Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

Rodney Howe, Editor, Chair
c/o AAVSO, 49 Bay State Rd
Cambridge, MA 02138 USA

Web: http://www.aavso.org/solar-bulletin
Email: solar@aavso.org
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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 SILSO (SIDC) data for North/South hemispheres on the sun and a monthly-mean uptick)

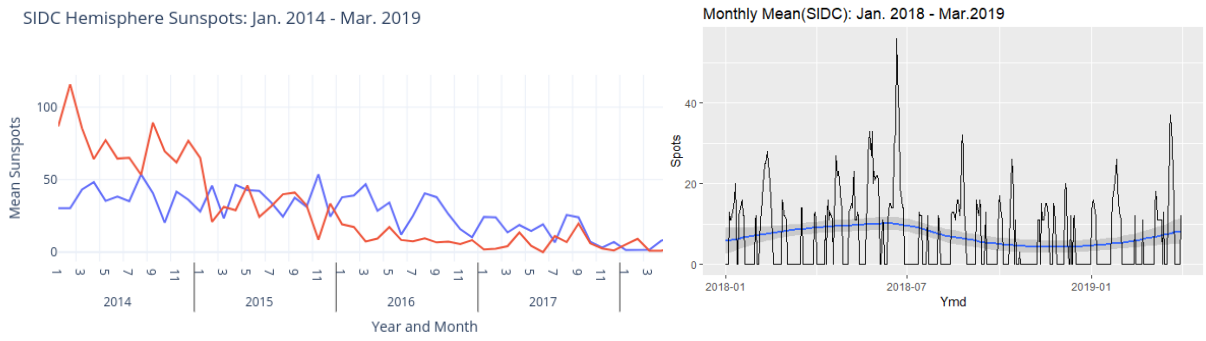

Figure 1: The left panel shows the North/South (North=blue, South=red) hemisphere ISN monthly data from SIDC. Right panel shows the monthly mean ISN from SIDC with a trend line.
Monthly SIDC data from here: (`http://sidc.be/silso/DATA/SN_d_tot_V2.0.csv`)

For the left panel North/South plot from SIDC monthly data with cross-overs around early 2015 and again late 2015 and again late 2017. These graphs from David Jackson (JDAC), who asks these questions: What do you think? What does it mean if the Northern sunspots increase and the Southern spots decrease? A new solar cycle? For the right panel: The thing that is interesting, the Monthly Mean seems to be trending upward. What does that mean?

Further reading: (`https://www.researchgate.net/publication/258259088_A_Study_of_the_Hemispheric_Asymmetry_of_Sunspot_Area_during_Solar_Cycles_23_and_24`)

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

March 2019 (Figure 2): The most active day this month was the 22nd of March where there were 22 flares recorded by GOES-15 XRA. However only the C1.4 flare around 2023 UT shows up as a SID event here in Fort Collins, Colorado. (Please note the y-axis values in these SID graphs are non-dimensional.)

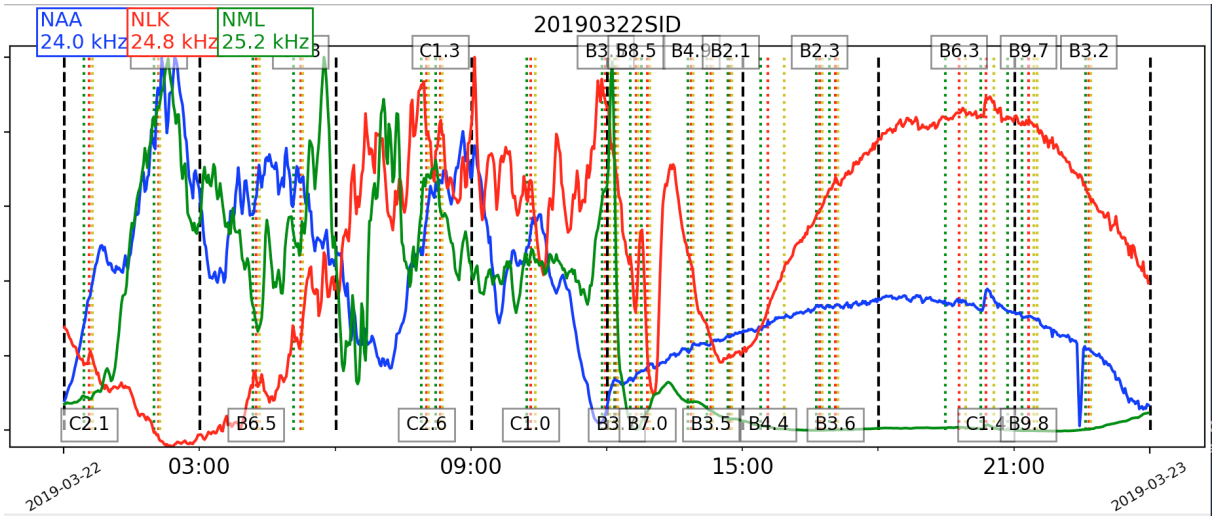

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In March 2019 we had 20 AAVSO SID observers who submitted VLF data as listed in Table 1. There were many observers who recorded SID events this month, mostly C class flares on the 21st and 22nd of March which matched to GOES-15 XRA and FLA events.

Table 1: 201903 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
F Adamson	A122	NAA
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	NLK NAU
I Ryumshin	A142	GQD DHO
R Rogge	A143	GQD
K Menzies	A146	NAA
R Russel	A147	NPM
L Ferreira	A149	NWC
G Wood	A150	NML

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.

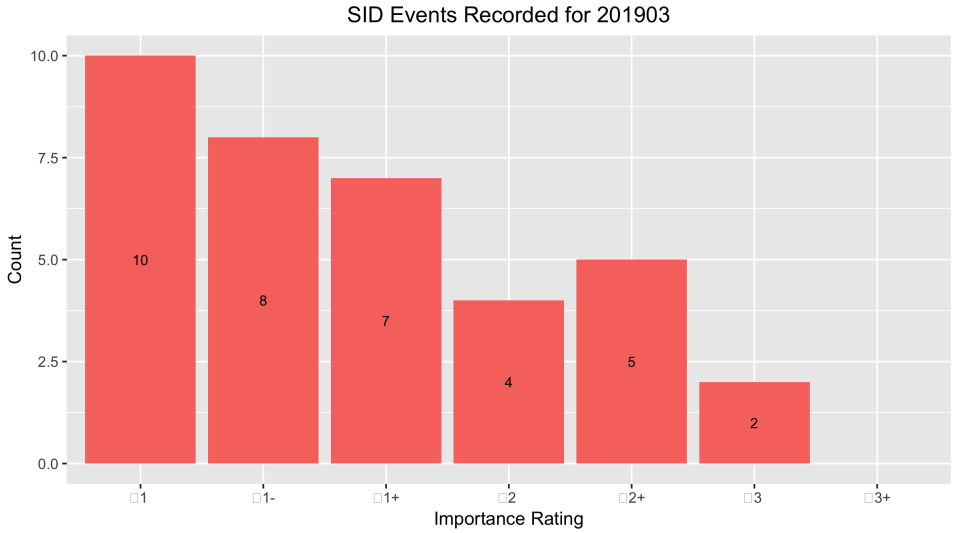

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-15 Data

In March 2019, there were 89 XRA flares from GOES-15 for March 2019. Thirteen C class flares, 72 B class flares and 4 A class flares. Far more flares this month compared to last. There were 17 days this month with no GOES-15 reports of flares. (see Figure 4).

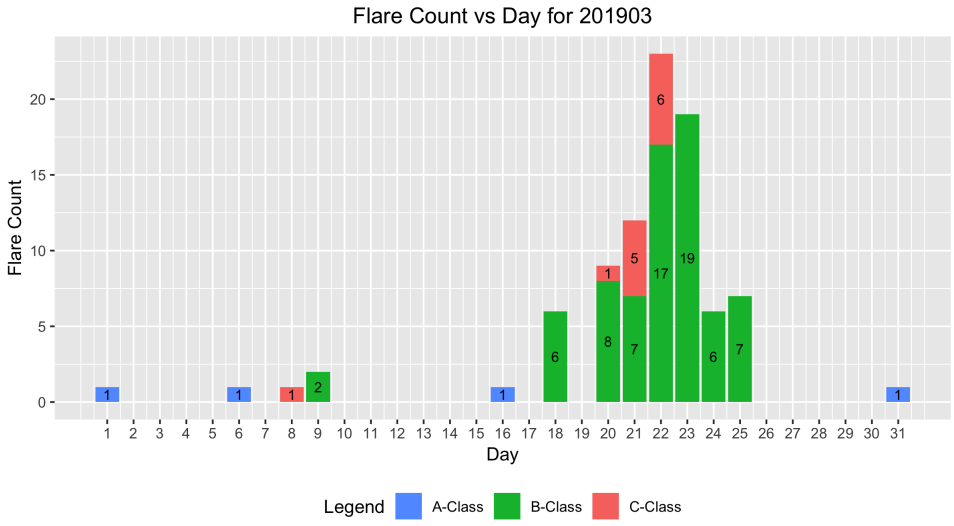

Figure 4: GOES - 15 XRA flares

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 March 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 5.

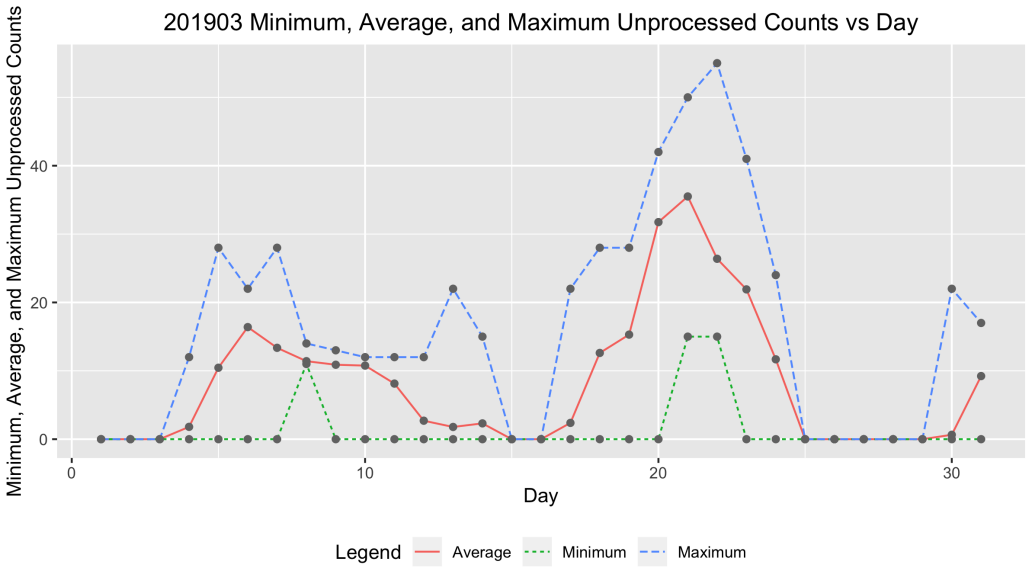

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

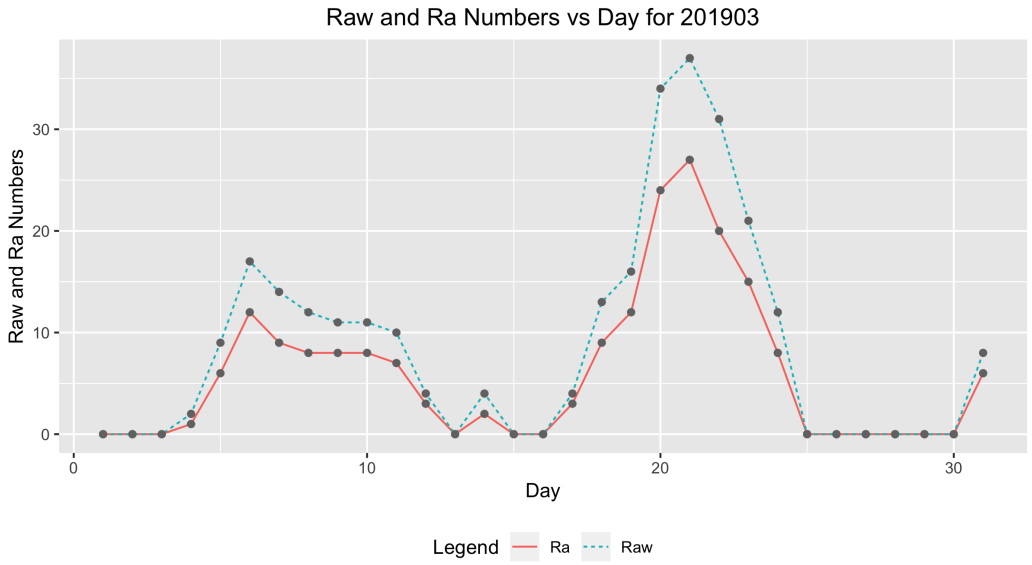

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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 (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: 201903 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	31	0	0
2	28	0	0
3	28	0	0
4	31	2	1
5	40	9	6
6	38	17	12
7	33	14	9
8	39	12	8
9	36	11	8
10	38	11	8
11	30	10	7
12	37	4	3
13	33	0	0
14	32	4	2
15	34	0	0

Continued

Table 2: 201903 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	40	0	0
17	39	4	3
18	44	13	9
19	44	16	12
20	40	34	24
21	30	37	27
22	39	31	20
23	44	21	15
24	44	12	8
25	41	0	0
26	43	0	0
27	37	0	0
28	38	0	0
29	35	0	0
30	34	0	0
31	39	8	6
Averges	36.7	8.7	6.1

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for March 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 64 and the total number of observations is 1139.

Table 3: 201903 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
AAX	19	Alexandre Amorim
AJV	25	J. Alonso
ARAG	30	Gema Araujo
ASA	24	Salvador Aguirre
ATE	24	Teofilo Arranz Heras
BARH	13	Howard Barnes
BATR	13	Roberto Battaiola
BERJ	29	Jose Alberto Berdejo
BMF	27	Michael Boschat
BRAD	27	David Branchett
BRAF	19	Raffaello Braga
BROB	23	Robert Brown
BSAB	19	Santanu Basu
CHAG	28	German Morales Chavez

Continued

Table 3: 201903 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
CKB	12	Brian Cudnik
CNT	20	Dean Chantiles
CVJ	13	Jose Carvajal
DEMF	11	Frank Dempsey
DIVA	19	Ivo Demeulenaere
DJOB	13	Jorge del Rosario
DMIB	29	Michel Deconinck
DROB	4	Bob Dudley
DUBF	22	Franky Dubois
EHOA	22	Howard Eskildsen
ERB	24	Bob Eramia
FERJ	26	Javier Ruiz Fernandez
FLET	16	Tom Fleming
FTAA	11	Tadeusz Figiel
HAYK	17	Kim Hay
HIVB	2	Ivan Hajdinjak
HOWR	21	Rodney Howe
HRUT	21	Timothy Hrutkay
JDAC	9	David Jackson
JENS	1	Simon Jenner
JGE	5	Gerardo Jimenez Lopez
JPG	3	Penko Jordanov
KAND	25	Kandilli Observatory
KAPJ	25	John Kaplan
KNJS	29	James & Shirley Knight
KROL	24	Larry Krozel
LEVM	17	Monty Leventhal
LKR	6	Kristine Larsen
LRRA	11	Robert Little
MARE	11	Enrico Mariani
MCE	22	Etsuiku Mochizuki
MILJ	13	Jay Miller
MJHA	24	John McCammon
MUDG	5	George Mudry
MWU	26	Walter Maluf
OAAA	21	Al Sadeem Astronomy Observator
OATS	6	Susan Oatney
ONJ	18	John O'Neill
SDOH	31	Solar Dynamics Obs - HMI
SMNA	7	Michael Stephanou
SNE	4	Neil Simmons
SONA	10	Andries Son
STAB	22	Brian Gordon-States

Continued

Table 3: 201903 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
SUZM	23	Miyoshi Suzuki
TESD	26	David Teske
TST	12	Steven Toothman
URBP	28	Piotr Urbanski
VARG	30	A. Gonzalo Vargas
VRUA	2	Ruben Verboven
WILW	20	William M. Wilson
Totals	1139	64

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 7 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.

4 Endnotes

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