

Monthly Report (00)

201906 Data Set

Sunday 14th July, 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.

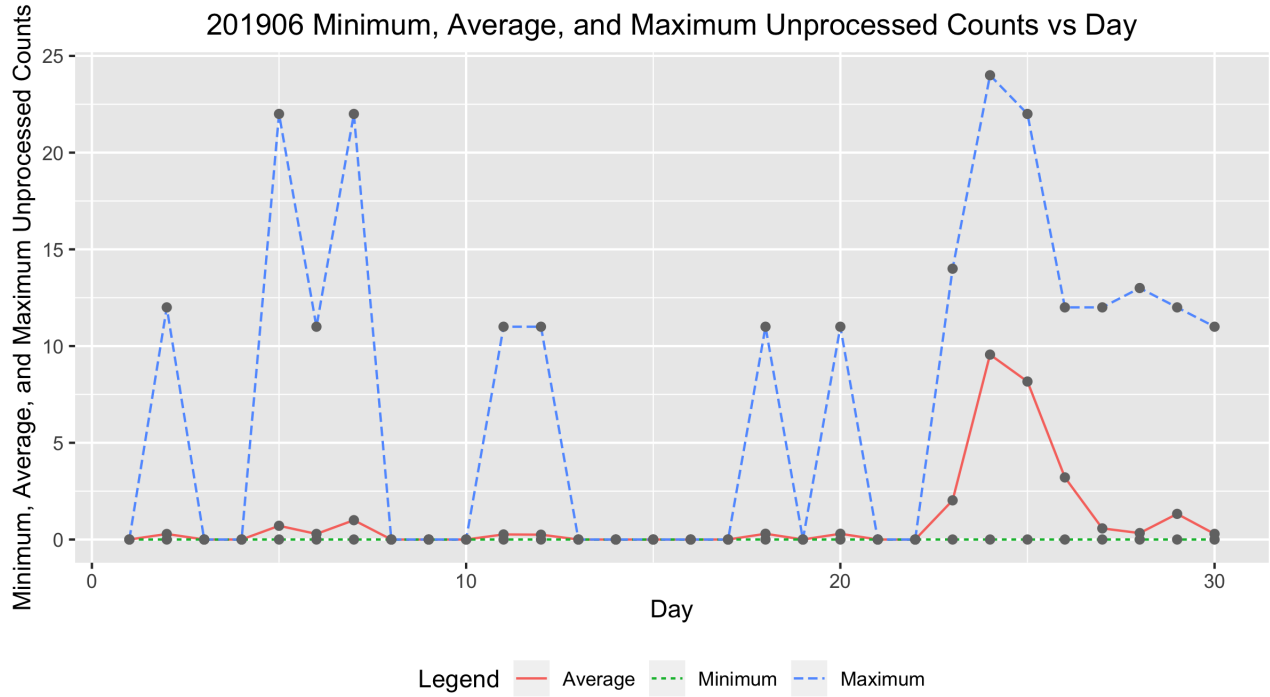


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201906 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	48.0000	0.0000	0.0000	0.0000
2.0000	42.0000	0.0000	0.2857	12.0000
3.0000	39.0000	0.0000	0.0000	0.0000
4.0000	38.0000	0.0000	0.0000	0.0000
5.0000	31.0000	0.0000	0.7097	22.0000
6.0000	38.0000	0.0000	0.2895	11.0000
7.0000	34.0000	0.0000	1.0000	22.0000
8.0000	44.0000	0.0000	0.0000	0.0000
9.0000	35.0000	0.0000	0.0000	0.0000
10.0000	36.0000	0.0000	0.0000	0.0000
11.0000	42.0000	0.0000	0.2619	11.0000
12.0000	44.0000	0.0000	0.2500	11.0000
13.0000	37.0000	0.0000	0.0000	0.0000
14.0000	41.0000	0.0000	0.0000	0.0000
15.0000	39.0000	0.0000	0.0000	0.0000
16.0000	38.0000	0.0000	0.0000	0.0000
17.0000	41.0000	0.0000	0.0000	0.0000
18.0000	37.0000	0.0000	0.2973	11.0000
19.0000	38.0000	0.0000	0.0000	0.0000
20.0000	37.0000	0.0000	0.2973	11.0000
21.0000	39.0000	0.0000	0.0000	0.0000
22.0000	43.0000	0.0000	0.0000	0.0000
23.0000	41.0000	0.0000	2.0244	14.0000
24.0000	43.0000	0.0000	9.5581	24.0000
25.0000	42.0000	0.0000	8.1667	22.0000
26.0000	38.0000	0.0000	3.2105	12.0000
27.0000	40.0000	0.0000	0.5750	12.0000
28.0000	39.0000	0.0000	0.3333	13.0000
29.0000	43.0000	0.0000	1.3256	12.0000
30.0000	38.0000	0.0000	0.2895	11.0000

3 Error Tables

Data are for the month of June 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	2.4083	3.1327	0.5000	1.0000
2009.01	5.8377	5.2066	6.4688	1.3000	1.3000
2009.02	5.0619	4.4998	5.6241	0.7000	1.2000
2009.03	6.6438	6.3792	6.9083	0.3000	0.6000
2009.04	7.4533	7.1793	7.7274	0.4000	1.2000
2009.05	7.5743	7.2666	7.8821	1.6000	2.9000
2009.06	6.6136	6.2726	6.9546	3.2000	6.3000
2009.07	6.3817	6.1199	6.6434	3.6000	5.5000
2009.08	7.0634	6.7767	7.3501	0.0000	0.0000
2009.09	7.5523	7.2774	7.8272	4.5000	7.1000
2009.10	7.0583	6.6795	7.4371	4.5000	7.7000
2009.11	7.0180	6.8247	7.2114	3.3000	6.9000
2009.12	6.5095	6.3240	6.6951	10.4000	16.3000
2010.01	21.5518	19.1015	24.0020	13.3000	19.5000
2010.02	16.9838	14.6776	19.2899	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	18.5654	16.2646	20.8662	15.4000	24.0000
2010.04	20.5703	18.1480	22.9927	7.0000	10.4000
2010.05	24.6762	24.2391	25.1132	8.4000	8.7000
2010.06	20.2077	19.8718	20.5435	11.0000	13.6000
2010.07	21.3715	21.0617	21.6814	15.2000	16.1000
2010.08	22.8669	22.4917	23.2420	18.3000	19.6000
2010.09	25.3843	24.9661	25.8025	22.8000	25.2000
2010.10	24.0029	23.5886	24.4172	21.0000	23.5000
2010.11	24.4473	24.0031	24.8915	20.9000	21.6000
2010.12	21.7502	21.3119	22.1884	13.9000	14.5000
2011.01	76.5896	75.0048	78.1744	17.7000	18.7000
2011.02	65.5742	64.1747	66.9738	29.1000	29.6000
2011.03	69.7536	68.4225	71.0847	48.0000	55.8000
2011.04	78.1299	76.7267	79.5331	47.3000	54.4000
2011.05	79.5417	78.1969	80.8866	37.3000	41.5000
2011.06	65.1332	63.9922	66.2741	35.2000	37.0000
2011.07	68.1828	67.0162	69.3495	41.5000	43.8000
2011.08	73.8215	72.6331	75.0100	42.4000	50.5000
2011.09	80.5644	79.1724	81.9565	73.8000	78.0000
2011.10	76.2147	74.9322	77.4973	78.9000	88.0000
2011.11	77.3986	75.7820	79.0152	84.6000	96.7000
2011.12	67.7669	66.3708	69.1631	65.8000	73.0000
2012.01	82.1889	80.5732	83.8046	55.8000	58.2000
2012.02	69.1845	67.7781	70.5910	29.2000	33.1000
2012.03	74.2821	72.9671	75.5972	53.1000	64.1000
2012.04	81.9738	80.5415	83.4060	51.4000	55.2000
2012.05	85.0525	83.6510	86.4540	61.8000	69.0000
2012.06	68.9510	67.7801	70.1218	59.7000	64.5000
2012.07	72.5774	71.3880	73.7668	64.2000	51.3000
2012.08	75.7849	74.5693	77.0004	57.7000	63.1000
2012.09	83.2422	81.7987	84.6856	57.7000	61.5000
2012.10	79.5892	78.1344	81.0441	48.3000	53.3000
2012.11	80.8066	79.1862	82.4270	56.7000	61.4000
2012.12	70.9292	69.3909	72.4676	37.4000	40.8000
2013.01	91.3882	89.6426	93.1337	63.8000	62.9000
2013.02	77.0872	75.5374	78.6371	37.8000	38.0000
2013.03	80.1567	78.5293	81.7842	50.6000	57.9000
2013.04	89.4080	87.8388	90.9772	70.6000	72.4000
2013.05	90.6584	89.0476	92.2692	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	75.0002	73.6759	76.3245	51.0000	52.5000
2013.07	77.9662	76.7159	79.2165	57.0000	57.0000
2013.08	82.9584	81.6261	84.2906	60.0000	66.0000
2013.09	89.8313	88.2303	91.4323	34.6000	36.9000
2013.10	84.8400	83.2684	86.4115	74.5000	85.6000
2013.11	84.5772	82.6816	86.4729	73.9000	77.6000
2013.12	76.3438	74.7147	77.9729	77.8000	90.3000
2014.01	106.4652	104.2268	108.7037	77.4000	82.0000
2014.02	91.5931	89.7903	93.3958	93.9000	102.8000
2014.03	97.4685	95.6953	99.2417	80.9000	92.2000
2014.04	108.8880	106.9887	110.7874	76.9000	84.7000
2014.05	111.1010	109.2067	112.9953	72.3000	75.2000
2014.06	91.7095	90.1606	93.2583	67.2000	71.0000
2014.07	95.0363	93.4561	96.6164	72.5000	72.5000
2014.08	101.2879	99.7068	102.8691	71.2000	74.7000
2014.09	110.8218	108.8695	112.7741	83.2000	87.6000
2014.10	104.3378	102.4175	106.2580	59.5000	60.6000
2014.11	105.0663	102.8799	107.2527	65.8000	71.1000
2014.12	92.8844	90.7319	95.0370	75.8000	78.0000
2015.01	65.8336	64.5160	67.1513	65.9000	67.0000
2015.02	55.2538	54.0372	56.4704	42.4000	44.8000
2015.03	59.5756	58.4853	60.6660	38.0000	38.4000
2015.04	66.1077	64.9225	67.2930	49.0000	54.4000
2015.05	67.7734	66.6524	68.8944	56.3000	58.8000
2015.06	55.8289	54.8213	56.8365	50.2000	68.3000
2015.07	57.3581	56.3784	58.3379	47.9000	65.8000
2015.08	62.3702	61.3214	63.4190	39.5000	57.2000
2015.09	67.3518	66.1267	68.5768	49.2000	72.1000
2015.10	63.9195	62.6843	65.1546	39.3000	48.3000
2015.11	65.0766	63.6634	66.4899	39.6000	55.9000
2015.12	57.6075	56.3421	58.8729	36.4000	44.8000
2016.01	36.0449	35.2925	36.7972	33.7000	43.3000
2016.02	30.3874	29.7537	31.0211	38.3000	46.8000
2016.03	32.2380	31.5946	32.8814	30.5000	38.9000
2016.04	35.6793	34.9990	36.3597	26.6000	30.9000
2016.05	36.6614	35.9910	37.3318	33.7000	48.4000
2016.06	29.8750	29.3651	30.3849	13.1000	19.5000
2016.07	31.2485	30.7458	31.7511	21.2000	27.5000
2016.08	33.6169	33.0252	34.2086	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	37.1687	36.4898	37.8476	27.7000	37.1000
2016.10	34.8669	34.1941	35.5398	22.7000	31.7000
2016.11	35.1027	34.3686	35.8368	14.0000	22.2000
2016.12	31.4683	30.7959	32.1408	11.1000	20.0000
2017.01	19.6099	19.1975	20.0223	18.4000	26.2000
2017.02	16.5975	16.2330	16.9620	14.4000	20.6000
2017.03	17.7620	17.4237	18.1003	11.3000	15.5000
2017.04	19.8708	19.5203	20.2214	21.6000	33.2000
2017.05	20.0878	19.7410	20.4346	12.5000	18.1000
2017.06	16.3796	16.1063	16.6529	15.5000	19.3000
2017.07	17.2159	16.9422	17.4897	11.5000	16.3000
2017.08	18.4591	18.1402	18.7780	22.8000	35.7000
2017.09	20.6973	20.2808	21.1137	34.6000	42.9000
2017.10	18.9745	18.5939	19.3551	10.5000	11.0000
2017.11	18.9514	18.5556	19.3472	4.2000	5.6000
2017.12	16.9023	16.6464	17.1582	4.0000	4.6000
2018.01	5.4319	5.3155	5.5482	3.1000	6.3000
2018.02	4.5573	4.4471	4.6674	6.8000	11.8000
2018.03	4.7907	4.6955	4.8860	1.1000	1.2000
2018.04	5.3134	5.2078	5.4190	4.7000	7.5000
2018.05	5.4843	5.3802	5.5884	8.4000	14.0000
2018.06	4.4684	4.3886	4.5482	10.2000	13.6000
2018.07	4.6889	4.6363	4.7415	0.5000	1.7000
2018.08	4.9768	4.8904	5.0633	5.9000	9.5000
2018.09	5.3750	5.2747	5.4753	1.6000	2.9000
2018.10	5.1904	5.0898	5.2909	2.5000	5.6000
2018.11	5.2196	5.1117	5.3275	3.1000	4.2000
2018.12	4.7599	4.6659	4.8539	1.6000	2.3000
2019.01	6.6460	6.5204	6.7717	5.4000	2.3000
2019.02	5.7233	5.6096	5.8369	0.1000	1.2000
2019.03	5.9370	5.8348	6.0393	6.1000	12.1000
2019.04	6.6227	6.4983	6.7471	6.2000	9.3000
2019.05	6.5714	6.4560	6.6868	7.0000	11.9000
2019.06	5.3859	5.2934	5.4784	0.7000	1.5000

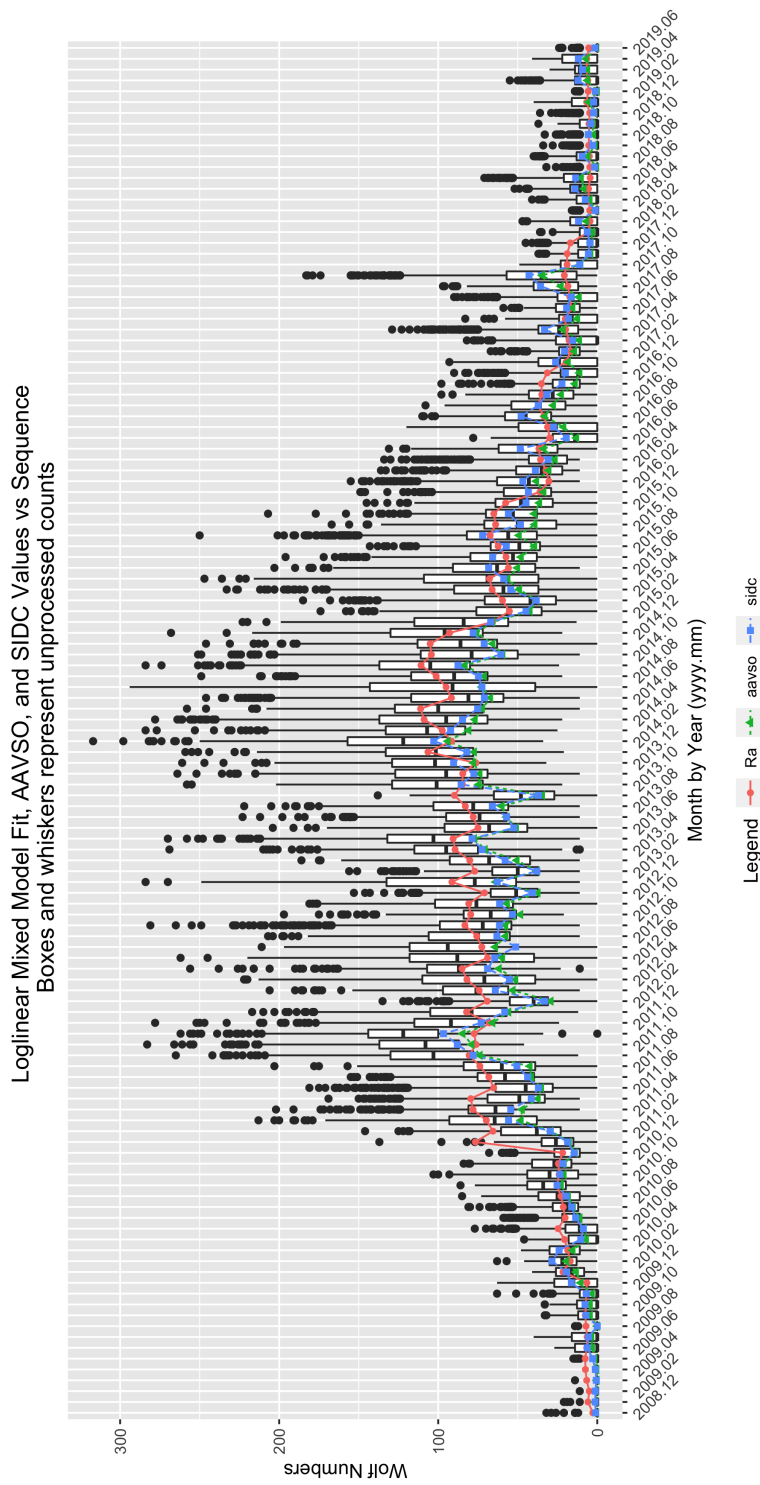


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201906 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4409	0.3138	4.5918	0.0000
seeF	-0.2180	0.0059	-36.8313	0.0000
seeG	-0.1162	0.0052	-22.5485	0.0000
seeM	-0.1984	0.0244	-8.1461	0.0000
seeP	-0.3239	0.0085	-38.2198	0.0000
sidc1	0.1434	0.0672	2.1348	0.0328
year2009	0.6406	0.3148	2.0349	0.0419
year2010	1.8508	0.3126	5.9198	0.0000
year2011	2.9710	0.3125	9.5058	0.0000
year2012	3.0083	0.3125	9.6252	0.0000
year2013	3.1043	0.3125	9.9326	0.0000
year2014	3.3012	0.3125	10.5629	0.0000
year2015	2.8165	0.3125	9.0114	0.0000
year2016	2.1997	0.3126	7.0373	0.0000
year2017	1.5946	0.3126	5.1007	0.0000
year2018	0.2998	0.3129	0.9580	0.3381
year2019	0.4918	0.3132	1.5700	0.1164
mon2	-0.1613	0.0093	-17.2845	0.0000
mon3	-0.1067	0.0087	-12.2311	0.0000
mon4	-0.0067	0.0084	-0.7903	0.4294
mon5	0.0076	0.0083	0.9238	0.3556
mon6	-0.1945	0.0087	-22.3990	0.0000
mon7	-0.1573	0.0084	-18.6152	0.0000
mon8	-0.0853	0.0083	-10.3155	0.0000
mon9	0.0127	0.0083	1.5243	0.1274
mon10	-0.0414	0.0085	-4.8522	0.0000
mon11	-0.0198	0.0089	-2.2214	0.0263
mon12	-0.1331	0.0091	-14.6342	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: 201906 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:114321	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 : 6.549	Mean :15.74		Mean :0.2606
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: 201906 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:114321	Length:114321
1st Qu.: 1.000	1st Qu.: 2.00	1st Qu.: 12.00	Class :character	Class :character
Median : 3.000	Median : 11.00	Median : 40.00	Mode :character	Mode :character
Mean : 3.157	Mean : 18.82	Mean : 50.39		
3rd Qu.: 5.000	3rd Qu.: 28.00	3rd Qu.: 79.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 201906 Summary of Sunspot Numbers

inst	filter	unit
Length:114321	Length:114321	Length:114321
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201906 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.0	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 70.0	1st Qu.: 3.00	1st Qu.: 500.0	1st Qu.: 40.0
Median : 89.0	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 100.3	Mean : 25.02	Mean : 996.5	Mean : 186.1
3rd Qu.: 120.0	3rd Qu.: 23.00	3rd Qu.:1233.0	3rd Qu.: 76.0
Max. :1524.0	Max. :2010.00	Max. :4300.0	Max. :4591.0

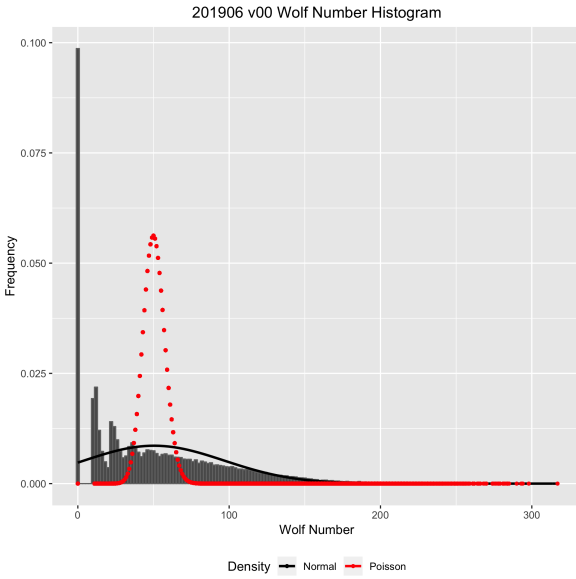


Figure 3: Box plots of raw Wolf number (w) by observer rank.

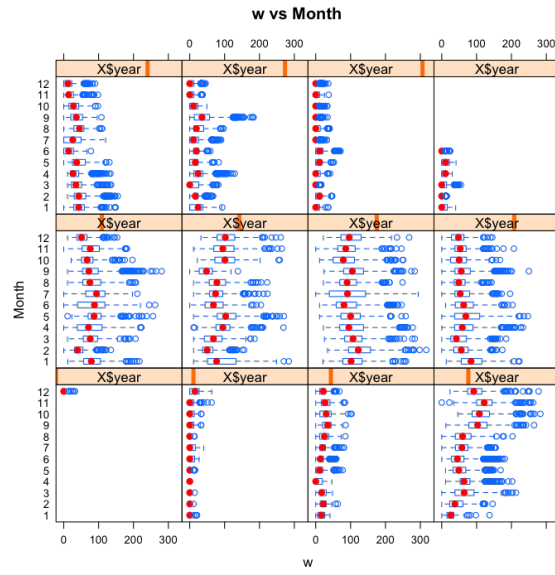


Figure 4: Box plots of raw Wolf number (w) by month and year.

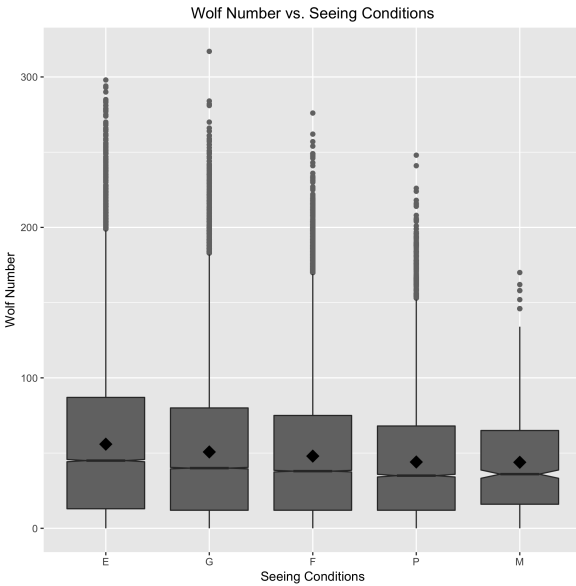


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

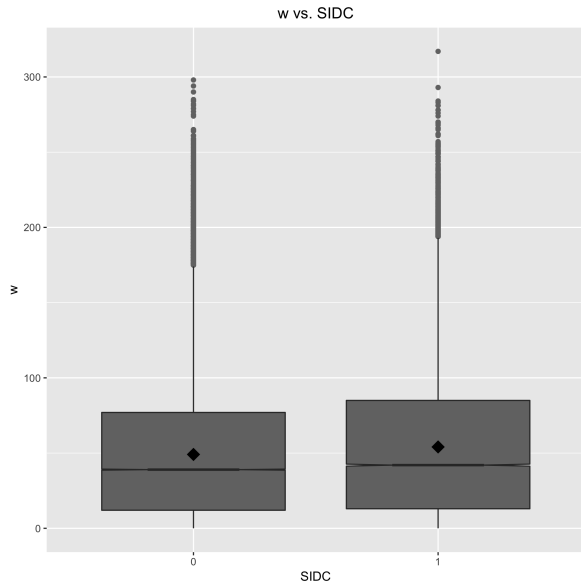


Figure 6: Box plots of raw Wolf number (w) by organization.

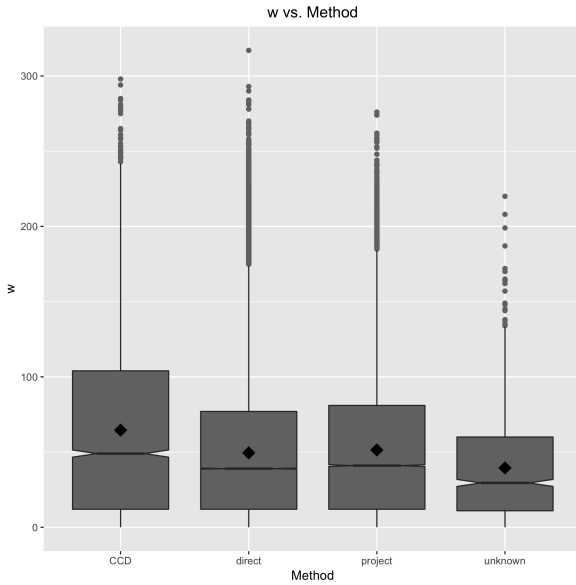


Figure 7: Box plots of raw Wolf number (w) by observer rank.

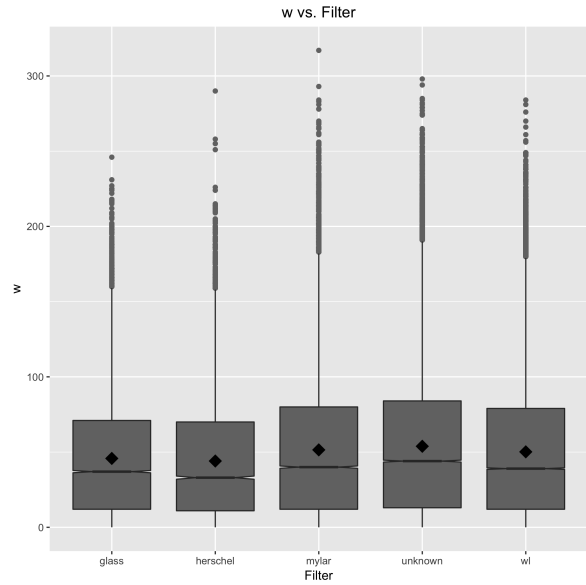


Figure 8: Box plots of raw Wolf number (w) by month and year.

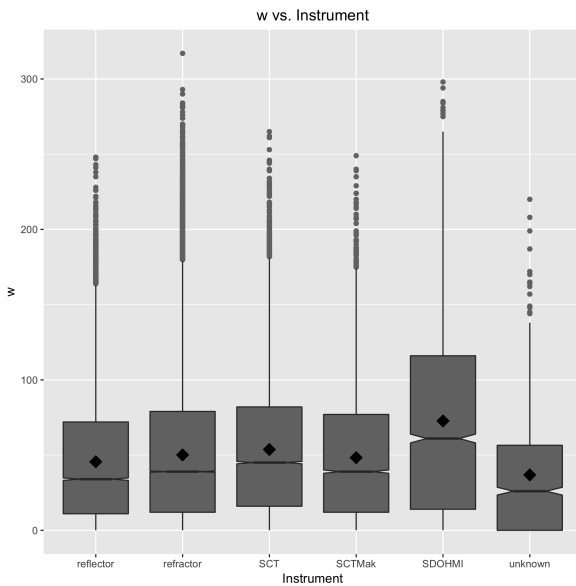


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

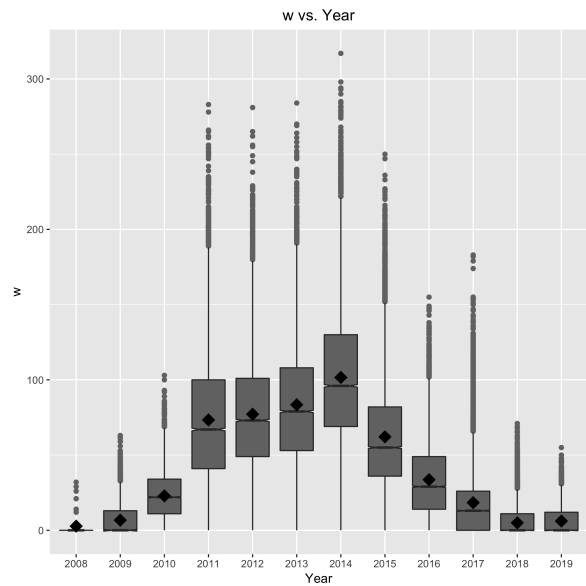


Figure 10: Box plots of raw Wolf number (w) by organization.

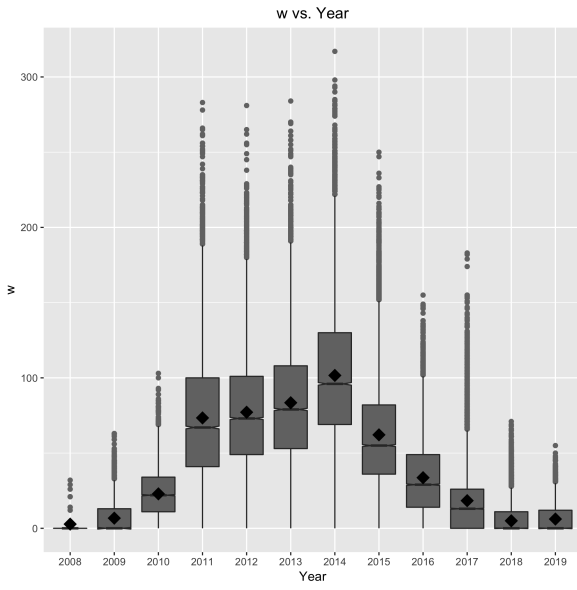


Figure 11: Box plots of raw Wolf number (w) by year.

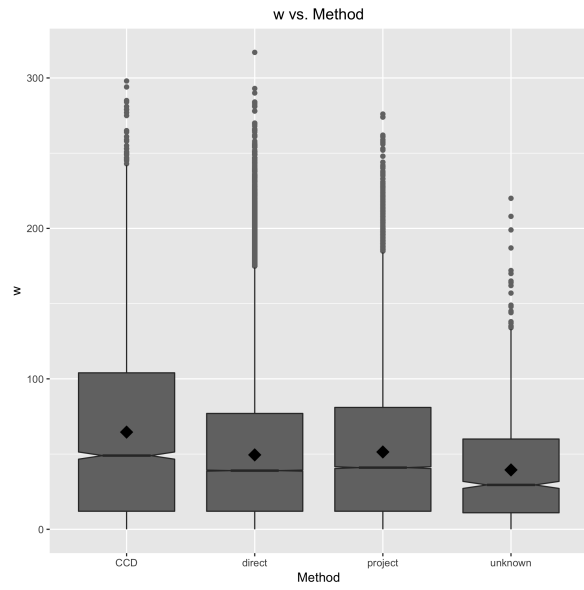


Figure 12: Box plots of raw Wolf number (w) by observing method.