

**Monthly Report (00)**  
**201905 Data Set**

**Wednesday 12<sup>th</sup> June, 2019**

**Prepared for**

**Statistics for Physical and Engineering Sciences**

**by**

**Jamie Riggs, Ph.D.**

Principal Statistician  
Statistics for Physical and Engineering Sciences Institute



## 1 Introduction

The process of reporting monthly Sunspot numbers consists of submitting 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 using the R statistics package (<http://www.R-project.org/>). This report is the portion of the analysis concerned with both the raw daily average counts and the data Accuracy, Consistency, and Completeness measures for a particular month. The checks are used to scrub or filter the data to assure only error-free data are used to determine the monthly sunspot number.

This report consists of four sections: the raw daily average counts (Section 2), the known data errors (Section 3), the processed counts using a Generalized Linear Mixed Model to produce the relative sunspot numbers (Section 4), and supporting information on the model construction (Section 5).

The raw daily average of counts consist of submitted counts from all observers who provided data in the particular month. These averaged counts are reported by the day of the month, and are either from data not scrubbed or corrected data. The table captions indicate which. The errors, if any, are reported according to type.

The Error Tables section contains reported errors on missing data, inconsistencies in year and month, inconsistencies in the reported day number (1-31), seeing coding errors, number of annual observations by observer, and inconsistencies between the reported Wolf number and the calculated Wolf number from the group counts and sunspot counts, among other errors that are given in that section.

The relative sunspot numbers  $R_a$  section contains the sunspot numbers after the submitted data are scrubbed and modeled by a Generalized Linear Mixed Model (GLMM). The GLMM is a statistical model that accounts for variation due to random effects and fixed effects. For the  $R_a$  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*.

The supporting information for the model is provided for clarification.

## 2 Raw Daily Average Counts

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 1 and Table 1.

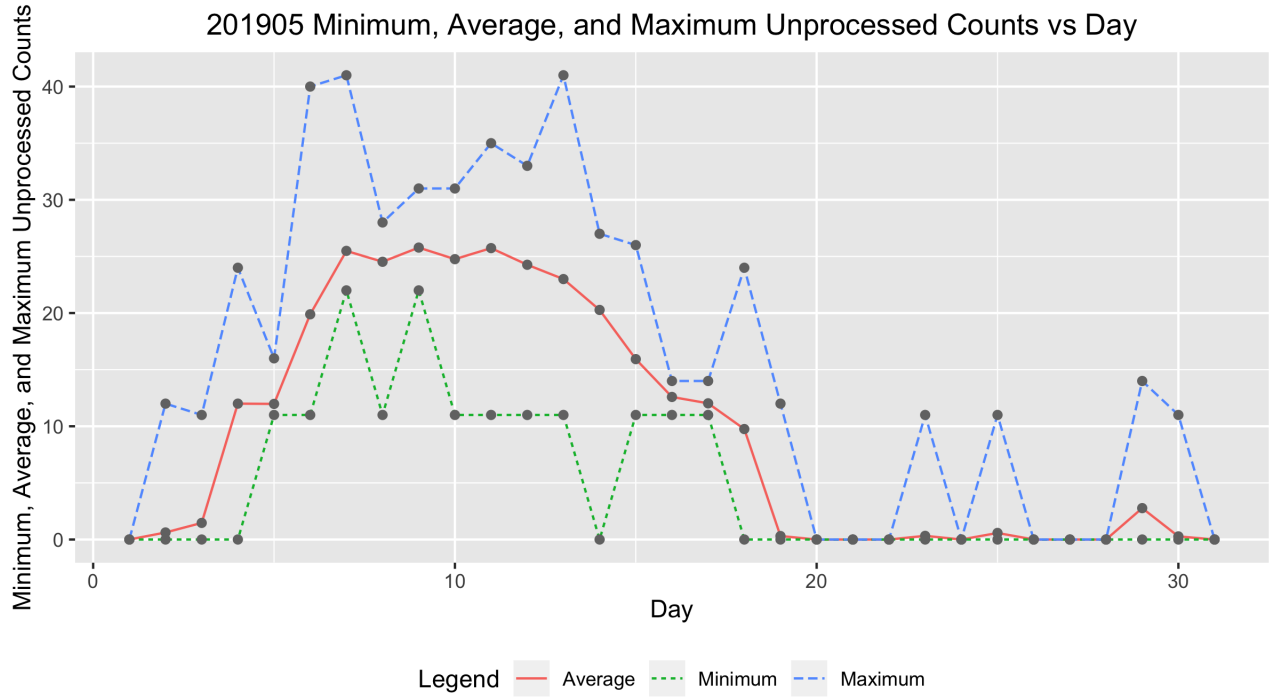


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201905 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	36.0000	0.0000	0.0000	0.0000
2.0000	37.0000	0.0000	0.6216	12.0000
3.0000	30.0000	0.0000	1.4667	11.0000
4.0000	34.0000	0.0000	12.0000	24.0000
5.0000	41.0000	11.0000	11.9756	16.0000
6.0000	45.0000	11.0000	19.8889	40.0000
7.0000	41.0000	22.0000	25.4878	41.0000
8.0000	36.0000	11.0000	24.5278	28.0000
9.0000	32.0000	22.0000	25.7812	31.0000
10.0000	29.0000	11.0000	24.7586	31.0000
11.0000	45.0000	11.0000	25.7333	35.0000
12.0000	38.0000	11.0000	24.2632	33.0000
13.0000	39.0000	11.0000	23.0000	41.0000
14.0000	44.0000	0.0000	20.2727	27.0000
15.0000	42.0000	11.0000	15.9286	26.0000
16.0000	39.0000	11.0000	12.5897	14.0000
17.0000	36.0000	11.0000	12.0278	14.0000
18.0000	37.0000	0.0000	9.7568	24.0000
19.0000	39.0000	0.0000	0.3077	12.0000
20.0000	35.0000	0.0000	0.0000	0.0000
21.0000	42.0000	0.0000	0.0000	0.0000
22.0000	34.0000	0.0000	0.0000	0.0000
23.0000	34.0000	0.0000	0.3235	11.0000
24.0000	38.0000	0.0000	0.0000	0.0000
25.0000	38.0000	0.0000	0.5789	11.0000
26.0000	40.0000	0.0000	0.0000	0.0000
27.0000	42.0000	0.0000	0.0000	0.0000
28.0000	35.0000	0.0000	0.0000	0.0000
29.0000	35.0000	0.0000	2.7714	14.0000
30.0000	40.0000	0.0000	0.2750	11.0000
31.0000	40.0000	0.0000	0.0000	0.0000

### 3 Error Tables

Data are for the month of May 2019. No errors were found, and hence no errors are reported.

### 4 Relative Sunspot Numbers

All data errors, if any, have been corrected prior to determining the following relative sunspot numbers. A Generalized Linear Mixed Model (GLMM) was constructed to provide monthly sunspot numbers (see Table 2). The GLMM treats observer as a random effect, with year, month, seeing conditions, observer rank, and dual submission to both AAVSO and SILSO as fixed effects.

Figure 2 shows the monthly  $R_a$  numbers for the years and months (ym) in Table 2. The solid cyan curve that connects the cyan X's are the GLMM model estimates given in 2. 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 dashed red curve connecting the red O's are the SILSO values for the monthly sequence.

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 of the box plot represents the InterQuartile Range (IQR), which depicts from the 25<sup>th</sup> through the 75<sup>th</sup> quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25<sup>th</sup> quartile, and 1.5 times the IQR above the 75<sup>th</sup> quartile. The black circles below and above the whiskers traditionally are considered outliers, but with GLMM modeling, they are observations that comprise overdispersion. Overdispersion skews the counts data from a true Poisson distribution. The GLMM adjusts for this overdispersion.

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2008.12	2.7705	2.4095	3.1315	0.5000	1.0000
2009.01	5.8276	5.1997	6.4556	1.3000	1.3000
2009.02	5.0531	4.4938	5.6124	0.7000	1.2000
2009.03	6.6274	6.3632	6.8915	0.3000	0.6000
2009.04	7.4354	7.1618	7.7090	0.4000	1.2000
2009.05	7.5579	7.2506	7.8652	1.6000	2.9000
2009.06	6.6881	6.3430	7.0332	3.2000	6.3000
2009.07	6.3814	6.1195	6.6434	3.6000	5.5000
2009.08	7.0630	6.7762	7.3499	0.0000	0.0000
2009.09	7.5521	7.2770	7.8272	4.5000	7.1000
2009.10	7.0581	6.6791	7.4371	4.5000	7.7000
2009.11	7.0185	6.8255	7.2115	3.3000	6.9000
2009.12	6.5099	6.3246	6.6952	10.4000	16.3000
2010.01	21.4910	19.0554	23.9266	13.3000	19.5000
2010.02	16.9420	14.6495	19.2346	19.4000	28.5000

Continued on next page

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2010.03	18.5170	16.2297	20.8044	15.4000	24.0000
2010.04	20.5181	18.1097	22.9264	7.0000	10.4000
2010.05	24.6032	24.1679	25.0384	8.4000	8.7000
2010.06	20.4169	20.0776	20.7562	11.0000	13.6000
2010.07	21.3514	21.0420	21.6608	15.2000	16.1000
2010.08	22.8454	22.4708	23.2200	18.3000	19.6000
2010.09	25.3608	24.9431	25.7785	22.8000	25.2000
2010.10	23.9802	23.5666	24.3939	21.0000	23.5000
2010.11	24.4250	23.9816	24.8684	20.9000	21.6000
2010.12	21.7316	21.2942	22.1689	13.9000	14.5000
2011.01	76.4091	74.8299	77.9884	17.7000	18.7000
2011.02	65.4229	64.0279	66.8179	29.1000	29.6000
2011.03	69.5851	68.2584	70.9117	48.0000	55.8000
2011.04	77.9459	76.5467	79.3451	47.3000	54.4000
2011.05	79.3674	78.0263	80.7086	37.3000	41.5000
2011.06	65.8604	64.7071	67.0137	35.2000	37.0000
2011.07	68.1758	67.0098	69.3419	41.5000	43.8000
2011.08	73.8112	72.6233	74.9991	42.4000	50.5000
2011.09	80.5564	79.1655	81.9473	73.8000	78.0000
2011.10	76.2061	74.9245	77.4877	78.9000	88.0000
2011.11	77.3902	75.7749	79.0054	84.6000	96.7000
2011.12	67.7624	66.3673	69.1576	65.8000	73.0000
2012.01	81.9940	80.3833	83.6048	55.8000	58.2000
2012.02	69.0263	67.6241	70.4286	29.2000	33.1000
2012.03	74.1066	72.7955	75.4177	53.1000	64.1000
2012.04	81.7866	80.3585	83.2146	51.4000	55.2000
2012.05	84.8748	83.4771	86.2726	61.8000	69.0000
2012.06	69.7318	68.5485	70.9151	59.7000	64.5000
2012.07	72.5818	71.3931	73.7706	64.2000	51.3000
2012.08	75.7890	74.5741	77.0039	57.7000	63.1000
2012.09	83.2505	81.8078	84.6933	57.7000	61.5000
2012.10	79.5953	78.1411	81.0494	48.3000	53.3000
2012.11	80.8141	79.1947	82.4335	56.7000	61.4000
2012.12	70.9350	69.3975	72.4724	37.4000	40.8000
2013.01	91.1682	89.4282	92.9083	63.8000	62.9000
2013.02	76.9103	75.3652	78.4555	37.8000	38.0000
2013.03	79.9660	78.3436	81.5884	50.6000	57.9000
2013.04	89.2030	87.6385	90.7675	70.6000	72.4000
2013.05	90.4692	88.8628	92.0755	77.4000	78.7000

Continued on next page

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2013.06	75.8502	74.5116	77.1888	51.0000	52.5000
2013.07	77.9702	76.7205	79.2199	57.0000	57.0000
2013.08	82.9622	81.6306	84.2938	60.0000	66.0000
2013.09	89.8382	88.2379	91.4384	34.6000	36.9000
2013.10	84.8451	83.2745	86.4157	74.5000	85.6000
2013.11	84.5810	82.6867	86.4753	73.9000	77.6000
2013.12	76.3477	74.7197	77.9756	77.8000	90.3000
2014.01	106.2155	103.9842	108.4469	77.4000	82.0000
2014.02	91.3856	89.5884	93.1827	93.9000	102.8000
2014.03	97.2433	95.4755	99.0110	80.9000	92.2000
2014.04	108.6436	106.7497	110.5374	76.9000	84.7000
2014.05	110.8763	108.9873	112.7654	72.3000	75.2000
2014.06	92.7505	91.1851	94.3160	67.2000	71.0000
2014.07	95.0443	93.4649	96.6236	72.5000	72.5000
2014.08	101.2949	99.7147	102.8751	71.2000	74.7000
2014.09	110.8324	108.8812	112.7835	83.2000	87.6000
2014.10	104.3449	102.4259	106.2639	59.5000	60.6000
2014.11	105.0752	102.8904	107.2600	65.8000	71.1000
2014.12	92.8931	90.7421	95.0442	75.8000	78.0000
2015.01	65.6811	64.3676	66.9946	65.9000	67.0000
2015.02	55.1303	53.9174	56.3433	42.4000	44.8000
2015.03	59.4363	58.3494	60.5232	38.0000	38.4000
2015.04	65.9573	64.7757	67.1390	49.0000	54.4000
2015.05	67.6322	66.5145	68.7500	56.3000	58.8000
2015.06	56.4640	55.4457	57.4822	50.2000	68.3000
2015.07	57.3630	56.3838	58.3422	47.9000	65.8000
2015.08	62.3779	61.3298	63.4261	39.5000	57.2000
2015.09	67.3598	66.1355	68.5842	49.2000	72.1000
2015.10	63.9252	62.6909	65.1595	39.3000	48.3000
2015.11	65.0820	63.6700	66.4940	39.6000	55.9000
2015.12	57.6150	56.3509	58.8792	36.4000	44.8000
2016.01	35.9556	35.2057	36.7055	33.7000	43.3000
2016.02	30.3144	29.6827	30.9461	38.3000	46.8000
2016.03	32.1598	31.5185	32.8011	30.5000	38.9000
2016.04	35.5952	34.9170	36.2733	26.6000	30.9000
2016.05	36.5844	35.9161	37.2528	33.7000	48.4000
2016.06	30.2109	29.6956	30.7261	13.1000	19.5000
2016.07	31.2506	30.7483	31.7528	21.2000	27.5000
2016.08	33.6192	33.0280	34.2103	33.0000	47.9000

Continued on next page



Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2016.09	37.1687	36.4904	37.8470	27.7000	37.1000
2016.10	34.8670	34.1948	35.5392	22.7000	31.7000
2016.11	35.1023	34.3690	35.8357	14.0000	22.2000
2016.12	31.4676	30.7958	32.1394	11.1000	20.0000
2017.01	19.5624	19.1514	19.9734	18.4000	26.2000
2017.02	16.5594	16.1962	16.9227	14.4000	20.6000
2017.03	17.7202	17.3830	18.0574	11.3000	15.5000
2017.04	19.8256	19.4762	20.1750	21.6000	33.2000
2017.05	20.0468	19.7011	20.3925	12.5000	18.1000
2017.06	16.5654	16.2892	16.8415	15.5000	19.3000
2017.07	17.2160	16.9424	17.4895	11.5000	16.3000
2017.08	18.4573	18.1391	18.7755	22.8000	35.7000
2017.09	20.6867	20.2743	21.0991	34.6000	42.9000
2017.10	18.9750	18.5962	19.3538	10.5000	11.0000
2017.11	18.9546	18.5598	19.3493	4.2000	5.6000
2017.12	16.9011	16.6457	17.1566	4.0000	4.6000
2018.01	5.4204	5.3043	5.5365	3.1000	6.3000
2018.02	4.5474	4.4376	4.6572	6.8000	11.8000
2018.03	4.7803	4.6852	4.8754	1.1000	1.2000
2018.04	5.2998	5.1944	5.4052	4.7000	7.5000
2018.05	5.4749	5.3714	5.5784	8.4000	14.0000
2018.06	4.5178	4.4372	4.5984	10.2000	13.6000
2018.07	4.6892	4.6368	4.7417	0.5000	1.7000
2018.08	4.9778	4.8918	5.0638	5.9000	9.5000
2018.09	5.3767	5.2767	5.4768	1.6000	2.9000
2018.10	5.1900	5.0896	5.2904	2.5000	5.6000
2018.11	5.2152	5.1072	5.3233	3.1000	4.2000
2018.12	4.7552	4.6610	4.8494	1.6000	2.3000
2019.01	7.6592	7.5140	7.8045	5.4000	2.3000
2019.02	6.5997	6.4685	6.7308	0.1000	1.2000
2019.03	6.8487	6.7312	6.9662	6.1000	12.1000
2019.04	7.6490	7.5062	7.7919	6.2000	9.3000
2019.05	7.6049	7.4731	7.7367	7.0000	11.9000

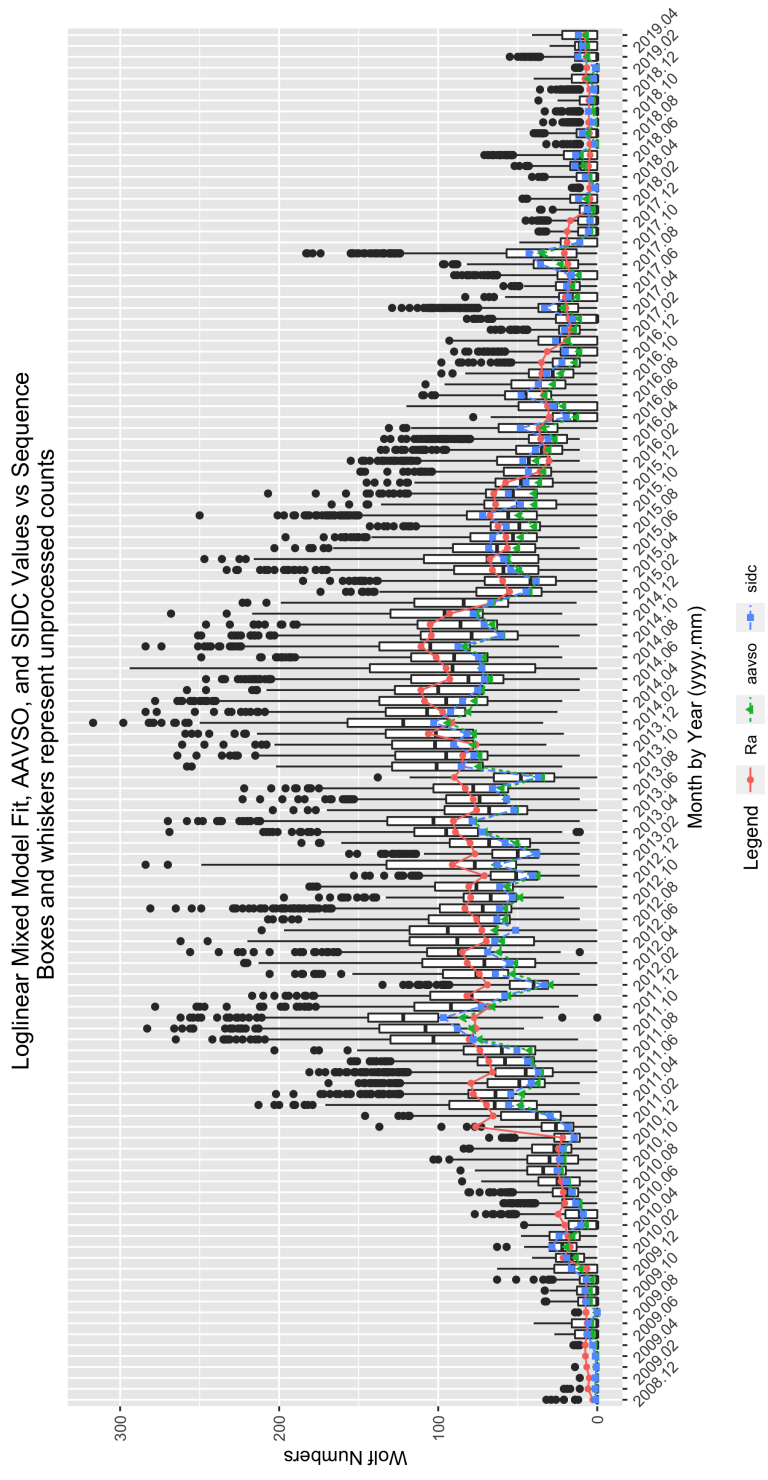


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

The GLMM parameter estimates and measures of importance in the determining the monthly  $R_a$  values are given in Table 3. The parameter estimates and levels of statistical significance are determined for the residual error size combined with the observer random effect error size. Thus, the parameter estimates are adjusted for the random effect of observer. The significance level is set at 0.05. Any  $\Pr(>|z|)$  values equal to or less than 0.05 are considered statistically significant.

Table 3: 201905 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4369	0.3143	4.5717	0.0000
seeF	-0.2180	0.0059	-36.7604	0.0000
seeG	-0.1163	0.0052	-22.5173	0.0000
seeM	-0.1981	0.0244	-8.1191	0.0000
seeP	-0.3240	0.0085	-38.1634	0.0000
sidc1	0.1539	0.0669	2.3007	0.0214
year2009	0.6414	0.3154	2.0337	0.0420
year2010	1.8506	0.3132	5.9091	0.0000
year2011	2.9717	0.3131	9.4919	0.0000
year2012	3.0092	0.3131	9.6117	0.0000
year2013	3.1052	0.3131	9.9184	0.0000
year2014	3.3021	0.3131	10.5476	0.0000
year2015	2.8173	0.3131	8.9987	0.0000
year2016	2.2005	0.3131	7.0277	0.0000
year2017	1.5954	0.3132	5.0945	0.0000
year2018	0.3017	0.3135	0.9624	0.3359
year2019	0.6397	0.3138	2.0385	0.0415
mon2	-0.1613	0.0094	-17.2467	0.0000
mon3	-0.1067	0.0087	-12.2083	0.0000
mon4	-0.0066	0.0084	-0.7771	0.4371
mon5	0.0080	0.0083	0.9614	0.3363
mon6	-0.1808	0.0087	-20.7537	0.0000
mon7	-0.1548	0.0085	-18.2864	0.0000
mon8	-0.0828	0.0083	-9.9978	0.0000
mon9	0.0151	0.0083	1.8191	0.0689
mon10	-0.0390	0.0086	-4.5567	0.0000
mon11	-0.0174	0.0089	-1.9459	0.0517
mon12	-0.1306	0.0091	-14.3376	0.0000

The year effect levels are given as year2011, year2012, and year2013. The yearly effect is significant as  $\Pr(>|z|) < 0.05$ . So the year in which the observations are made is commensurate with the expected rise toward and anticipated sunspot number maximum. Similarly, the monthly effect, denoted as mon2 through mon12, is significant at the 0.05 level.

The seeing conditions account for a significant amount of deviation in sunspot numbers. The

seeing conditions are denoted as seeF (Fair), seeG (Good), and seeP (Poor), and are significant at the 0.05 level. Therefore, seeing conditions influence the reported sunspot numbers, as intuition anticipates.

The level of observer experience (denoted r1000B through r5000H, which is least to most experience) is not significant at the 0.05 significance level. It therefore does not contribute to changes in the monthly sunspot numbers.

Whether an observer contributes counts to the SILSO as well as the AAVSO (silsoy) is not significant at the 0.05 level, and hence we conclude that those observers who contribution to both institutions tend to differ from those observers contributing only to the AAVSO.

## 5 Supporting Information

Table 4: 201905 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:113136	Min. :0.0000
1st Qu.:2012	1st Qu.: 4.000	1st Qu.: 8.00	Class :character	1st Qu.:0.0000
Median :2014	Median : 7.000	Median :16.00	Mode :character	Median :0.0000
Mean :2014	Mean : 6.555	Mean :15.74		Mean :0.2609
3rd Qu.:2017	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2019	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 201905 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:113136	Length:113136
1st Qu.: 1.000	1st Qu.: 2.00	1st Qu.: 12.00	Class :character	Class :character
Median : 3.000	Median : 12.00	Median : 40.00	Mode :character	Mode :character
Mean : 3.189	Mean : 19.02	Mean : 50.91		
3rd Qu.: 5.000	3rd Qu.: 28.00	3rd Qu.: 79.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 201905 Summary of Sunspot Numbers

inst	filter	unit
Length:113136	Length:113136	Length:113136
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201905 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.0	Min. : 0.00	Min. : 0	Min. : 0.0
1st Qu.: 70.0	1st Qu.: 3.00	1st Qu.: 506	1st Qu.: 40.0
Median : 89.0	Median : 13.00	Median : 910	Median : 57.5
Mean : 101.2	Mean : 24.61	Mean :1007	Mean : 186.2
3rd Qu.: 120.0	3rd Qu.: 23.00	3rd Qu.:1233	3rd Qu.: 76.0
Max. :1524.0	Max. :2010.00	Max. :4300	Max. :4591.0

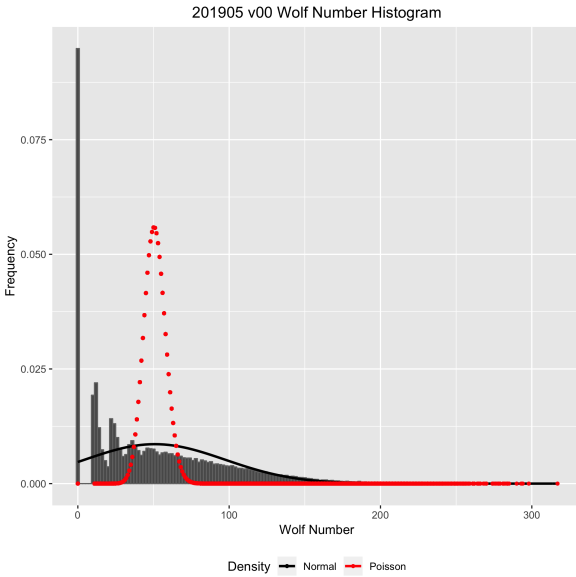


Figure 3: Box plots of raw Wolf number (w) by observer rank.

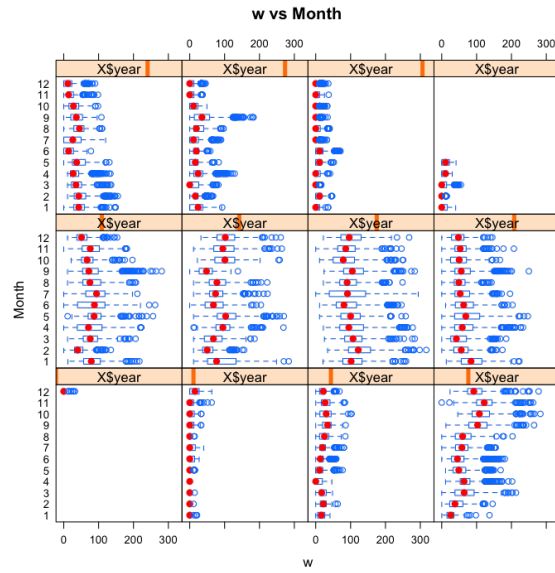


Figure 4: Box plots of raw Wolf number (w) by month and year.

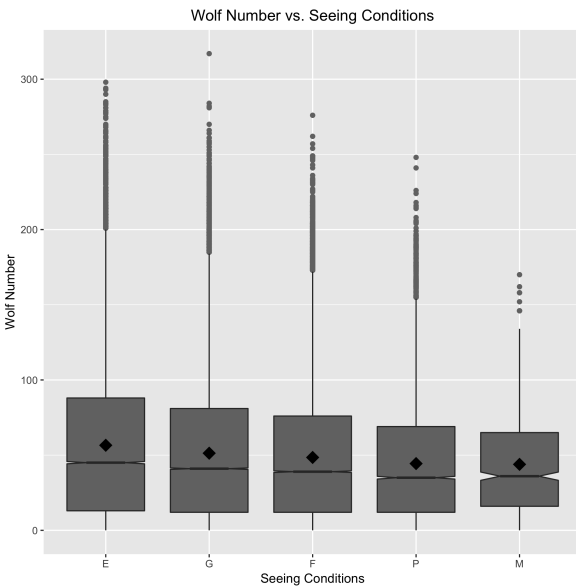


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

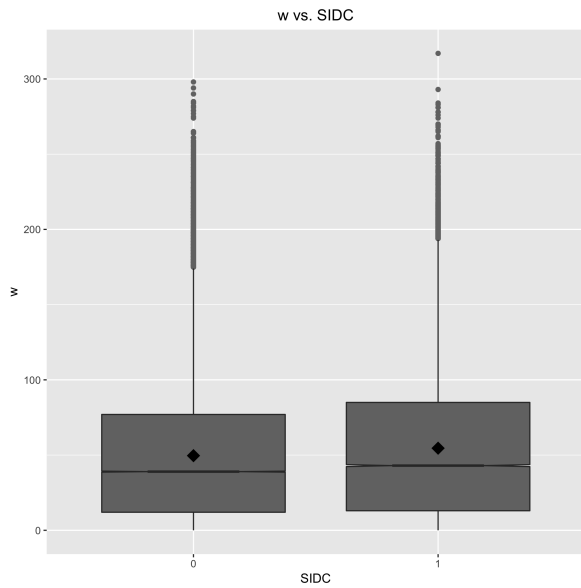


Figure 6: Box plots of raw Wolf number (w) by organization.

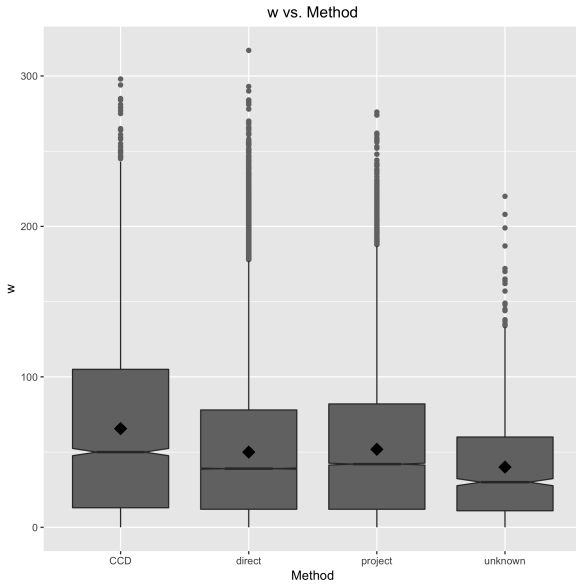


Figure 7: Box plots of raw Wolf number (w) by observer rank.

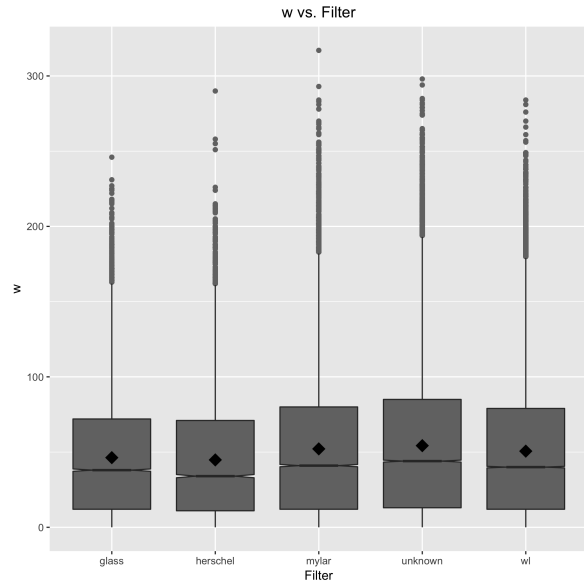


Figure 8: Box plots of raw Wolf number (w) by month and year.

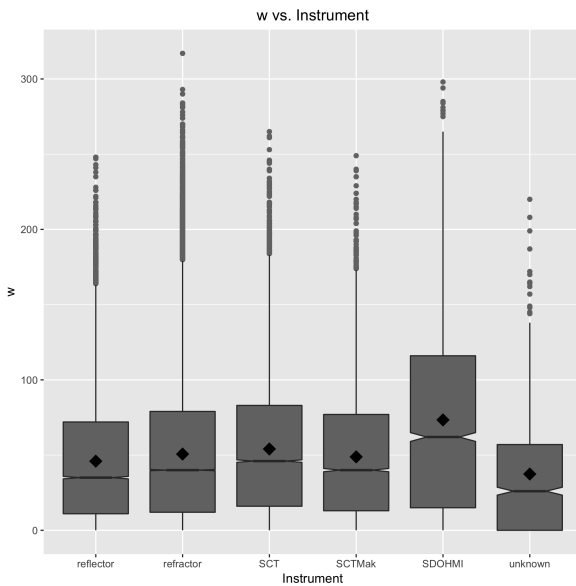


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

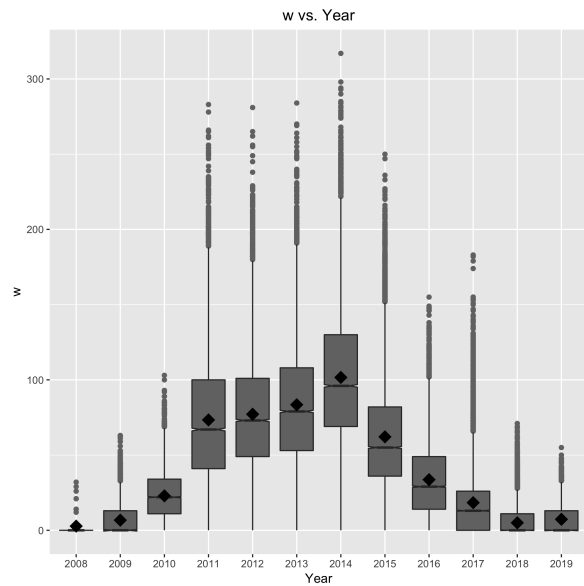


Figure 10: Box plots of raw Wolf number (w) by organization.

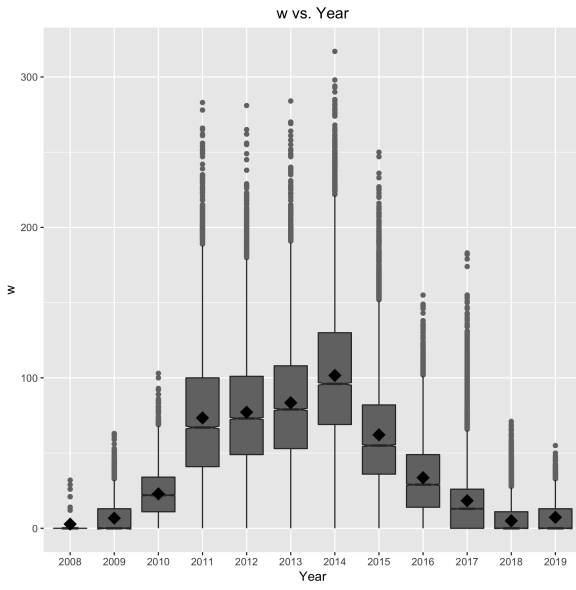


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

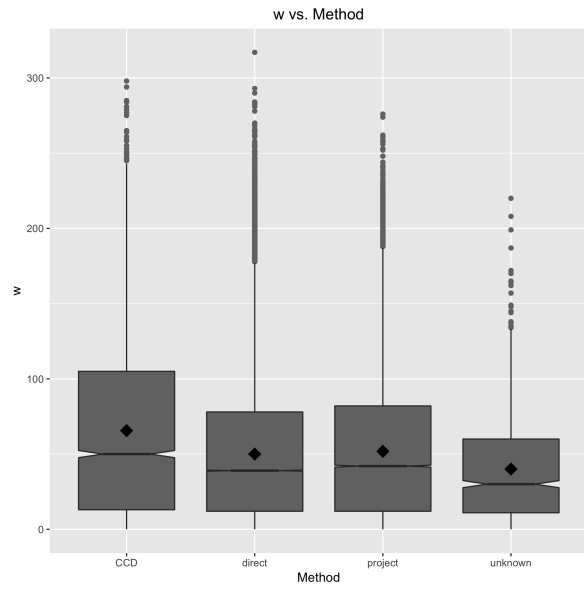


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.