

**Monthly Report (00)**  
**201909 Data Set**

Wednesday 16<sup>th</sup> October, 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.

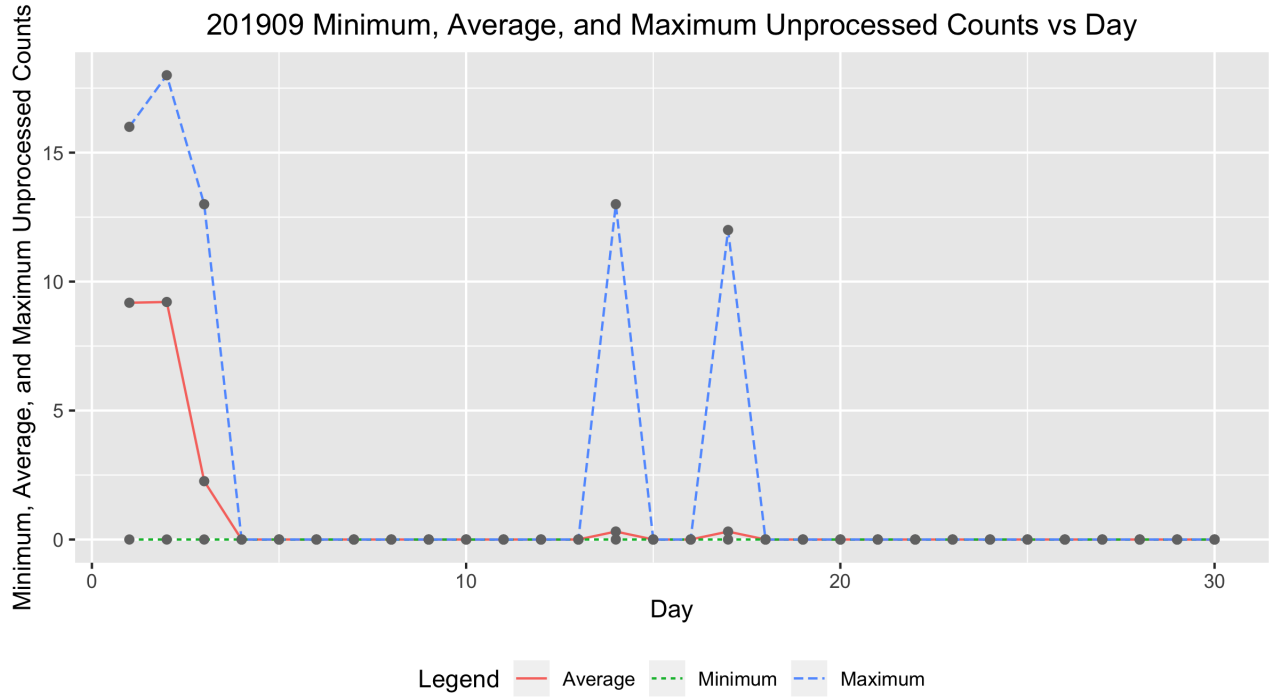


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201909 Daily Raw Counts

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Day	Submissions	Minimum	Average	Maximum
1.0000	39.0000	0.0000	9.1795	16.0000
2.0000	43.0000	0.0000	9.2093	18.0000
3.0000	42.0000	0.0000	2.2619	13.0000
4.0000	38.0000	0.0000	0.0000	0.0000
5.0000	38.0000	0.0000	0.0000	0.0000
6.0000	40.0000	0.0000	0.0000	0.0000
7.0000	47.0000	0.0000	0.0000	0.0000
8.0000	46.0000	0.0000	0.0000	0.0000
9.0000	43.0000	0.0000	0.0000	0.0000
10.0000	40.0000	0.0000	0.0000	0.0000
11.0000	38.0000	0.0000	0.0000	0.0000
12.0000	45.0000	0.0000	0.0000	0.0000
13.0000	38.0000	0.0000	0.0000	0.0000
14.0000	42.0000	0.0000	0.3095	13.0000
15.0000	42.0000	0.0000	0.0000	0.0000
16.0000	34.0000	0.0000	0.0000	0.0000
17.0000	39.0000	0.0000	0.3077	12.0000
18.0000	43.0000	0.0000	0.0000	0.0000
19.0000	45.0000	0.0000	0.0000	0.0000
20.0000	41.0000	0.0000	0.0000	0.0000
21.0000	36.0000	0.0000	0.0000	0.0000
22.0000	36.0000	0.0000	0.0000	0.0000
23.0000	39.0000	0.0000	0.0000	0.0000
24.0000	32.0000	0.0000	0.0000	0.0000
25.0000	37.0000	0.0000	0.0000	0.0000
26.0000	38.0000	0.0000	0.0000	0.0000
27.0000	42.0000	0.0000	0.0000	0.0000
28.0000	43.0000	0.0000	0.0000	0.0000
29.0000	45.0000	0.0000	0.0000	0.0000
30.0000	41.0000	0.0000	0.0000	0.0000

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### 3 Error Tables

Data are for the month of September 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	2.4051	3.1359	0.5000	1.0000
2009.01	5.8573	5.2180	6.4965	1.3000	1.3000
2009.02	5.0792	4.5098	5.6487	0.7000	1.2000
2009.03	6.6801	6.4148	6.9455	0.3000	0.6000
2009.04	7.4929	7.2180	7.7677	0.4000	1.2000
2009.05	7.6102	7.3015	7.9188	1.6000	2.9000
2009.06	6.6464	6.3041	6.9887	3.2000	6.3000
2009.07	6.3302	6.0710	6.5893	3.6000	5.5000
2009.08	7.0061	6.7221	7.2900	0.0000	0.0000
2009.09	7.4935	7.2213	7.7656	4.5000	7.1000
2009.10	7.0592	6.6811	7.4372	4.5000	7.7000
2009.11	7.0178	6.8236	7.2120	3.3000	6.9000
2009.12	6.5104	6.3239	6.6968	10.4000	16.3000
2010.01	21.6792	19.1922	24.1662	13.3000	19.5000
2010.02	17.0674	14.7271	19.4076	19.4000	28.5000

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

ym	Ra	lci99	uci99	aavso	sidc
2010.03	18.6626	16.3284	20.9968	15.4000	24.0000
2010.04	20.6750	18.2179	23.1320	7.0000	10.4000
2010.05	24.8342	24.3924	25.2760	8.4000	8.7000
2010.06	20.3468	20.0083	20.6854	11.0000	13.6000
2010.07	21.2416	20.9330	21.5501	15.2000	16.1000
2010.08	22.7310	22.3578	23.1043	18.3000	19.6000
2010.09	25.2379	24.8216	25.6542	22.8000	25.2000
2010.10	24.0556	23.6399	24.4714	21.0000	23.5000
2010.11	24.4963	24.0507	24.9419	20.9000	21.6000
2010.12	21.7963	21.3562	22.2364	13.9000	14.5000
2011.01	76.9889	75.3916	78.5861	17.7000	18.7000
2011.02	65.8994	64.4886	67.3102	29.1000	29.6000
2011.03	70.1224	68.7809	71.4638	48.0000	55.8000
2011.04	78.5373	77.1251	79.9494	47.3000	54.4000
2011.05	79.9107	78.5568	81.2646	37.3000	41.5000
2011.06	65.4517	64.3034	66.5999	35.2000	37.0000
2011.07	67.6427	66.4843	68.8011	41.5000	43.8000
2011.08	73.2341	72.0539	74.4143	42.4000	50.5000
2011.09	79.9573	78.5721	81.3424	73.8000	78.0000
2011.10	76.2279	74.9431	77.5128	78.9000	88.0000
2011.11	77.4044	75.7858	79.0231	84.6000	96.7000
2011.12	67.7765	66.3784	69.1745	65.8000	73.0000
2012.01	82.6152	80.9893	84.2410	55.8000	58.2000
2012.02	69.5349	68.1200	70.9498	29.2000	33.1000
2012.03	74.6701	73.3467	75.9934	53.1000	64.1000
2012.04	82.3901	80.9493	83.8309	51.4000	55.2000
2012.05	85.4433	84.0343	86.8524	61.8000	69.0000
2012.06	69.2747	68.0971	70.4523	59.7000	64.5000
2012.07	71.9789	70.7980	73.1597	64.2000	51.3000
2012.08	75.1645	73.9580	76.3711	57.7000	63.1000
2012.09	82.5766	81.1441	84.0090	57.7000	61.5000
2012.10	79.5882	78.1322	81.0442	48.3000	53.3000
2012.11	80.7951	79.1734	82.4168	56.7000	61.4000
2012.12	70.9278	69.3885	72.4670	37.4000	40.8000
2013.01	91.8760	90.1199	93.6322	63.8000	62.9000
2013.02	77.4774	75.9184	79.0365	37.8000	38.0000
2013.03	80.5785	78.9414	82.2157	50.6000	57.9000
2013.04	89.8556	88.2765	91.4347	70.6000	72.4000
2013.05	91.0731	89.4535	92.6928	77.4000	78.7000

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

ym	Ra	lci99	uci99	aavso	sidc
2013.06	75.3534	74.0217	76.6850	51.0000	52.5000
2013.07	77.3214	76.0807	78.5622	57.0000	57.0000
2013.08	82.2706	80.9484	83.5928	60.0000	66.0000
2013.09	89.1072	87.5184	90.6961	34.6000	36.9000
2013.10	84.8281	83.2559	86.4004	74.5000	85.6000
2013.11	84.5688	82.6722	86.4653	73.9000	77.6000
2013.12	76.3436	74.7136	77.9737	77.8000	90.3000
2014.01	107.0269	104.7753	109.2785	77.4000	82.0000
2014.02	92.0525	90.2391	93.8659	93.9000	102.8000
2014.03	97.9706	96.1867	99.7545	80.9000	92.2000
2014.04	109.4212	107.5108	111.3315	76.9000	84.7000
2014.05	111.5903	109.6861	113.4945	72.3000	75.2000
2014.06	92.1326	90.5755	93.6896	67.2000	71.0000
2014.07	94.2382	92.6701	95.8062	72.5000	72.5000
2014.08	100.4412	98.8722	102.0102	71.2000	74.7000
2014.09	109.9285	107.9910	111.8661	83.2000	87.6000
2014.10	104.3182	102.3972	106.2392	59.5000	60.6000
2014.11	105.0543	102.8673	107.2413	65.8000	71.1000
2014.12	92.8718	90.7184	95.0252	75.8000	78.0000
2015.01	66.1681	64.8434	67.4928	65.9000	67.0000
2015.02	55.5295	54.3068	56.7522	42.4000	44.8000
2015.03	59.8782	58.7821	60.9743	38.0000	38.4000
2015.04	66.4321	65.2408	67.6234	49.0000	54.4000
2015.05	68.0734	66.9474	69.1994	56.3000	58.8000
2015.06	56.0780	55.0656	57.0904	50.2000	68.3000
2015.07	56.8772	55.9057	57.8488	47.9000	65.8000
2015.08	61.8461	60.8060	62.8863	39.5000	57.2000
2015.09	66.8048	65.5893	68.0202	49.2000	72.1000
2015.10	63.9012	62.6660	65.1364	39.3000	48.3000
2015.11	65.0634	63.6499	66.4768	39.6000	55.9000
2015.12	57.5948	56.3286	58.8610	36.4000	44.8000
2016.01	36.2336	35.4773	36.9898	33.7000	43.3000
2016.02	30.5403	29.9034	31.1773	38.3000	46.8000
2016.03	32.4029	31.7561	33.0497	30.5000	38.9000
2016.04	35.8595	35.1757	36.5432	26.6000	30.9000
2016.05	36.8273	36.1540	37.5006	33.7000	48.4000
2016.06	30.0116	29.4994	30.5238	13.1000	19.5000
2016.07	30.9869	30.4886	31.4853	21.2000	27.5000
2016.08	33.3365	32.7498	33.9231	33.0000	47.9000

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

ym	Ra	lci99	uci99	aavso	sidc
2016.09	36.8673	36.1940	37.5406	27.7000	37.1000
2016.10	34.8619	34.1894	35.5345	22.7000	31.7000
2016.11	35.0985	34.3646	35.8324	14.0000	22.2000
2016.12	31.4621	30.7894	32.1348	11.1000	20.0000
2017.01	19.7089	19.2942	20.1236	18.4000	26.2000
2017.02	16.6795	16.3131	17.0458	14.4000	20.6000
2017.03	17.8515	17.5114	18.1916	11.3000	15.5000
2017.04	19.9657	19.6134	20.3181	21.6000	33.2000
2017.05	20.1748	19.8264	20.5232	12.5000	18.1000
2017.06	16.4537	16.1792	16.7283	15.5000	19.3000
2017.07	17.0709	16.7994	17.3424	11.5000	16.3000
2017.08	18.3064	17.9889	18.6240	22.8000	35.7000
2017.09	20.5598	20.1363	20.9834	34.6000	42.9000
2017.10	18.9749	18.5915	19.3583	10.5000	11.0000
2017.11	18.9478	18.5513	19.3442	4.2000	5.6000
2017.12	16.8956	16.6395	17.1517	4.0000	4.6000
2018.01	5.4699	5.3529	5.5869	3.1000	6.3000
2018.02	4.5910	4.4795	4.7024	6.8000	11.8000
2018.03	4.8231	4.7278	4.9185	1.1000	1.2000
2018.04	5.3477	5.2412	5.4542	4.7000	7.5000
2018.05	5.5050	5.4005	5.6095	8.4000	14.0000
2018.06	4.4899	4.4101	4.5696	10.2000	13.6000
2018.07	4.6503	4.5982	4.7023	0.5000	1.7000
2018.08	4.9348	4.8491	5.0205	5.9000	9.5000
2018.09	5.3342	5.2347	5.4337	1.6000	2.9000
2018.10	5.1954	5.0950	5.2957	2.5000	5.6000
2018.11	5.2299	5.1227	5.3370	3.1000	4.2000
2018.12	4.7642	4.6711	4.8572	1.6000	2.3000
2019.01	4.4048	4.3223	4.4873	5.4000	2.3000
2019.02	3.7886	3.7142	3.8629	0.1000	1.2000
2019.03	3.9274	3.8599	3.9948	6.1000	12.1000
2019.04	4.3786	4.2957	4.4614	6.2000	9.3000
2019.05	4.3346	4.2571	4.4121	7.0000	11.9000
2019.06	3.5394	3.4768	3.6021	0.7000	1.5000
2019.07	3.6826	3.6247	3.7405	0.4000	2.2000
2019.08	3.9827	3.9211	4.0442	0.3000	0.8000
2019.09	4.4042	4.3322	4.4762	0.5000	1.0000

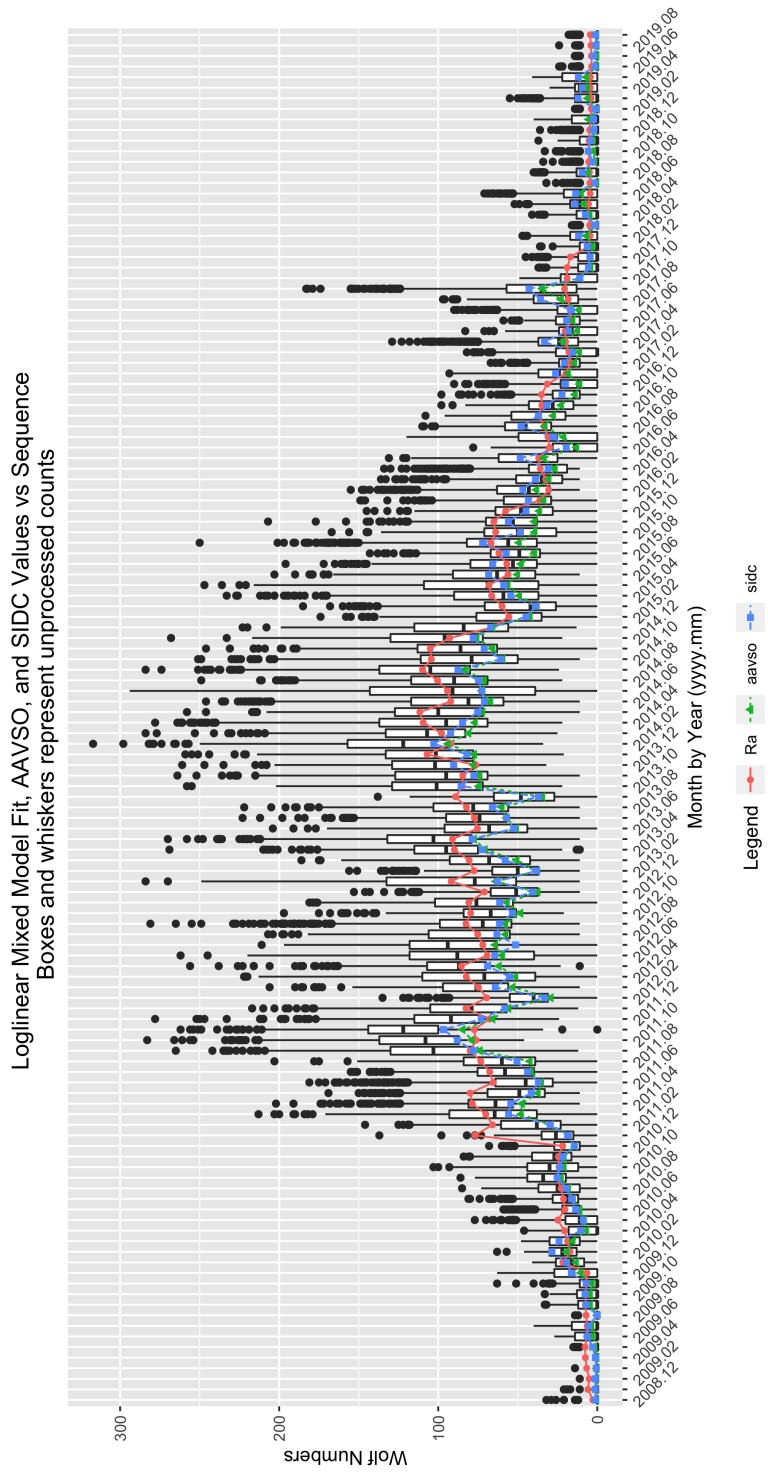


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201909 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4490	0.3118	4.6477	0.0000
seeF	-0.2185	0.0059	-37.1649	0.0000
seeG	-0.1166	0.0051	-22.7644	0.0000
seeM	-0.2012	0.0242	-8.3142	0.0000
seeP	-0.3240	0.0084	-38.4854	0.0000
sidc1	0.1335	0.0689	1.9368	0.0528
year2009	0.6387	0.3127	2.0424	0.0411
year2010	1.8508	0.3105	5.9600	0.0000
year2011	2.9688	0.3104	9.5635	0.0000
year2012	3.0057	0.3104	9.6825	0.0000
year2013	3.1018	0.3104	9.9920	0.0000
year2014	3.2987	0.3104	10.6263	0.0000
year2015	2.8138	0.3104	9.0639	0.0000
year2016	2.1970	0.3105	7.0765	0.0000
year2017	1.5917	0.3105	5.1262	0.0000
year2018	0.2962	0.3108	0.9531	0.3405
year2019	0.0677	0.3111	0.2176	0.8278
mon2	-0.1615	0.0093	-17.4221	0.0000
mon3	-0.1068	0.0087	-12.3234	0.0000
mon4	-0.0069	0.0084	-0.8288	0.4072
mon5	0.0068	0.0082	0.8337	0.4045
mon6	-0.1952	0.0086	-22.6308	0.0000
mon7	-0.1710	0.0084	-20.3920	0.0000
mon8	-0.0990	0.0082	-12.0611	0.0000
mon9	-0.0008	0.0082	-0.0922	0.9265
mon10	-0.0468	0.0085	-5.5253	0.0000
mon11	-0.0252	0.0089	-2.8470	0.0044
mon12	-0.1384	0.0090	-15.3295	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: 201909 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:118168	Min. :0.0000
1st Qu.:2012	1st Qu.: 4.000	1st Qu.: 8.00	Class :character	1st Qu.:0.0000
Median :2015	Median : 7.000	Median :16.00	Mode :character	Median :0.0000
Mean :2015	Mean : 6.596	Mean :15.74		Mean :0.2599
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: 201909 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:118168	Length:118168
1st Qu.: 1.000	1st Qu.: 1.00	1st Qu.: 11.00	Class :character	Class :character
Median : 2.000	Median : 10.00	Median : 37.00	Mode :character	Mode :character
Mean : 3.055	Mean : 18.21	Mean : 48.76		
3rd Qu.: 5.000	3rd Qu.: 27.00	3rd Qu.: 77.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 201909 Summary of Sunspot Numbers

inst	filter	unit
Length:118168	Length:118168	Length:118168
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201909 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 64.00	1st Qu.: 3.00	1st Qu.: 480.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 97.49	Mean : 26.22	Mean : 964.6	Mean : 185.3
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1203.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

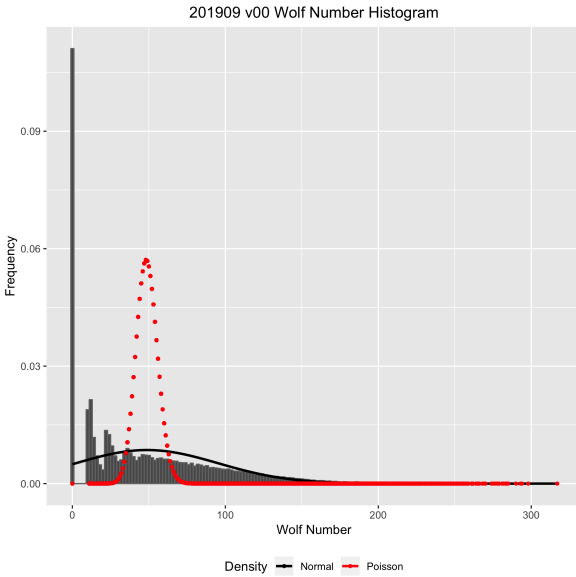


Figure 3: Box plots of raw Wolf number ( $w$ ) by observer rank.

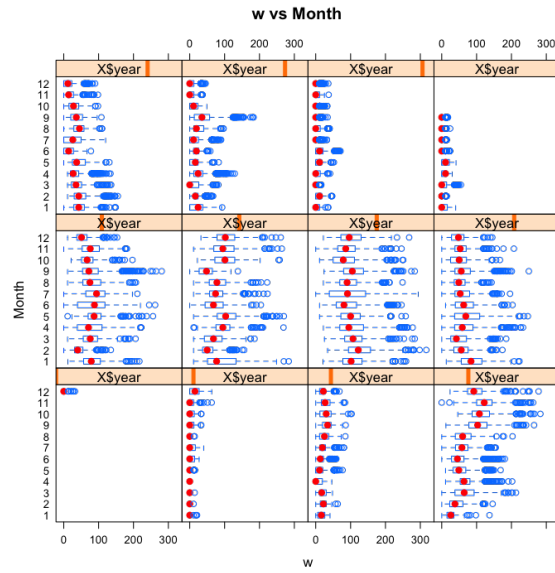


Figure 4: Box plots of raw Wolf number ( $w$ ) by month and year.

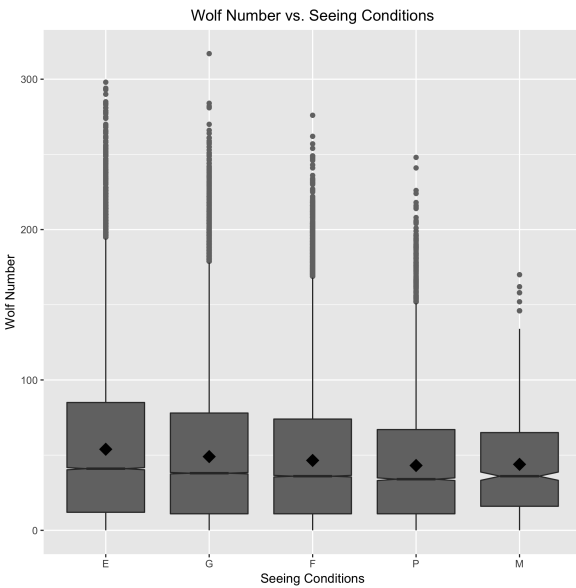


Figure 5: Box plots of raw Wolf number ( $w$ ) by seeing condition.

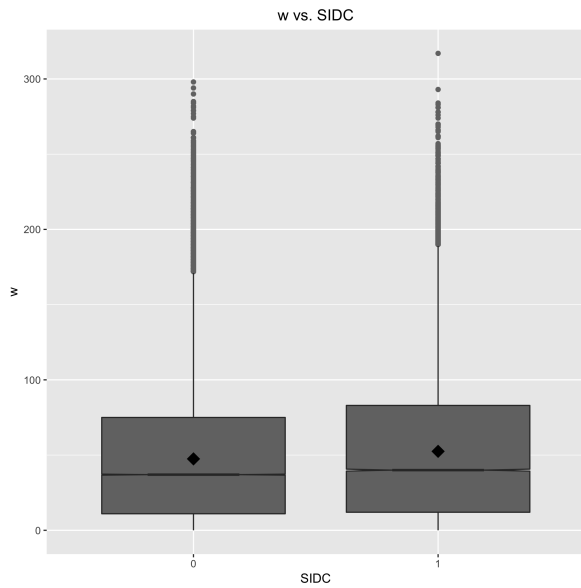


Figure 6: Box plots of raw Wolf number ( $w$ ) by organization.

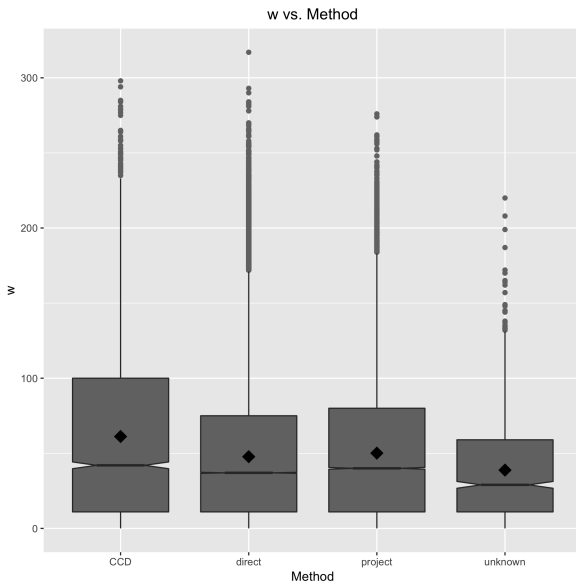


Figure 7: Box plots of raw Wolf number ( $w$ ) by observer rank.

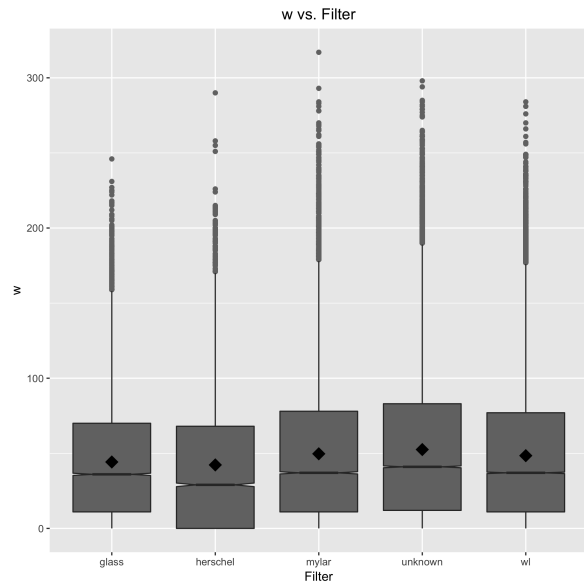


Figure 8: Box plots of raw Wolf number ( $w$ ) by month and year.

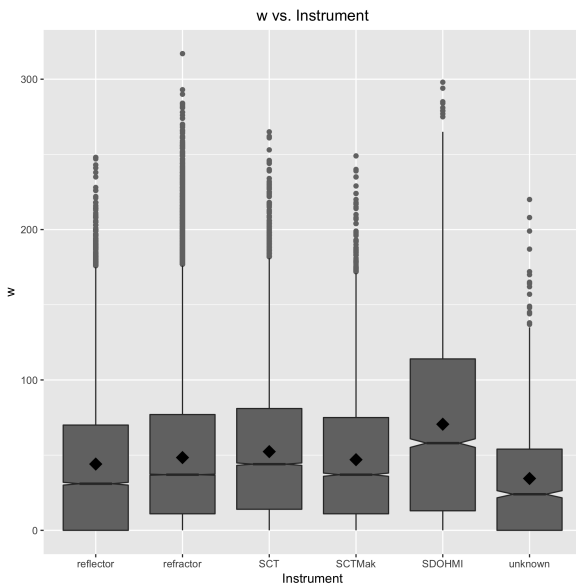


Figure 9: Box plots of raw Wolf number ( $w$ ) by seeing condition.

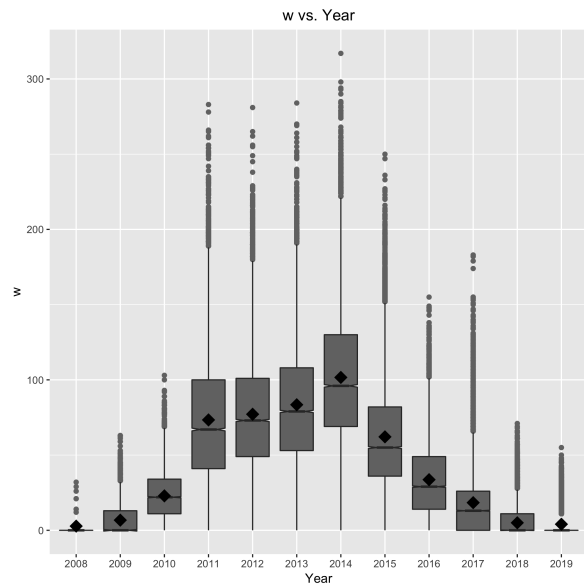


Figure 10: Box plots of raw Wolf number ( $w$ ) by organization.

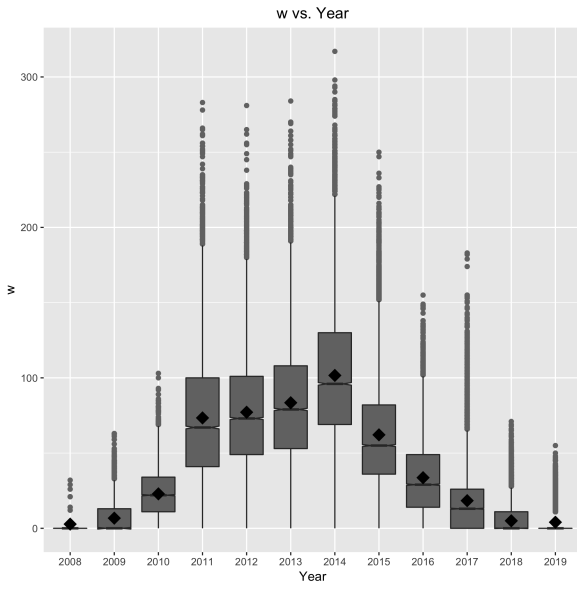


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

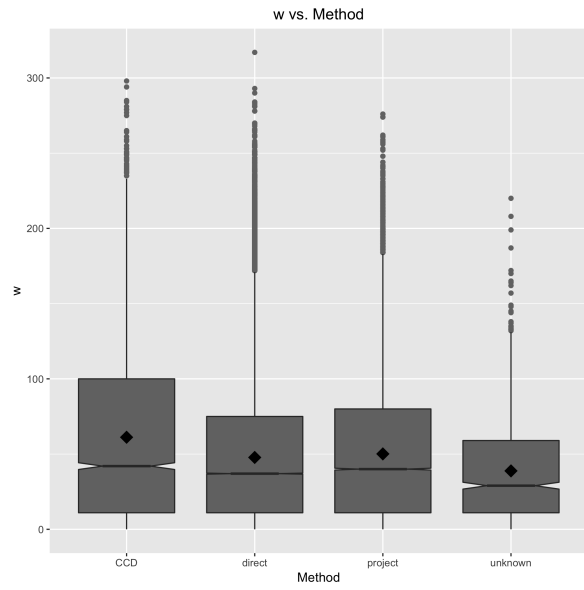


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.