

Monthly Report (00)
201907 Data Set

Sunday 11th August, 2019

Prepared for

Statistics for Physical and Engineering Sciences

by

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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.

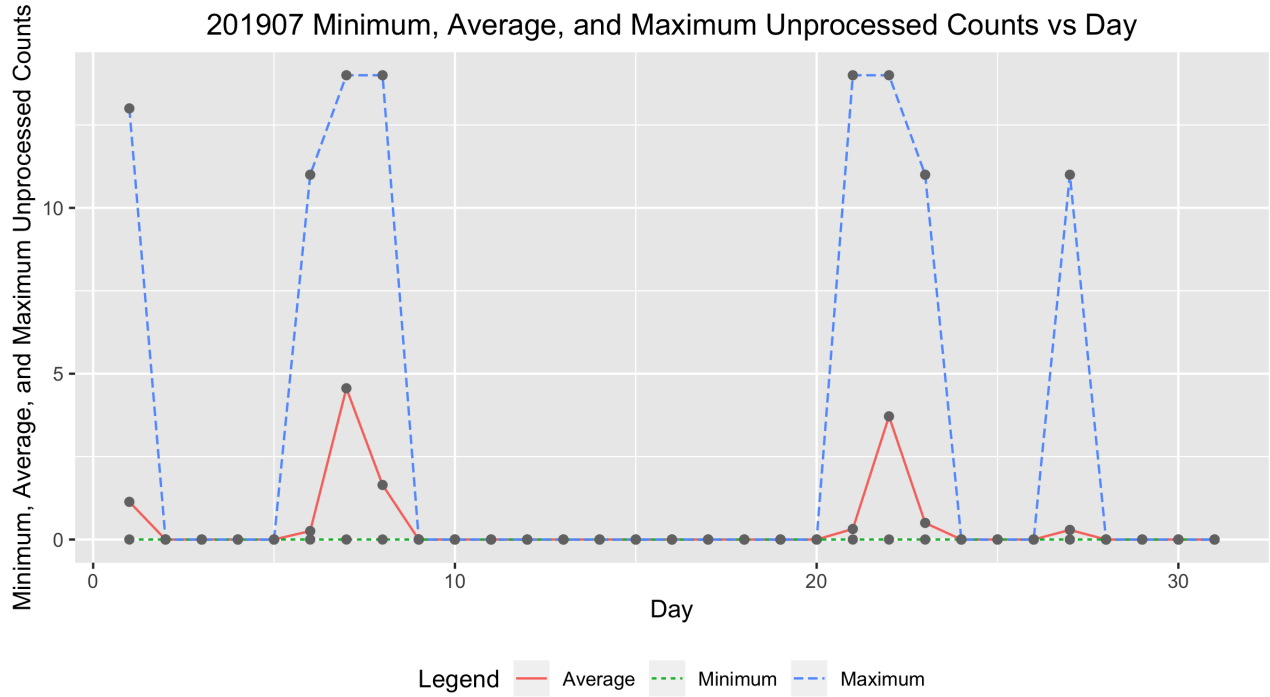


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201907 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	44.0000	0.0000	1.1364	13.0000
2.0000	42.0000	0.0000	0.0000	0.0000
3.0000	40.0000	0.0000	0.0000	0.0000
4.0000	41.0000	0.0000	0.0000	0.0000
5.0000	38.0000	0.0000	0.0000	0.0000
6.0000	43.0000	0.0000	0.2558	11.0000
7.0000	41.0000	0.0000	4.5610	14.0000
8.0000	45.0000	0.0000	1.6444	14.0000
9.0000	48.0000	0.0000	0.0000	0.0000
10.0000	46.0000	0.0000	0.0000	0.0000
11.0000	42.0000	0.0000	0.0000	0.0000
12.0000	46.0000	0.0000	0.0000	0.0000
13.0000	44.0000	0.0000	0.0000	0.0000
14.0000	38.0000	0.0000	0.0000	0.0000
15.0000	42.0000	0.0000	0.0000	0.0000
16.0000	43.0000	0.0000	0.0000	0.0000
17.0000	41.0000	0.0000	0.0000	0.0000
18.0000	38.0000	0.0000	0.0000	0.0000
19.0000	44.0000	0.0000	0.0000	0.0000
20.0000	43.0000	0.0000	0.0000	0.0000
21.0000	44.0000	0.0000	0.3182	14.0000
22.0000	42.0000	0.0000	3.7143	14.0000
23.0000	44.0000	0.0000	0.5000	11.0000
24.0000	47.0000	0.0000	0.0000	0.0000
25.0000	44.0000	0.0000	0.0000	0.0000
26.0000	49.0000	0.0000	0.0000	0.0000
27.0000	38.0000	0.0000	0.2895	11.0000
28.0000	39.0000	0.0000	0.0000	0.0000
29.0000	40.0000	0.0000	0.0000	0.0000
30.0000	44.0000	0.0000	0.0000	0.0000
31.0000	41.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of July 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 25th through the 75th quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25th quartile, and 1.5 times the IQR above the 75th 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	2.4071	3.1339	0.5000	1.0000
2009.01	5.8462	5.2119	6.4806	1.3000	1.3000
2009.02	5.0695	4.5044	5.6345	0.7000	1.2000
2009.03	6.6590	6.3941	6.9240	0.3000	0.6000
2009.04	7.4699	7.1955	7.7444	0.4000	1.2000
2009.05	7.5892	7.2810	7.8973	1.6000	2.9000
2009.06	6.6273	6.2857	6.9689	3.2000	6.3000
2009.07	6.3119	6.0531	6.5706	3.6000	5.5000
2009.08	7.0632	6.7767	7.3498	0.0000	0.0000
2009.09	7.5523	7.2777	7.8270	4.5000	7.1000
2009.10	7.0584	6.6799	7.4370	4.5000	7.7000
2009.11	7.0177	6.8241	7.2114	3.3000	6.9000
2009.12	6.5100	6.3241	6.6959	10.4000	16.3000
2010.01	21.6121	19.1464	24.0779	13.3000	19.5000
2010.02	17.0250	14.7044	19.3456	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	18.6125	16.2976	20.9274	15.4000	24.0000
2010.04	20.6213	18.1843	23.0583	7.0000	10.4000
2010.05	24.7480	24.3089	25.1870	8.4000	8.7000
2010.06	20.2698	19.9327	20.6069	11.0000	13.6000
2010.07	21.1610	20.8539	21.4680	15.2000	16.1000
2010.08	22.8920	22.5162	23.2677	18.3000	19.6000
2010.09	25.4114	24.9924	25.8304	22.8000	25.2000
2010.10	24.0297	23.6146	24.4447	21.0000	23.5000
2010.11	24.4721	24.0272	24.9170	20.9000	21.6000
2010.12	21.7733	21.3342	22.2124	13.9000	14.5000
2011.01	76.7569	75.1670	78.3467	17.7000	18.7000
2011.02	65.7116	64.3074	67.1158	29.1000	29.6000
2011.03	69.9085	68.5731	71.2438	48.0000	55.8000
2011.04	78.2988	76.8918	79.7059	47.3000	54.4000
2011.05	79.6970	78.3486	81.0454	37.3000	41.5000
2011.06	65.2683	64.1244	66.4122	35.2000	37.0000
2011.07	67.4435	66.2892	68.5977	41.5000	43.8000
2011.08	73.8283	72.6393	75.0173	42.4000	50.5000
2011.09	80.5678	79.1746	81.9611	73.8000	78.0000
2011.10	76.2191	74.9356	77.5025	78.9000	88.0000
2011.11	77.3980	75.7806	79.0155	84.6000	96.7000
2011.12	67.7687	66.3716	69.1657	65.8000	73.0000
2012.01	82.3669	80.7471	83.9867	55.8000	58.2000
2012.02	69.3299	67.9199	70.7400	29.2000	33.1000
2012.03	74.4445	73.1259	75.7631	53.1000	64.1000
2012.04	82.1471	80.7111	83.5830	51.4000	55.2000
2012.05	85.2146	83.8099	86.6193	61.8000	69.0000
2012.06	69.0858	67.9121	70.2594	59.7000	64.5000
2012.07	71.7796	70.6027	72.9565	64.2000	51.3000
2012.08	75.7798	74.5636	76.9959	57.7000	63.1000
2012.09	83.2330	81.7892	84.6768	57.7000	61.5000
2012.10	79.5825	78.1272	81.0379	48.3000	53.3000
2012.11	80.7978	79.1767	82.4189	56.7000	61.4000
2012.12	70.9253	69.3865	72.4641	37.4000	40.8000
2013.01	91.5968	89.8465	93.3470	63.8000	62.9000
2013.02	77.2531	75.6992	78.8070	37.8000	38.0000
2013.03	80.3370	78.7052	81.9687	50.6000	57.9000
2013.04	89.6003	88.0267	91.1739	70.6000	72.4000
2013.05	90.8355	89.2207	92.4503	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	75.1505	73.8229	76.4782	51.0000	52.5000
2013.07	77.1108	75.8736	78.3479	57.0000	57.0000
2013.08	82.9548	81.6219	84.2878	60.0000	66.0000
2013.09	89.8246	88.2230	91.4261	34.6000	36.9000
2013.10	84.8354	83.2633	86.4076	74.5000	85.6000
2013.11	84.5738	82.6775	86.4701	73.9000	77.6000
2013.12	76.3446	74.7147	77.9744	77.8000	90.3000
2014.01	106.7006	104.4564	108.9448	77.4000	82.0000
2014.02	91.7855	89.9780	93.5929	93.9000	102.8000
2014.03	97.6793	95.9014	99.4572	80.9000	92.2000
2014.04	109.1144	107.2102	111.0186	76.9000	84.7000
2014.05	111.3082	109.4096	113.2068	72.3000	75.2000
2014.06	91.8887	90.3363	93.4411	67.2000	71.0000
2014.07	93.9881	92.4247	95.5514	72.5000	72.5000
2014.08	101.2792	99.6976	102.8609	71.2000	74.7000
2014.09	110.8100	108.8573	112.7628	83.2000	87.6000
2014.10	104.3279	102.4071	106.2487	59.5000	60.6000
2014.11	105.0594	102.8724	107.2464	65.8000	71.1000
2014.12	92.8756	90.7226	95.0286	75.8000	78.0000
2015.01	65.9745	64.6537	67.2953	65.9000	67.0000
2015.02	55.3709	54.1515	56.5903	42.4000	44.8000
2015.03	59.7046	58.6117	60.7976	38.0000	38.4000
2015.04	66.2462	65.0582	67.4343	49.0000	54.4000
2015.05	67.9011	66.7778	69.0245	56.3000	58.8000
2015.06	55.9353	54.9257	56.9450	50.2000	68.3000
2015.07	56.7257	55.7566	57.6948	47.9000	65.8000
2015.08	62.3625	61.3137	63.4114	39.5000	57.2000
2015.09	67.3431	66.1179	68.5683	49.2000	72.1000
2015.10	63.9113	62.6761	65.1465	39.3000	48.3000
2015.11	65.0716	63.6583	66.4850	39.6000	55.9000
2015.12	57.6019	56.3361	58.8677	36.4000	44.8000
2016.01	36.1274	35.3733	36.8815	33.7000	43.3000
2016.02	30.4547	29.8195	31.0899	38.3000	46.8000
2016.03	32.3099	31.6649	32.9548	30.5000	38.9000
2016.04	35.7581	35.0762	36.4400	26.6000	30.9000
2016.05	36.7343	36.0625	37.4060	33.7000	48.4000
2016.06	29.9359	29.4248	30.4469	13.1000	19.5000
2016.07	30.9053	30.4080	31.4026	21.2000	27.5000
2016.08	33.6156	33.0237	34.2075	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	37.1665	36.4875	37.8456	27.7000	37.1000
2016.10	34.8668	34.1938	35.5397	22.7000	31.7000
2016.11	35.1013	34.3670	35.8355	14.0000	22.2000
2016.12	31.4679	30.7952	32.1406	11.1000	20.0000
2017.01	19.6539	19.2404	20.0674	18.4000	26.2000
2017.02	16.6330	16.2676	16.9984	14.4000	20.6000
2017.03	17.8009	17.4617	18.1401	11.3000	15.5000
2017.04	19.9119	19.5605	20.2634	21.6000	33.2000
2017.05	20.1245	19.7769	20.4721	12.5000	18.1000
2017.06	16.4120	16.1380	16.6860	15.5000	19.3000
2017.07	17.0273	16.7565	17.2981	11.5000	16.3000
2017.08	18.4600	18.1406	18.7795	22.8000	35.7000
2017.09	20.7077	20.2875	21.1280	34.6000	42.9000
2017.10	18.9755	18.5937	19.3573	10.5000	11.0000
2017.11	18.9501	18.5538	19.3464	4.2000	5.6000
2017.12	16.8991	16.6430	17.1553	4.0000	4.6000
2018.01	5.4529	5.3362	5.5695	3.1000	6.3000
2018.02	4.5755	4.4649	4.6861	6.8000	11.8000
2018.03	4.8088	4.7134	4.9042	1.1000	1.2000
2018.04	5.3323	5.2265	5.4382	4.7000	7.5000
2018.05	5.4982	5.3940	5.6025	8.4000	14.0000
2018.06	4.4806	4.4008	4.5605	10.2000	13.6000
2018.07	4.6399	4.5879	4.6919	0.5000	1.7000
2018.08	4.9790	4.8924	5.0655	5.9000	9.5000
2018.09	5.3794	5.2790	5.4799	1.6000	2.9000
2018.10	5.1958	5.0953	5.2963	2.5000	5.6000
2018.11	5.2277	5.1200	5.3355	3.1000	4.2000
2018.12	4.7650	4.6713	4.8588	1.6000	2.3000
2019.01	5.6929	5.5857	5.8001	5.4000	2.3000
2019.02	4.9010	4.8042	4.9978	0.1000	1.2000
2019.03	5.0815	4.9941	5.1689	6.1000	12.1000
2019.04	5.6661	5.5592	5.7729	6.2000	9.3000
2019.05	5.6151	5.5155	5.7148	7.0000	11.9000
2019.06	4.5950	4.5147	4.6752	0.7000	1.5000
2019.07	4.7821	4.7079	4.8562	0.4000	2.2000

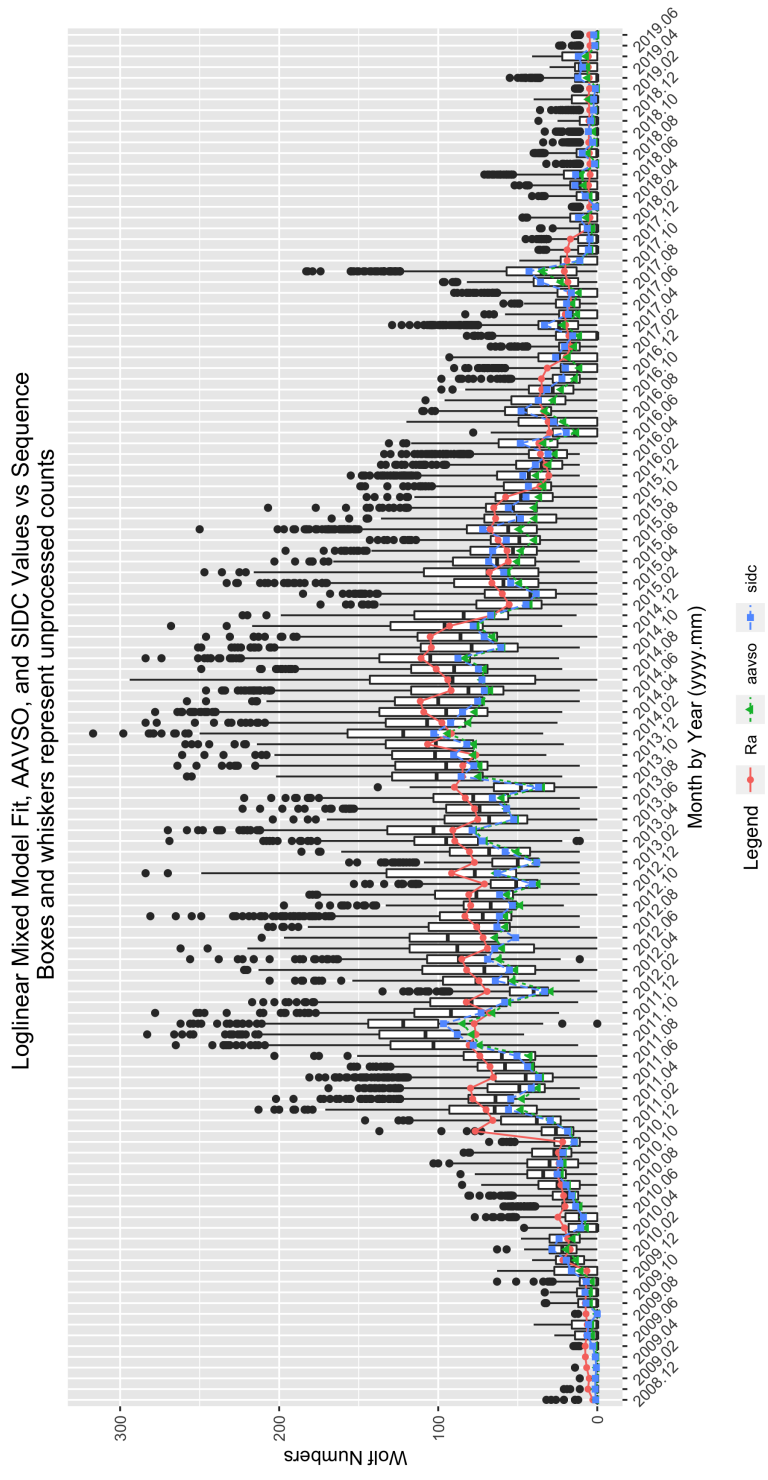


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201907 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4447	0.3131	4.6135	0.0000
seeF	-0.2182	0.0059	-36.9452	0.0000
seeG	-0.1164	0.0051	-22.6309	0.0000
seeM	-0.1993	0.0243	-8.1987	0.0000
seeP	-0.3239	0.0085	-38.2960	0.0000
sidc1	0.1364	0.0677	2.0136	0.0441
year2009	0.6399	0.3141	2.0369	0.0417
year2010	1.8511	0.3120	5.9338	0.0000
year2011	2.9702	0.3119	9.5241	0.0000
year2012	3.0073	0.3119	9.6432	0.0000
year2013	3.1034	0.3119	9.9516	0.0000
year2014	3.3003	0.3118	10.5830	0.0000
year2015	2.8155	0.3119	9.0281	0.0000
year2016	2.1988	0.3119	7.0499	0.0000
year2017	1.5936	0.3119	5.1090	0.0000
year2018	0.2995	0.3122	0.9592	0.3374
year2019	0.3319	0.3125	1.0621	0.2882
mon2	-0.1614	0.0093	-17.3295	0.0000
mon3	-0.1067	0.0087	-12.2599	0.0000
mon4	-0.0068	0.0084	-0.8030	0.4220
mon5	0.0073	0.0082	0.8860	0.3756
mon6	-0.1948	0.0087	-22.4803	0.0000
mon7	-0.1706	0.0084	-20.2543	0.0000
mon8	-0.0876	0.0082	-10.6193	0.0000
mon9	0.0103	0.0083	1.2475	0.2122
mon10	-0.0437	0.0085	-5.1313	0.0000
mon11	-0.0221	0.0089	-2.4832	0.0130
mon12	-0.1353	0.0091	-14.9175	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: 201907 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:115642	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 : 6.554	Mean :15.74		Mean :0.2604
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: 201907 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:115642	Length:115642
1st Qu.: 1.000	1st Qu.: 2.00	1st Qu.: 12.00	Class :character	Class :character
Median : 3.000	Median : 11.00	Median : 39.00	Mode :character	Mode :character
Mean : 3.121	Mean : 18.61	Mean : 49.82		
3rd Qu.: 5.000	3rd Qu.: 28.00	3rd Qu.: 78.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 201907 Summary of Sunspot Numbers

inst	filter	unit
Length:115642	Length:115642	Length:115642
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201907 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 70.00	1st Qu.: 3.00	1st Qu.: 500.0	1st Qu.: 40.0
Median : 88.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 99.32	Mean : 25.44	Mean : 985.3	Mean : 185.8
3rd Qu.: 120.00	3rd Qu.: 23.00	3rd Qu.:1233.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

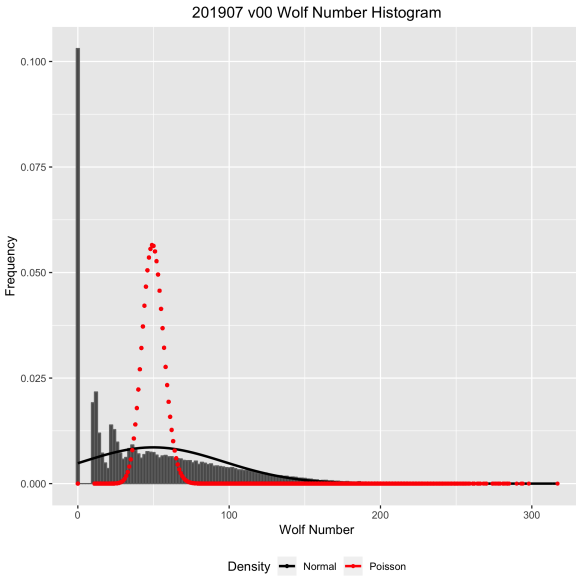


Figure 3: Box plots of raw Wolf number (w) by observer rank.

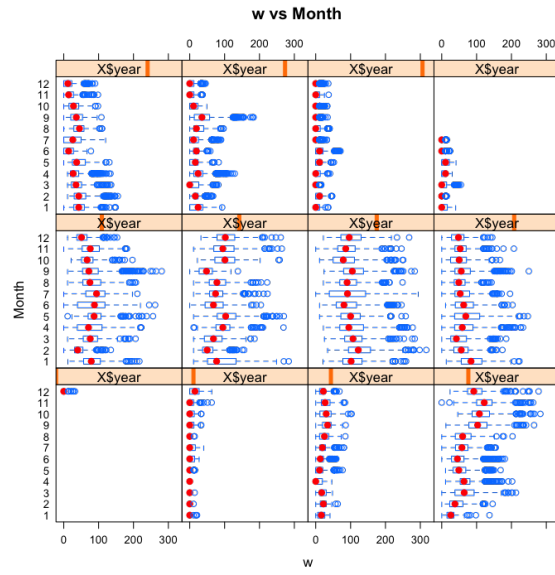


Figure 4: Box plots of raw Wolf number (w) by month and year.

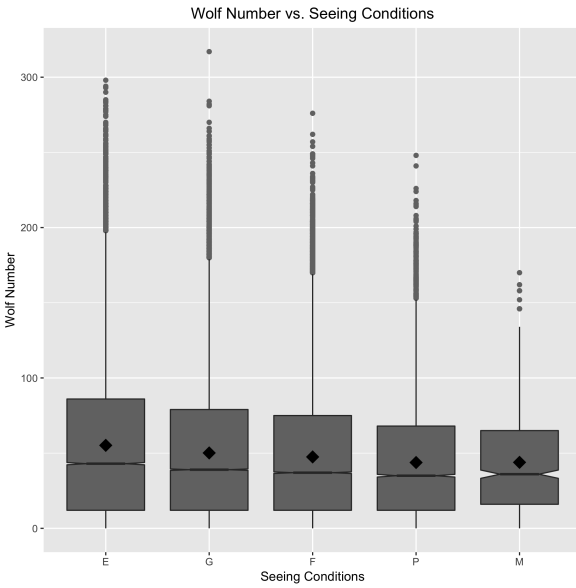


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

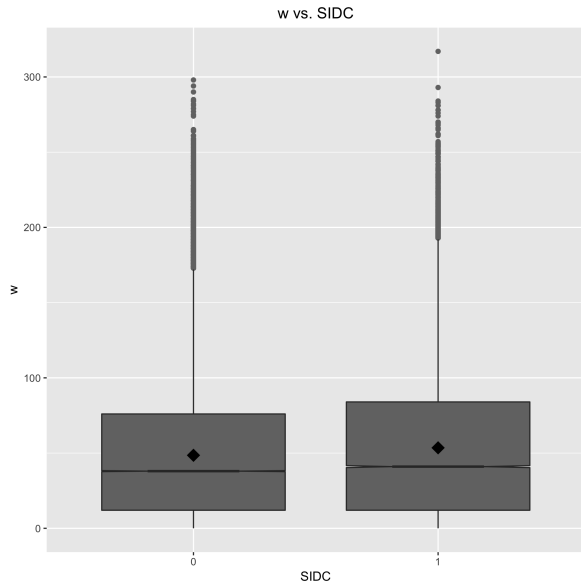


Figure 6: Box plots of raw Wolf number (w) by organization.

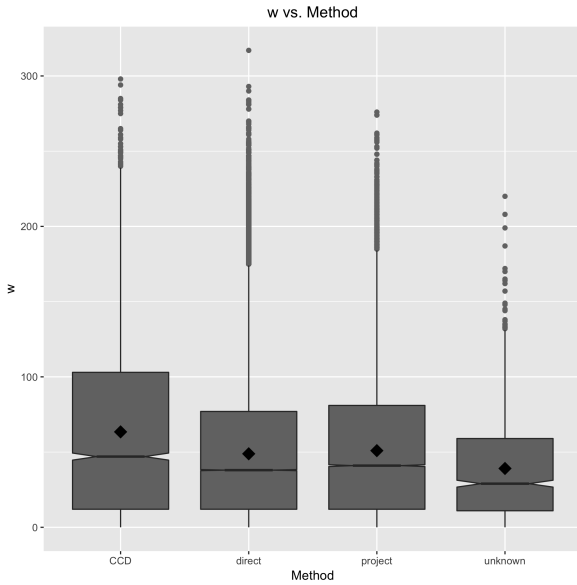


Figure 7: Box plots of raw Wolf number (w) by observer rank.

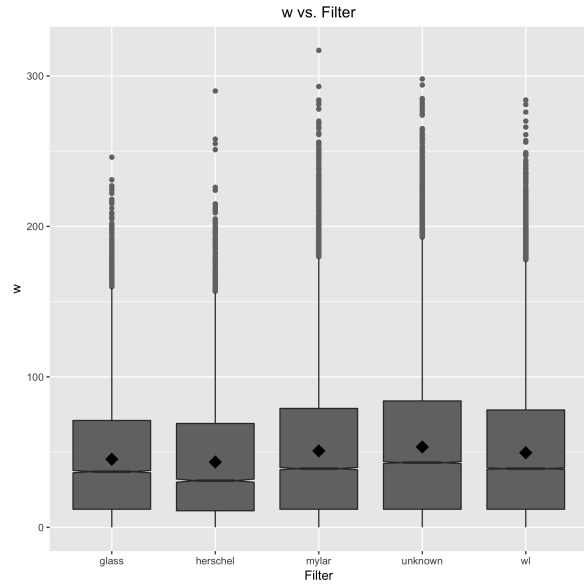


Figure 8: Box plots of raw Wolf number (w) by month and year.

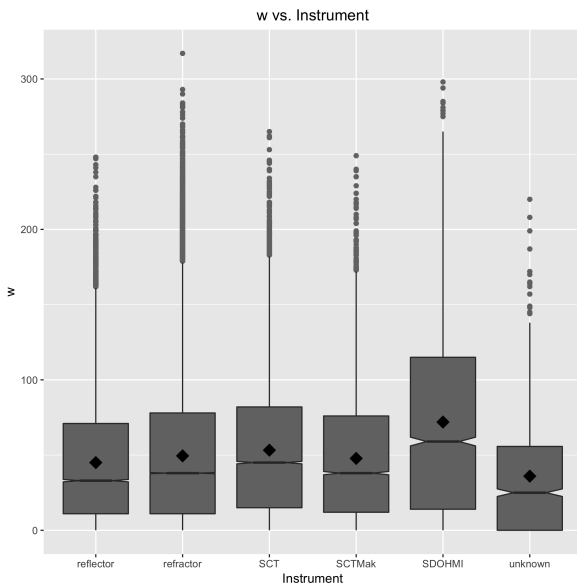


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

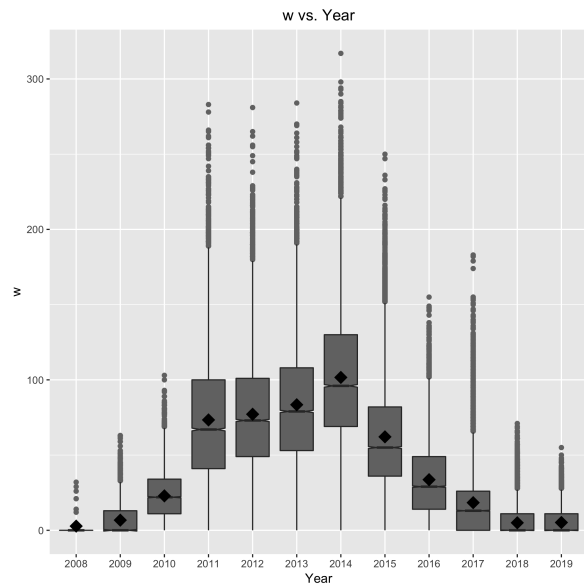


Figure 10: Box plots of raw Wolf number (w) by organization.

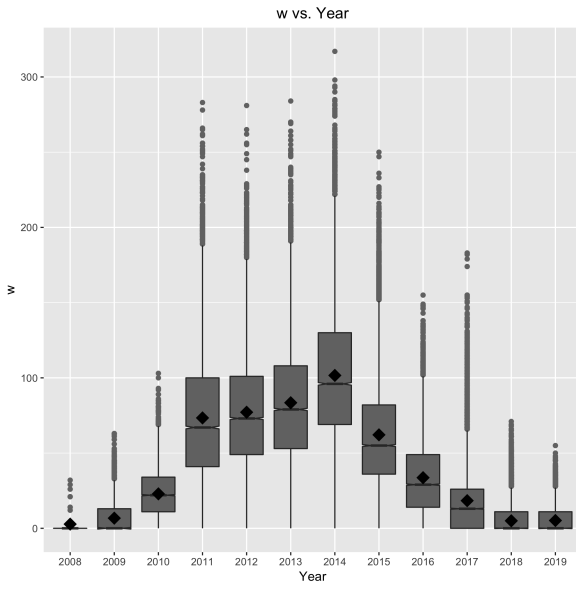


Figure 11: Box plots of raw Wolf number (w) by year.

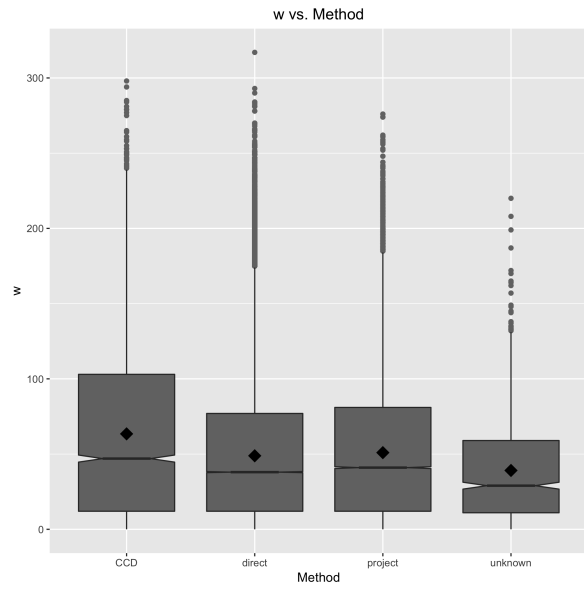


Figure 12: Box plots of raw Wolf number (w) by observing method.