	36	26	18
9	32	27	19
10	29	26	19
11	45	27	19
12	38	26	19
13	39	26	18
14	44	23	16

Continued

Table 2: 201905 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	42	17	11
16	39	13	9
17	36	12	8
18	37	9	6
19	39	0	0
20	35	0	0
21	42	0	0
22	34	0	0
23	34	0	0
24	38	0	0
25	38	0	0
26	40	0	0
27	42	0	0
28	35	0	0
29	35	4	2
30	40	1	0
31	40	0	0
Averages	37.8	10.1	7

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for May 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 66 and the total number of observations is 1173.

Table 3: 201905 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
AAX	17	Alexandre Amorim
AJV	20	J. Alonso
ARAG	31	Gema Araujo
ASA	28	Salvador Aguirre
ATE	12	Teofilo Arranz Heras
BARH	12	Howard Barnes
BATR	3	Roberto Battaiola
BERJ	27	Jose Alberto Berdejo
BLAJ	1	John A. Blackwell
BMF	19	Michael Boschat
BRAD	20	David Branchett
BRAF	13	Raffaello Braga

Continued

Table 3: 201905 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
BROB	26	Robert Brown
BSAB	27	Santanu Basu
CHAG	29	German Morales Chavez
CIOA	7	Ioannis Chouinavas
CKB	16	Brian Cudnik
CNT	15	Dean Chantiles
CVJ	9	Jose Carvajal
DEMF	7	Frank Dempsey
DIVA	22	Ivo Demeulenaere
DJOB	12	Jorge del Rosario
DMIB	26	Michel Deconinck
DROB	12	Bob Dudley
DUBF	28	Franky Dubois
EHOA	18	Howard Eskildsen
ERB	21	Bob Eramia
FERJ	21	Javier Ruiz Fernandez
FLET	22	Tom Fleming
FLF	8	Fredirico Luiz Funari
FUJK	8	K. Fujimori
HAYK	16	Kim Hay
HOWR	20	Rodney Howe
HRUT	30	Timothy Hrutkay
JDAC	20	David Jackson
JENS	1	Simon Jenner
JGE	6	Gerardo Jimenez Lopez
JPG	1	Penko Jordanov
KAND	27	Kandilli Observatory
KAPJ	26	John Kaplan
KNJS	31	James & Shirley Knight
KROL	21	Larry Krozel
LEVM	24	Monty Leventhal
LKR	6	Kristine Larsen
LRRA	14	Robert Little
MARC	12	Arnaud Mengus
MARE	9	Enrico Mariani
MCE	26	Etsuiku Mochizuki
MILJ	17	Jay Miller
MJHA	24	John McCammon
MUDG	10	George Mudry
MWU	15	Walter Maluf
OAAA	28	Al Sadeem Astronomy Observatory
OATS	2	Susan Oatney
ONJ	15	John O'Neill

Continued

Table 3: 201905 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
SDOH	31	Solar Dynamics Obs - HMI
SNE	12	Neil Simmons
SONA	10	Andries Son
STAB	30	Brian Gordon-States
SUZM	25	Miyoshi Suzuki
TESD	27	David Teske
TST	17	Steven Toothman
URBP	20	Piotr Urbanski
VARG	29	A. Gonzalo Vargas
VIDD	12	Daniel Vidican
WILW	22	William M. Wilson
Totals	1173	66

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 8 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.

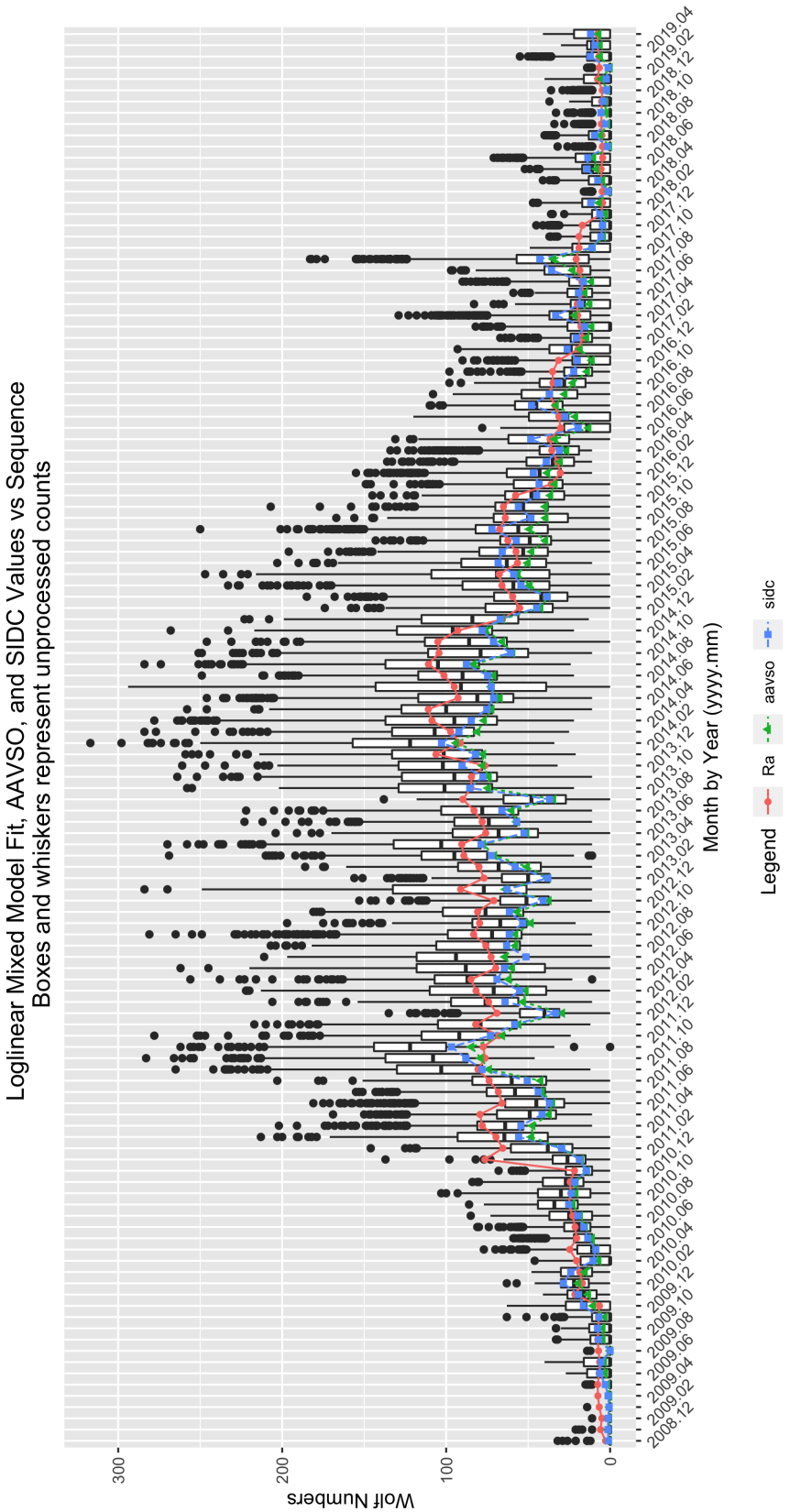

Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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