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.

Figure 1: Sunrise seen with fog, dust and clouds show some poor seeing for counting sunspots: Susan Oatney (OATS), Partridge Kansas. However, it is important to submit sunspot counts when conditions are poor.

1 Wolf Number Affected by Seeing Conditions?

The answer to asking if seeing conditions affect the observed Wolf number seems an obvious yes: after all, usually the thicker the cloud cover, the fewer the number of sunspots and sunspot groups that are countable. A better question is: Are the *calculated* Wolf numbers affected by seeing conditions? This question is more exact because the calculated Wolf numbers are determined from the submitted monthly sunspot and sunspot group counts. Statistical methods are used to derive Wolf numbers from these observed counts, and the statistical methods must account for the seeing conditions. We begin our exploratory analysis with how to read the box plots in Figures 2 and 3.

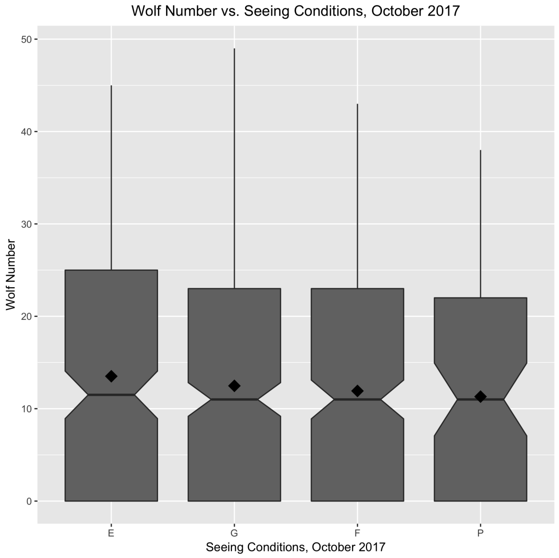

Figure 2: The October 2017 Wolf numbers for E (n=236), G (n=398), F (n=300), and P (n=78).

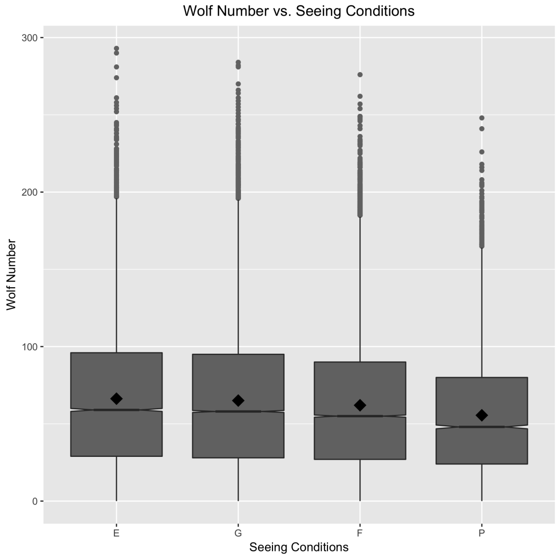

Figure 3: The May 2010 through October 2017 Wolf numbers for E (n=12,014), G (n=27,463), F (n=19,597), and P (n=5,194).

Figures 1 and 2. Seeing condition levels are E = Excellent, G = good, F = fair, and P = poor.

For each of the box plots in Figures 2 and 3, the boxes with whiskers span the range of observed Wolf numbers for each seeing condition level (Excellent, Good, Fair and Poor). Figure 2 are the observed Wolf numbers for October 2017, and Figure 3 are the observed Wolf numbers for the span of from May 2010 through October 2017. The heavy solid lines approximately midway in the gray boxes represent the Wolf number medians. Opening outwards from either side of the median lines are notches whose size at the box sides represent an approximate 95% confidence interval for the medians. The diamonds in the boxes represent the Wolf number averages calculated from the observed Wolf numbers. The upper and lower edges of the boxes represent the Inter-Quartile Range (IQR), which depicts the 25th through the 75th quartiles of the observed Wolf numbers. The lower and upper whiskers extend as much as 1.5 times the IQR below the 25^{th} quartiles, and 1.5 times the IQR above the 75^{th} quartile. Any black circles below or above the whiskers are beyond approximately 95% of all the observed Wolf numbers for the seeing condition levels,

Let's return to the question of whether the seeing conditions affect the magnitude of the calculated Wolf numbers; i.e., are the median Wolf numbers the same for each level of the seeing conditions? For the October data, the box plot median confidence interval sizes in Figure 2 give us a depiction of the equivalence of the medians. If we make pairwise comparisons of the four seeing condition levels, we note that the confidence notches for any pairing of levels overlap. Overlapping notches indicate that the medians are equivalent; i.e., there is no statistical evidence that the medians are different. Hence, we may conclude that the October 2017 median Wolf numbers for each of the seeing condition levels is the same.

The notches in Figure 3 do not overlap. The obvious reason is the difference in the number of Wolf number submissions. The October data consist of 1,012 observations spanning one month while the multi-year data have 64,268 observations spanning ninety months. The additional data disallow combinations of pairwise comparisons of the seeing condition median Wolf number confidence intervals to overlap, and hence we reject that the median Wolf numbers are equivalent. Excellent seeing gives a median Wolf number statistically larger than the median Wolf number for good seeing, good seeing gives a statistically higher Wolf number than fair seeing, and so on for all the other possible pairwise comparisons.

Do larger sample sizes imply that the seeing condition level medians will always show statistically significant differences? The answer is that it depends on the statistical method used to analyze the data. Our simple exploratory analysis above does not consider the influences due to observer, observer equipment, position in the eleven-year solar cycle, and other effects that may influence the Wolf numbers submitted. A class of statistical models exists that are designed explicitly for counts data such as Wolf numbers. (Recall that Wolf number are equal to 10 times the number of counted sunspot groups plus the count of all the sunspots.) Use of counts models can identify the specific role of seeing conditions, as well as any other effects like observer, such that all the other effects and the sample size have an accurate accounting, resulting in Wolf numbers adjusted for these effects. A future article will describe how the class of counts models treat observer differences.

Regardless of the statistical model used to determine monthly Wolf numbers, no model is effective if there are no data. This is particularly true in times of sunspot minimum. Daily sunspot observations of even zero counts, along with the seeing conditions, allow counts models to segregate influencing effects including seeing conditions, as well as permit determination of minimum onset and minimum end. Also, unusual or unexpected solar disturbances may be identified. No data, no model, no monthly Wolf numbers.

I welcome questions and comments on the statistical analysis of Wolf numbers. You may contact me at jamie.riggs@northwestern.edu.

2 Sudden Ionospheric Disturbance (SID) Report

Sudden ionospheric disturbances (SID) occur in Earth's atmosphere by solar flares, causing large increases in the ionization in the ionosphere over the daytime regions of the Earth. Here we show how a 24 bit external sound card can be used to record VLF SID data without a receiver or any electric amplification: (`https://www.asus.com/us/Sound-Cards/Xonar_U5/`) I bought one of these because an electrical engineer, Nathan Towne, who works at the NRAO Very Large Array in New Mexico has written Python software for it: (`http://myplace.frontier.com/~nathan56/sidmon/sidmon.html#equipment`) I put the SID loop antenna right into the mic input of the Xonar, no need for amplification (SuperSID or otherwise).

2.1 SID Records

November 2017 (Figure 4) Very few, if any B class flares will show up on our VLF SID graphs. There were two small B class flares on the 12th of November, and they were during the day-time hours here in Fort Collins, Colorado, however, you can see there were no VLF SID Events recorded in the ionosphere:

1680 + 2000 2020 2029 G15 5 XRA 1-8A B1.8 2.4E-04

1690 + 2256 2300 2303 G15 5 XRA 1-8A B2.4 6.2E-05

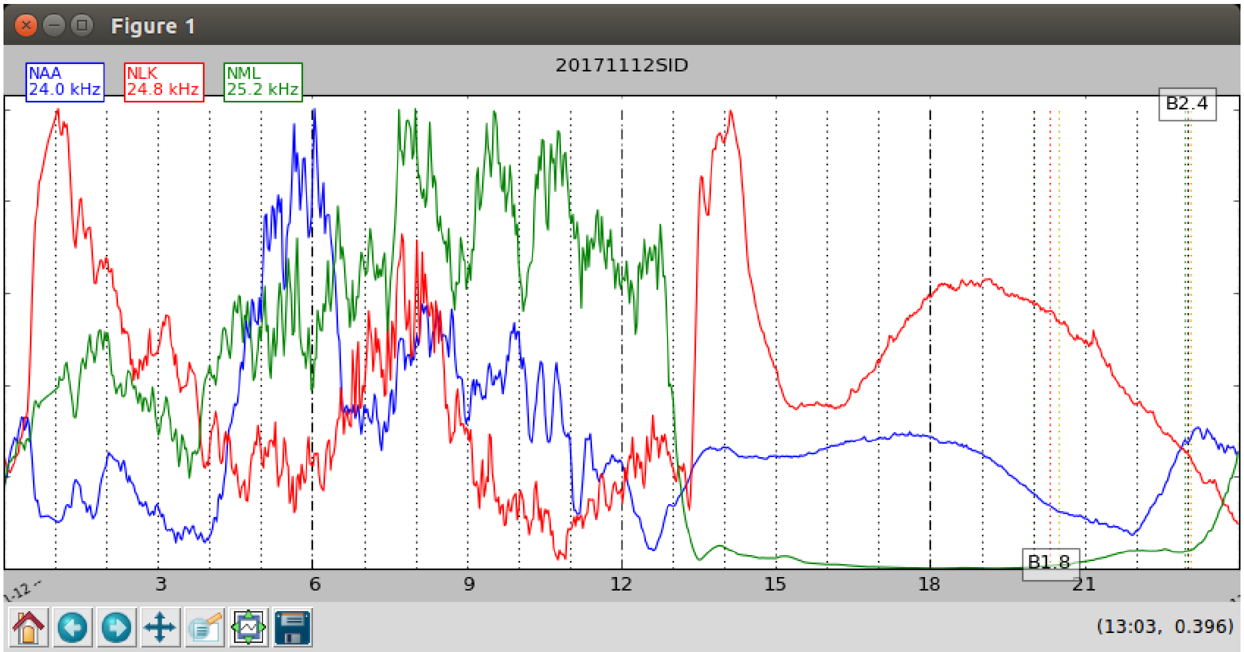

Figure 4: VLF recording using the sidmon.py software from Nathan Towne.

2.2 SID Observers

In November 2017 we have 18 AAVSO SID observers who submitted VLF data as listed in Table 1. Observers monitor from one to three stations to provide SID data.

Table 1: 201711 VLF Observers

Observer	Code	Stations
A McWilliams	A94	NML
R Battaiola	A96	ICV
J Wallace	A97	NAA
L Loudet	A118	GBZ
J Godet	A119	GBZ GQD ICV
B Terrill	A120	NWC
F Adamson	A122	NWC
S Oatney	A125	NML
J Karlovsky	A131	DHO NSY
R Green	A134	NWC
R Mrllak	A136	GQD NSY
S Aguirre	A138	NPM
G Silvis	A141	NAA
I Ryumshin	A142	ICV DHO
R Rogge	A143	DHO GQD ICV
K Menzies	A146	NAA
D Russel	A147	NML
L Ferreira	A149	NWC

Figure 5 depicts the importance rating of the solar events. The durations 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.

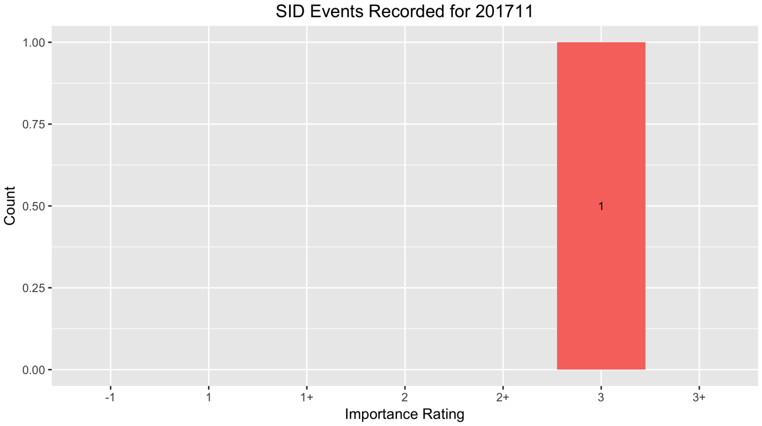

Figure 5: Solar Events Y-axis, Importance Rating X-axis.

2.3 Solar Flare Summary from GOES-15 Data

In November 2017, There were 14 solar flares measured by GOES-15. (see Figure 6). 14 B class flares. Far less flaring this month compared to last month. There were 20 days this month with no GOES-15 reports of flares.

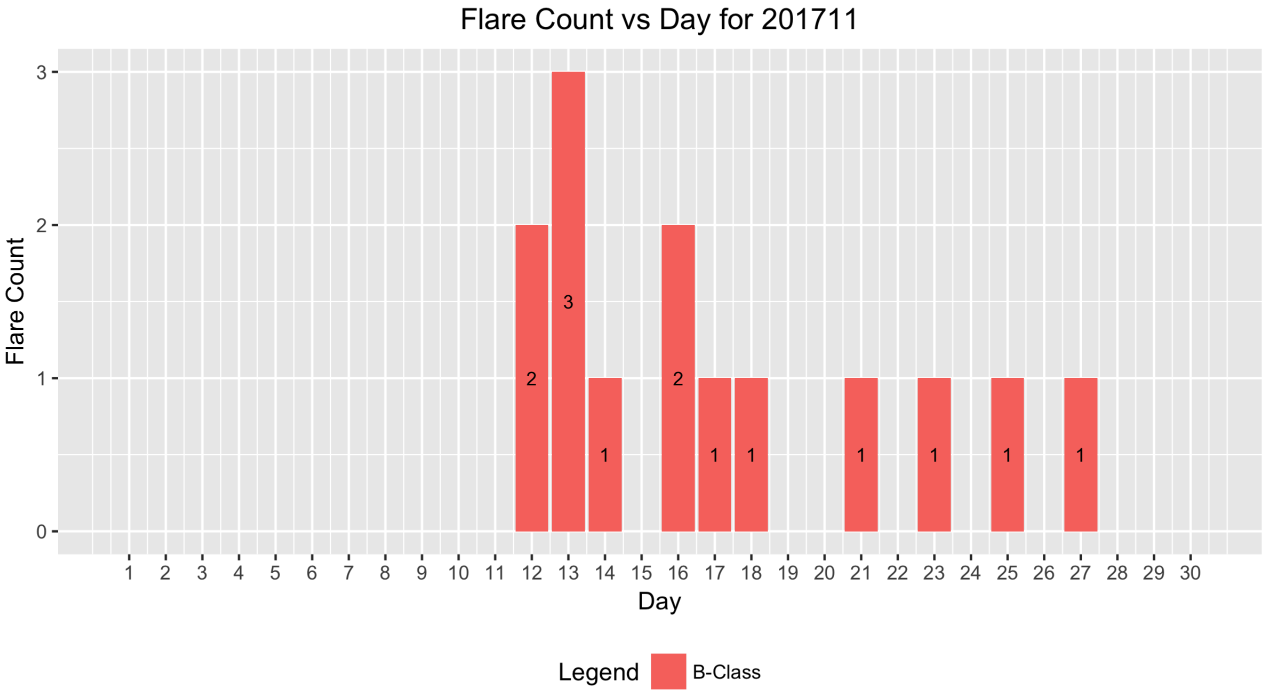

Figure 6: GOES - 15 XRA flares

3 Relative Sunspot Numbers (Ra)

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 November 2017. 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 8.

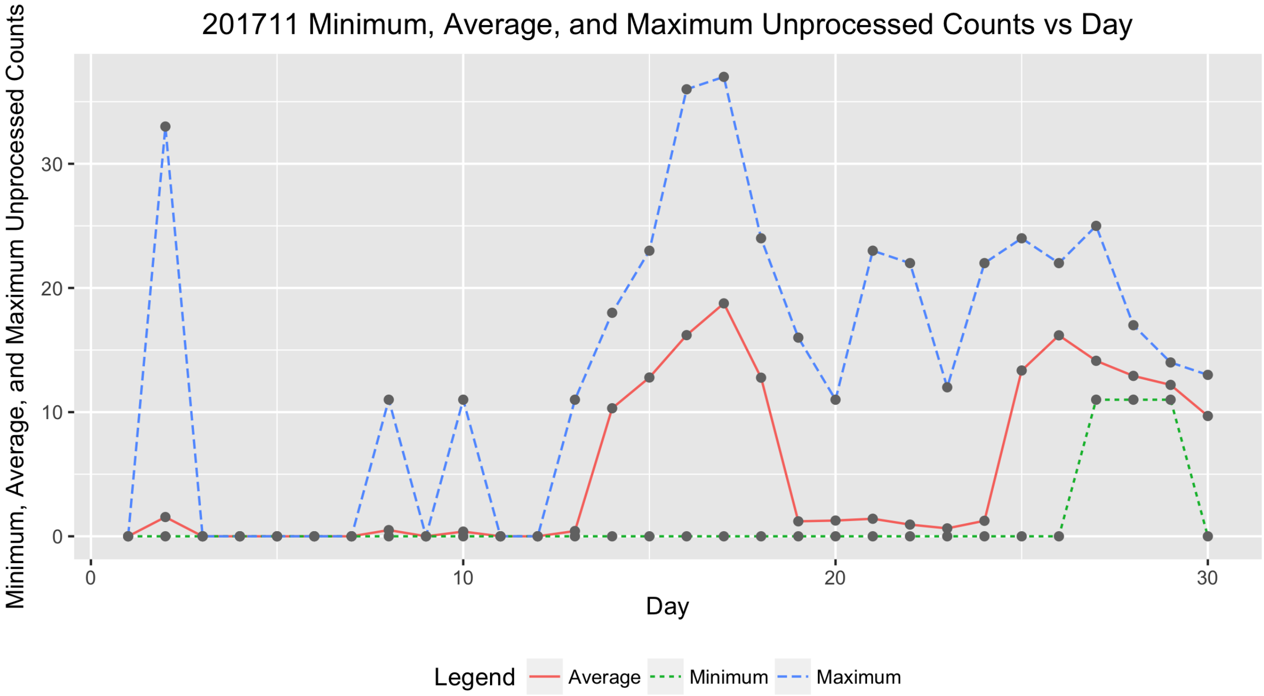

Figure 7: Raw average, minimum and maximum counts by day of the month by observer.

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. See Table 2.

Table 2: 201711 American Relative Sunspot Numbers (Ra)

Day	NumObs	Raw	Ra
1	30	0	0
2	29	1	0
3	30	0	0
4	25	0	0
5	30	0	0
6	25	0	0
7	26	0	0
8	22	0	0
9	32	0	0
10	29	0	0
11	34	0	0
12	32	0	0
13	26	0	0
14	29	10	8
15	33	13	11

Continued

Table 2: 201711 American Relative Sunspot Numbers (Ra)

Day	NumObs	Raw	Ra
16	30	15	13
17	33	19	15
18	31	11	10
19	34	0	0
20	26	1	1
21	29	1	1
22	35	1	0
23	36	1	0
24	36	1	1
25	34	13	11
26	38	17	14
27	30	15	13
28	37	13	11
29	36	12	10
30	29	9	8
Averges	30.9	5.1	4.2

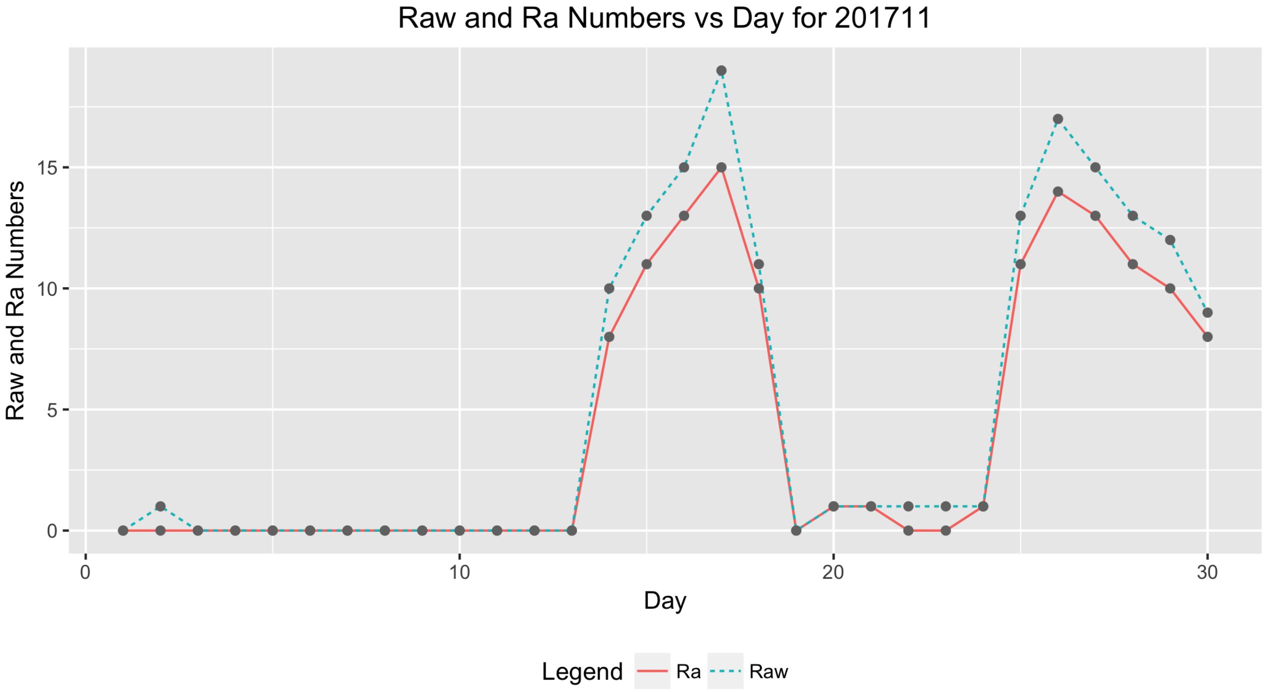

Figure 8: Raw Wolf and Ra numbers by day of the month by observer.

3.3 Sunspot Observers

Table 3 lists the observer code (obs), the number of observations submitted for November 2017, and the observer's name. 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 60 and the total number of observations is 926.

Table 3: 201711 Number of observations by observer

Obs	NumObs	Name
AAX	17	Alexandre Amorim
AJV	23	J. Alonso
ARAG	29	Gema Araujo
ASA	27	Salvador Aguirre
BARH	13	Howard Barnes
BATR	4	Roberto Battaiola
BERJ	27	Jose Alberto Berdejo
BMF	22	Michael Boschat
BRAF	9	Raffaello Braga
BROB	20	Robert Brown
BSAB	29	Santanu Basu
CHAG	28	German Morales Chavez
CIOA	22	Ioannis Chouinavas
CKB	23	Brian Cudnik
CNT	4	Dean Chantiles
CVJ	18	Jose Carvajal
DEMF	1	Frank Dempsey
DJOB	10	Jorge del Rosario
DROB	6	Bob Dudley
DUBF	23	Franky Dubois
FERJ	20	Javier Ruiz Fernandez
FLET	23	Tom Fleming
FLF	11	Fredirico Luiz Funari
FUJK	22	K. Fujimori
HAYK	3	Kim Hay
HOWR	21	Rodney Howe
JDAC	15	David Jackson
JGE	4	Gerardo Jimenez Lopez
JPG	1	Penko Jordanov
KAPJ	13	John Kaplan
KNJS	30	James & Shirley Knight
KROL	19	Larry Krozel
LEVM	18	Monty Leventhal
LKR	3	Kristine Larsen
LRRA	22	Robert Little
MCE	21	Etsuiku Mochizuki
MILJ	9	Jay Miller
MJAF	30	Juan Antonio Moreno Quesada

Continued on next page

Table 3: 201711 Number of observations by observer

Obs	NumObs	Name
MJHA	28	John McCammon
MMAV	9	Marcelino Vzquez
MUDG	12	George Mudry
MWU	8	Walter Maluf
ONJ	3	John O'Neill
RLM	12	Mat Raymonde
SDOH	30	Solar Dynamics Obs - HMI
SIMC	5	Clyde Simpson
SMNA	2	Michael Stephanou
SNE	7	Neil Simmons
SONA	10	Andries Son
SPIA	3	Piotr Skorupski
STAB	28	Brian Gordon-States
SUZM	27	Miyoshi Suzuki
TESD	24	David Teske
TPJB	5	Patrick Thibault
URBP	7	Piotr Urbanski
VARG	27	A. Gonzalo Vargas
VIDD	6	Dan Vidican
WCHD	12	Charles White
WILW	18	William M. Wilson
WRP	3	Russell Wheeler
Totals	926	60

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 the sunspot counts research page. The paper title is *A Generalized Linear Mixed Model for Enumerated Sunspots.*

Figure 9 shows the monthly GLMM R_a 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 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

Reporting Addresses

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

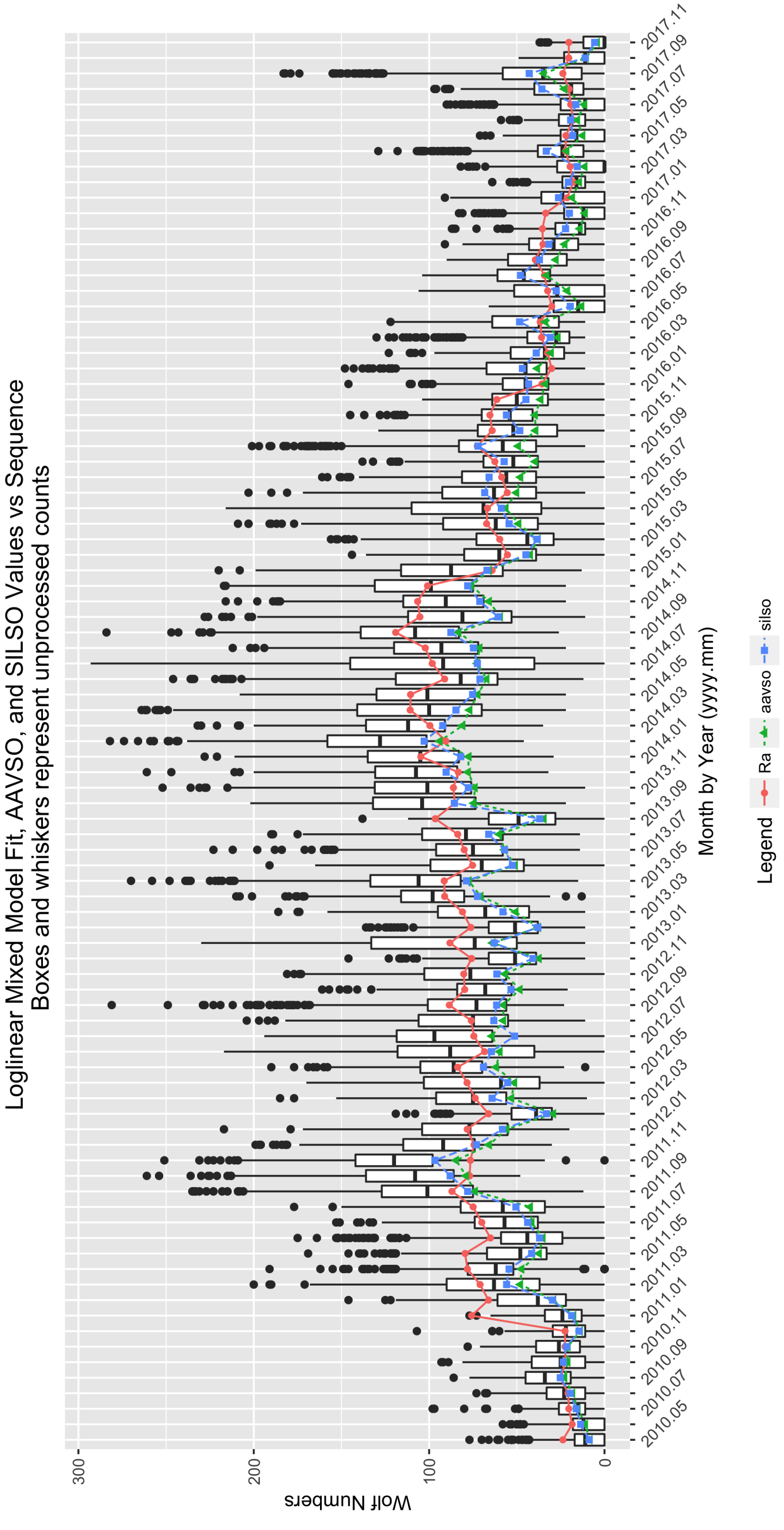

Figure 9: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels