Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

Rodney Howe, Kristine Larsen, Co-Chairs
c/o AAVSO, 49 Bay State Rd
Cambridge, MA 02138 USA

Web: http://www.aavso.org/solar-bulletin
Email: solar@aavso.org
ISSN 0271-8480

Volume 75 Number 12 December 2019

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 Images of the Annular Solar Eclipse from India

Figure 1: (left) Phases of the eclipse from Prabir Biswas, (right) End of the eclipse from Shouvik Ghosh

In the following Figure 1 image description: The image on the left was taken from Ooty, India, date: 26-12-2019, time: 0821 to 1015 HRS (IST), place: Ooty, state: Tamil Nadu, INDIA (`https://www.tourtravelworld.com/india/ooty/pykara-falls.htm`). The image on the right was taken from a small town in India, date: 26-12-2019, time: 10:37am (IST), place: a small hamlet, Kungumam Palayam Pirivu, near the town Tiruppur, state: Tamil Nadu, INDIA (`https://www.onefivenine.com/india/villages/Tiruppur/Palladam/K.ayyampalayam`). These images courtesy of Santanu Basu (BSAB), from his friends who made it to southern India from Kolkata, West Bengal.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

December 2019 (Figure 2): There were no SID events recorded here in Fort Collins, Colorado for the month of December, nor on the 20th of December, as the A8.7 solar flare was during the night-time. (Please note the y-axis values in these SID graphs are non-dimensional.)

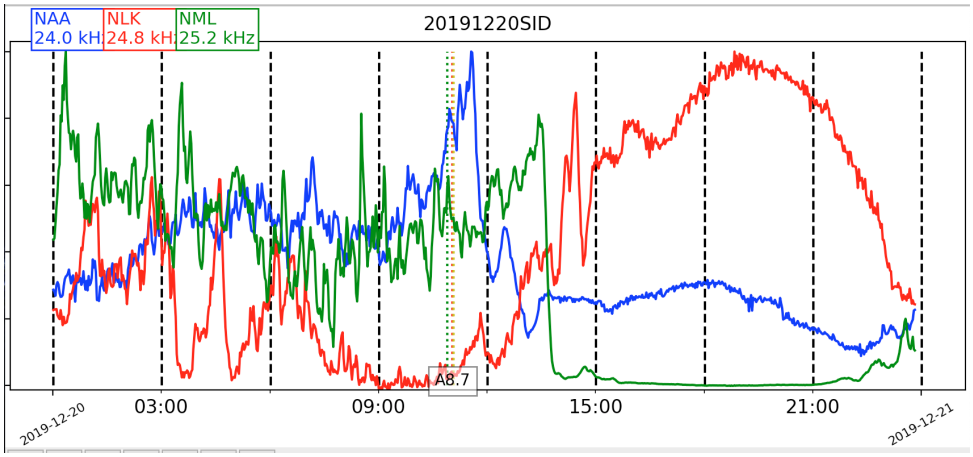

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In December 2019 we had 13 AAVSO SID observers who submitted VLF data as listed in Table 1. There were no observers who recorded SID events this month, which matched to GOES-15 XRA and FLA events.

Table 1: 201912 VLF Observers

Observer	Code	Stations
A McWilliams	A94	NML
J Wallace	A97	NAA
L Loudet	A118	DHO GBZ
J Godet	A119	GBZ
B Terrill	A120	NWC
F Adamson	A122	NWC
S Oatney	A125	NML NLK NAA
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
G Silvis	A141	HWU NAU
R Rogge	A143	GQD
K Menzies	A146	NAA

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.

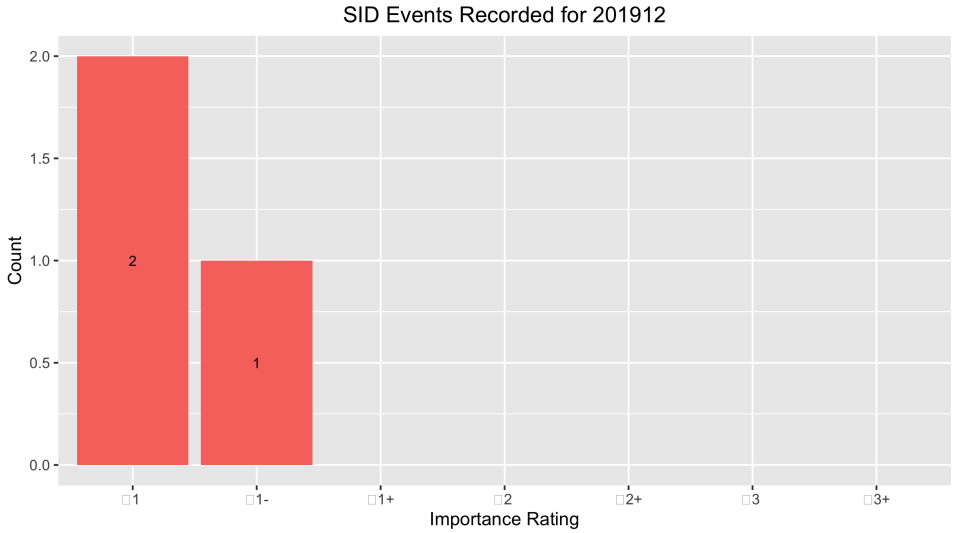

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-15 Data

In December 2019, there were four A-class flares recorded from GOES-15. A little less flaring this month compared to last. There were 27 days this month with no GOES-15 reports of flares (see Figure 4).

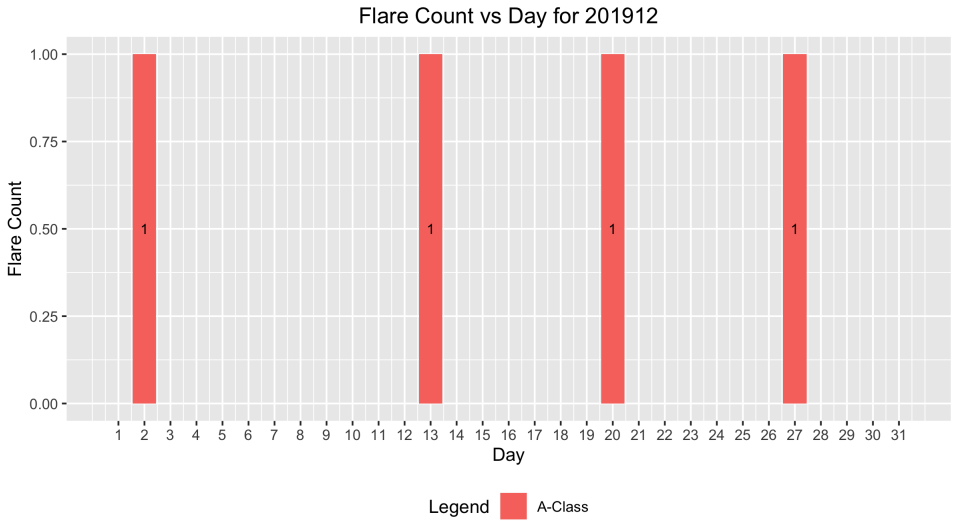

Figure 4: GOES - 15 XRA flares

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 December 2019. 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.

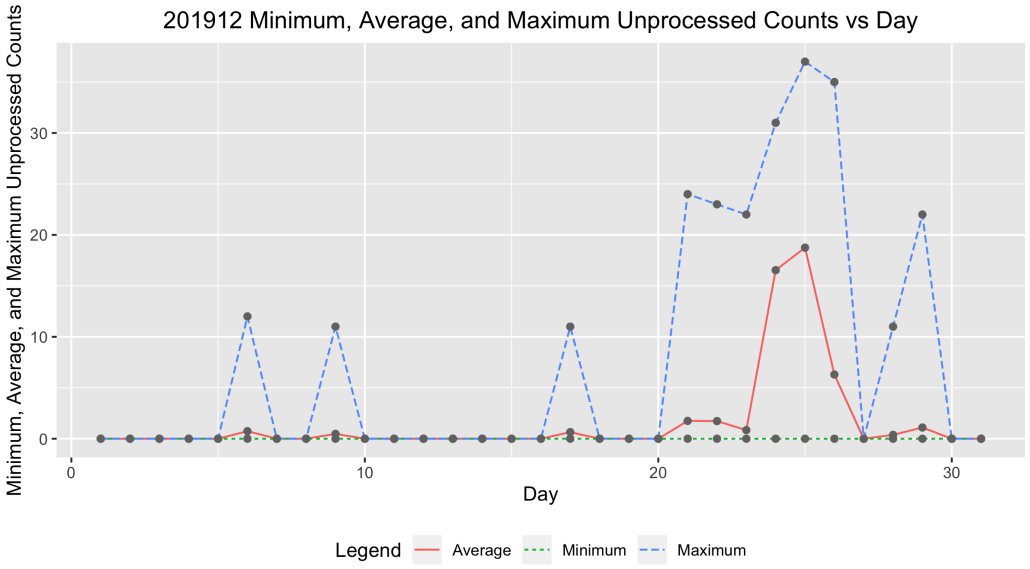

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

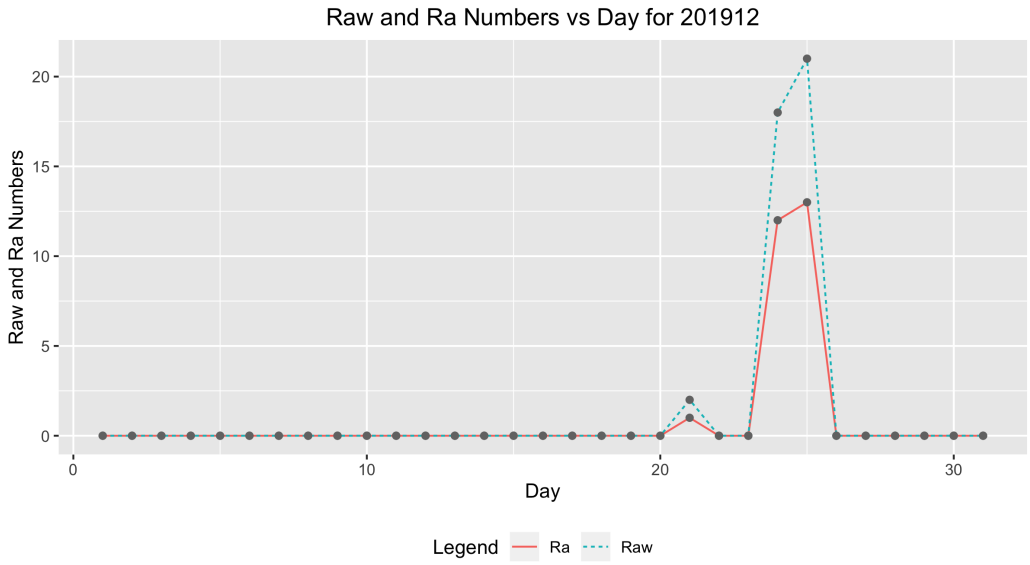

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 Observations (column 2), the raw Wolf number (column 3), and the Shapley Correction (R_a) (column 4).

Table 2: 201912 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	24	0	0
2	30	0	0
3	36	0	0
4	28	0	0
5	25	0	0
6	31	0	0
7	31	0	0
8	33	0	0
9	23	0	0
10	29	0	0
11	30	0	0
12	31	0	0
13	25	0	0
14	30	0	0

Continued

Table 2: 201912 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	37	0	0
16	26	0	0
17	17	0	0
18	32	0	0
19	25	0	0
20	27	0	0
21	28	2	1
22	26	0	0
23	26	0	0
24	35	18	12
25	28	21	13
26	27	0	0
27	25	0	0
28	29	0	0
29	30	0	0
30	28	0	0
31	31	0	0
Averages	28.5	1.3	0.8

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 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 62 and the total number of observations is 883.

Table 3: 201912 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
AAX	25	Alexandre Amorim
AJV	18	J. Alonso
ARAG	29	Gema Araujo
ASA	13	Salvador Aguirre
ATE	19	Teofilo Arranz Heras
BARH	12	Howard Barnes
BATR	2	Roberto Battaiola
BERJ	22	Jose Alberto Berdejo
BMF	20	Michael Boschat
BRAF	9	Raffaello Braga
BROB	18	Robert Brown
BSAB	23	Santanu Basu

Continued

Table 3: 201912 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
CHAG	26	German Morales Chavez
CIOA	11	Ioannis Chouinavas
CKB	15	Brian Cudnik
CNT	21	Dean Chantiles
CVJ	8	Jose Carvajal
DIVA	12	Ivo Demeulenaere
DJOB	12	Jorge del Rosario
DMIB	14	Michel Deconinck
DUBF	18	Franky Dubois
EHOA	12	Howard Eskildsen
ERB	1	Bob Eramia
FERJ	19	Javier Ruiz Fernandez
FLET	24	Tom Fleming
FLF	1	Fredirico Luiz Funari
FUJK	20	K. Fujimori
HAYK	9	Kim Hay
HMQ	16	Mark Harris
HOWR	17	Rodney Howe
HRUT	25	Timothy Hrutkay
JDAC	10	David Jackson
JGE	8	Gerardo Jimenez Lopez
KAND	17	Kandilli Observatory
KAPJ	10	John Kaplan
KNJS	31	James & Shirley Knight
KROL	2	Larry Krozel
LEVM	3	Monty Leventhal
LGEC	11	Georgios Lekkas
LKR	4	Kristine Larsen
LRRA	7	Robert Little
MARC	10	Arnaud Mengus
MARE	4	Enrico Mariani
MCE	21	Etsuiku Mochizuki
MILJ	11	Jay Miller
MJHA	28	John McCammon
MUDG	5	George Mudry
MWU	15	Walter Maluf
OAAA	5	Al Sadeem Astronomy Observatory
ONJ	13	John O'Neill
RLM	7	Mat Raymonde
SDOH	31	Solar Dynamics Obs - HMI
SNE	6	Neil Simmons
STAB	25	Brian Gordon-States
SUZM	22	Miyoshi Suzuki

Continued

Table 3: 201912 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
TESD	18	David Teske
TST	1	Steven Toothman
URBP	9	Piotr Urbanski
VARG	27	A. Gonzalo Vargas
VIDD	7	Daniel Vidican
VRUA	12	Ruben Verboven
WILW	12	William M. Wilson
Totals	883	62

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

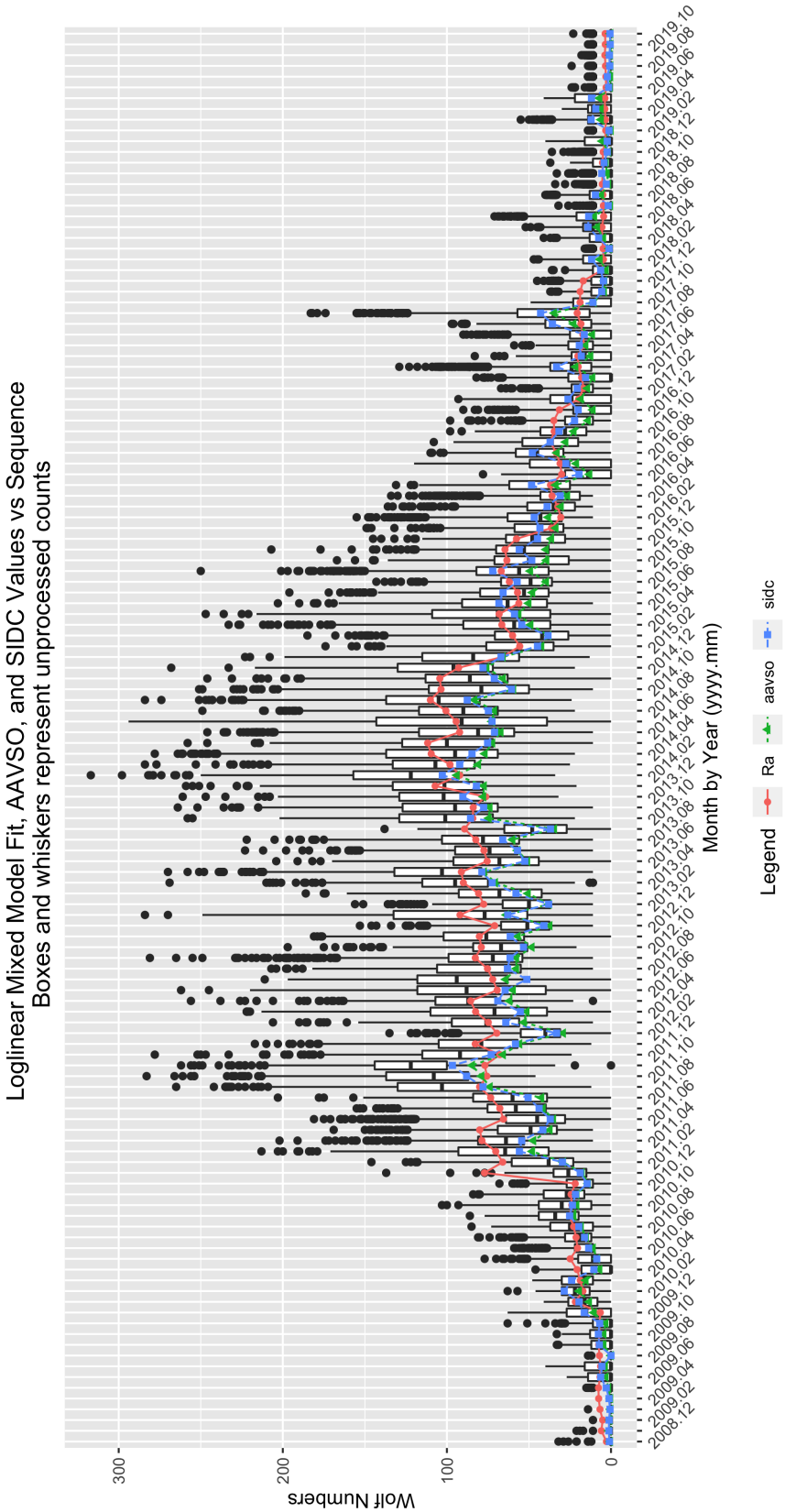

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels