

Monthly Report (00)
201908 Data Set

Friday 13th September, 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.

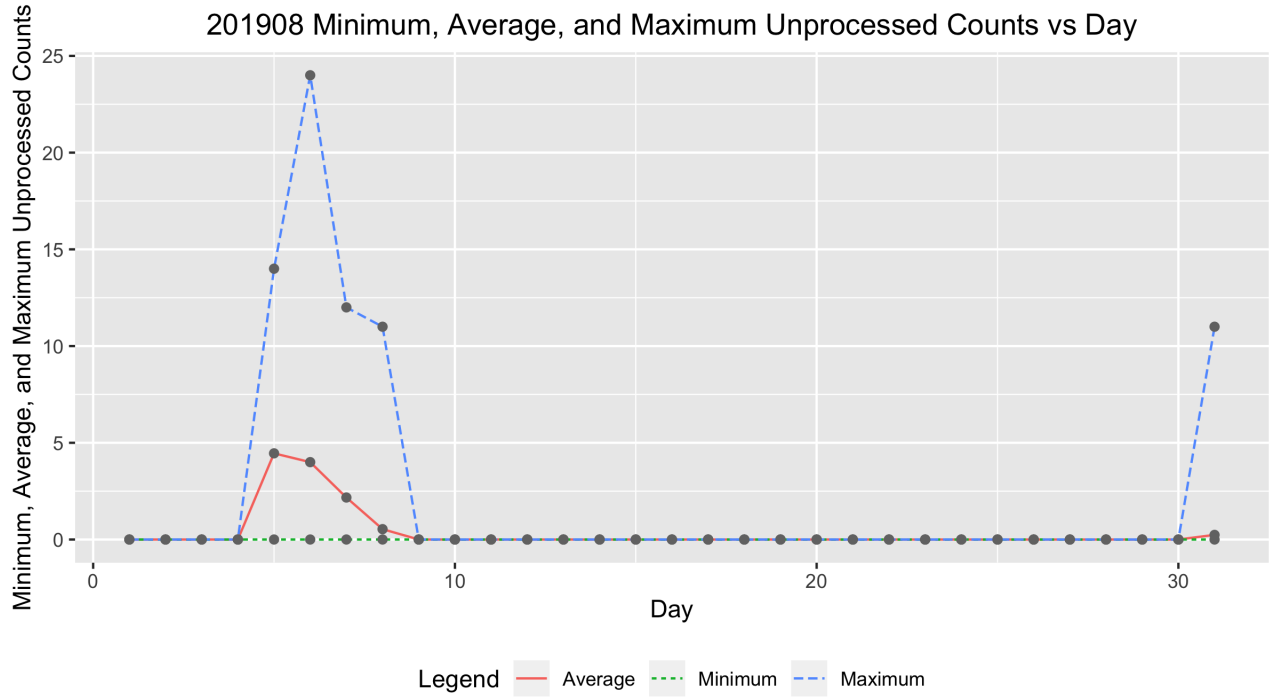


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201908 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	43.0000	0.0000	0.0000	0.0000
2.0000	44.0000	0.0000	0.0000	0.0000
3.0000	42.0000	0.0000	0.0000	0.0000
4.0000	41.0000	0.0000	0.0000	0.0000
5.0000	44.0000	0.0000	4.4545	14.0000
6.0000	34.0000	0.0000	4.0000	24.0000
7.0000	41.0000	0.0000	2.1707	12.0000
8.0000	41.0000	0.0000	0.5366	11.0000
9.0000	44.0000	0.0000	0.0000	0.0000
10.0000	42.0000	0.0000	0.0000	0.0000
11.0000	43.0000	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	44.0000	0.0000	0.0000	0.0000
15.0000	44.0000	0.0000	0.0000	0.0000
16.0000	43.0000	0.0000	0.0000	0.0000
17.0000	39.0000	0.0000	0.0000	0.0000
18.0000	45.0000	0.0000	0.0000	0.0000
19.0000	40.0000	0.0000	0.0000	0.0000
20.0000	46.0000	0.0000	0.0000	0.0000
21.0000	42.0000	0.0000	0.0000	0.0000
22.0000	39.0000	0.0000	0.0000	0.0000
23.0000	37.0000	0.0000	0.0000	0.0000
24.0000	43.0000	0.0000	0.0000	0.0000
25.0000	40.0000	0.0000	0.0000	0.0000
26.0000	42.0000	0.0000	0.0000	0.0000
27.0000	43.0000	0.0000	0.0000	0.0000
28.0000	39.0000	0.0000	0.0000	0.0000
29.0000	48.0000	0.0000	0.0000	0.0000
30.0000	45.0000	0.0000	0.0000	0.0000
31.0000	46.0000	0.0000	0.2391	11.0000

3 Error Tables

Data are for the month of August 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	2.4059	3.1350	0.5000	1.0000
2009.01	5.8526	5.2155	6.4897	1.3000	1.3000
2009.02	5.0751	4.5075	5.6427	0.7000	1.2000
2009.03	6.6711	6.4059	6.9363	0.3000	0.6000
2009.04	7.4830	7.2083	7.7577	0.4000	1.2000
2009.05	7.6011	7.2926	7.9095	1.6000	2.9000
2009.06	6.6382	6.2961	6.9802	3.2000	6.3000
2009.07	6.3223	6.0633	6.5814	3.6000	5.5000
2009.08	6.9976	6.7139	7.2813	0.0000	0.0000
2009.09	7.5524	7.2779	7.8269	4.5000	7.1000
2009.10	7.0586	6.6804	7.4369	4.5000	7.7000
2009.11	7.0178	6.8238	7.2118	3.3000	6.9000
2009.12	6.5103	6.3241	6.6965	10.4000	16.3000
2010.01	21.6498	19.1721	24.1275	13.3000	19.5000
2010.02	17.0488	14.7172	19.3805	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	18.6407	16.3150	20.9665	15.4000	24.0000
2010.04	20.6515	18.2032	23.0997	7.0000	10.4000
2010.05	24.7968	24.3562	25.2374	8.4000	8.7000
2010.06	20.3135	19.9756	20.6515	11.0000	13.6000
2010.07	21.2068	20.8989	21.5147	15.2000	16.1000
2010.08	22.6936	22.3210	23.0661	18.3000	19.6000
2010.09	25.4254	25.0061	25.8447	22.8000	25.2000
2010.10	24.0433	23.6279	24.4587	21.0000	23.5000
2010.11	24.4845	24.0392	24.9298	20.9000	21.6000
2010.12	21.7863	21.3466	22.2260	13.9000	14.5000
2011.01	76.8906	75.2963	78.4849	17.7000	18.7000
2011.02	65.8194	64.4112	67.2275	29.1000	29.6000
2011.03	70.0318	68.6928	71.3708	48.0000	55.8000
2011.04	78.4367	77.0266	79.8469	47.3000	54.4000
2011.05	79.8232	78.4715	81.1748	37.3000	41.5000
2011.06	65.3759	64.2295	66.5224	35.2000	37.0000
2011.07	67.5628	66.4062	68.7195	41.5000	43.8000
2011.08	73.1505	71.9720	74.3291	42.4000	50.5000
2011.09	80.5732	79.1790	81.9674	73.8000	78.0000
2011.10	76.2245	74.9399	77.5090	78.9000	88.0000
2011.11	77.4011	75.7825	79.0197	84.6000	96.7000
2011.12	67.7742	66.3762	69.1722	65.8000	73.0000
2012.01	82.5109	80.8873	84.1345	55.8000	58.2000
2012.02	69.4496	68.0366	70.8627	29.2000	33.1000
2012.03	74.5767	73.2551	75.8983	53.1000	64.1000
2012.04	82.2896	80.8506	83.7286	51.4000	55.2000
2012.05	85.3483	83.9408	86.7559	61.8000	69.0000
2012.06	69.1971	68.0209	70.3734	59.7000	64.5000
2012.07	71.8971	70.7178	73.0765	64.2000	51.3000
2012.08	75.0794	73.8741	76.2846	57.7000	63.1000
2012.09	83.2323	81.7883	84.6763	57.7000	61.5000
2012.10	79.5860	78.1301	81.0419	48.3000	53.3000
2012.11	80.7961	79.1745	82.4178	56.7000	61.4000
2012.12	70.9283	69.3889	72.4677	37.4000	40.8000
2013.01	91.7614	90.0074	93.5154	63.8000	62.9000
2013.02	77.3848	75.8277	78.9419	37.8000	38.0000
2013.03	80.4793	78.8442	82.1144	50.6000	57.9000
2013.04	89.7507	88.1737	91.3276	70.6000	72.4000
2013.05	90.9757	89.3578	92.5935	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	75.2700	73.9399	76.6001	51.0000	52.5000
2013.07	77.2351	75.9957	78.4745	57.0000	57.0000
2013.08	82.1811	80.8603	83.5019	60.0000	66.0000
2013.09	89.8192	88.2175	91.4209	34.6000	36.9000
2013.10	84.8312	83.2588	86.4036	74.5000	85.6000
2013.11	84.5723	82.6755	86.4690	73.9000	77.6000
2013.12	76.3465	74.7163	77.9767	77.8000	90.3000
2014.01	106.8940	104.6453	109.1428	77.4000	82.0000
2014.02	91.9439	90.1328	93.7549	93.9000	102.8000
2014.03	97.8525	96.0709	99.6341	80.9000	92.2000
2014.04	109.2967	107.3887	111.2046	76.9000	84.7000
2014.05	111.4764	109.5744	113.3784	72.3000	75.2000
2014.06	92.0334	90.4782	93.5886	67.2000	71.0000
2014.07	94.1373	92.5711	95.7035	72.5000	72.5000
2014.08	100.3352	98.7680	101.9024	71.2000	74.7000
2014.09	110.8069	108.8538	112.7600	83.2000	87.6000
2014.10	104.3246	102.4034	106.2458	59.5000	60.6000
2014.11	105.0596	102.8725	107.2467	65.8000	71.1000
2014.12	92.8768	90.7233	95.0303	75.8000	78.0000
2015.01	66.0862	64.7631	67.4093	65.9000	67.0000
2015.02	55.4627	54.2414	56.6840	42.4000	44.8000
2015.03	59.8052	58.7104	60.9000	38.0000	38.4000
2015.04	66.3543	65.1644	67.5443	49.0000	54.4000
2015.05	68.0009	66.8760	69.1259	56.3000	58.8000
2015.06	56.0185	55.0072	57.0298	50.2000	68.3000
2015.07	56.8138	55.8432	57.7844	47.9000	65.8000
2015.08	61.7785	60.7395	62.8175	39.5000	57.2000
2015.09	67.3359	66.1107	68.5612	49.2000	72.1000
2015.10	63.9042	62.6689	65.1395	39.3000	48.3000
2015.11	65.0659	63.6525	66.4794	39.6000	55.9000
2015.12	57.5980	56.3319	58.8642	36.4000	44.8000
2016.01	36.1893	35.4338	36.9447	33.7000	43.3000
2016.02	30.5045	29.8683	31.1408	38.3000	46.8000
2016.03	32.3643	31.7182	33.0104	30.5000	38.9000
2016.04	35.8174	35.1344	36.5004	26.6000	30.9000
2016.05	36.7886	36.1159	37.4613	33.7000	48.4000
2016.06	29.9801	29.4684	30.4918	13.1000	19.5000
2016.07	30.9530	30.4551	31.4510	21.2000	27.5000
2016.08	33.3004	32.7142	33.8866	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	37.1626	36.4837	37.8414	27.7000	37.1000
2016.10	34.8643	34.1915	35.5370	22.7000	31.7000
2016.11	35.0998	34.3657	35.8339	14.0000	22.2000
2016.12	31.4656	30.7928	32.1383	11.1000	20.0000
2017.01	19.6862	19.2719	20.1004	18.4000	26.2000
2017.02	16.6602	16.2942	17.0262	14.4000	20.6000
2017.03	17.8305	17.4908	18.1702	11.3000	15.5000
2017.04	19.9432	19.5912	20.2952	21.6000	33.2000
2017.05	20.1535	19.8055	20.5016	12.5000	18.1000
2017.06	16.4362	16.1618	16.7106	15.5000	19.3000
2017.07	17.0529	16.7817	17.3241	11.5000	16.3000
2017.08	18.2865	17.9696	18.6033	22.8000	35.7000
2017.09	20.7143	20.2908	21.1377	34.6000	42.9000
2017.10	18.9738	18.5911	19.3564	10.5000	11.0000
2017.11	18.9473	18.5508	19.3438	4.2000	5.6000
2017.12	16.8930	16.6367	17.1493	4.0000	4.6000
2018.01	5.4655	5.3486	5.5824	3.1000	6.3000
2018.02	4.5861	4.4749	4.6973	6.8000	11.8000
2018.03	4.8185	4.7231	4.9140	1.1000	1.2000
2018.04	5.3418	5.2355	5.4480	4.7000	7.5000
2018.05	5.5028	5.3983	5.6074	8.4000	14.0000
2018.06	4.4858	4.4059	4.5657	10.2000	13.6000
2018.07	4.6449	4.5929	4.6970	0.5000	1.7000
2018.08	4.9294	4.8436	5.0151	5.9000	9.5000
2018.09	5.3772	5.2767	5.4777	1.6000	2.9000
2018.10	5.1960	5.0955	5.2965	2.5000	5.6000
2018.11	5.2286	5.1211	5.3361	3.1000	4.2000
2018.12	4.7638	4.6704	4.8572	1.6000	2.3000
2019.01	4.9377	4.8449	5.0305	5.4000	2.3000
2019.02	4.2489	4.1653	4.3326	0.1000	1.2000
2019.03	4.4037	4.3279	4.4795	6.1000	12.1000
2019.04	4.9107	4.8178	5.0035	6.2000	9.3000
2019.05	4.8628	4.7760	4.9496	7.0000	11.9000
2019.06	3.9755	3.9054	4.0456	0.7000	1.5000
2019.07	4.1356	4.0708	4.2003	0.4000	2.2000
2019.08	4.4748	4.4062	4.5435	0.3000	0.8000

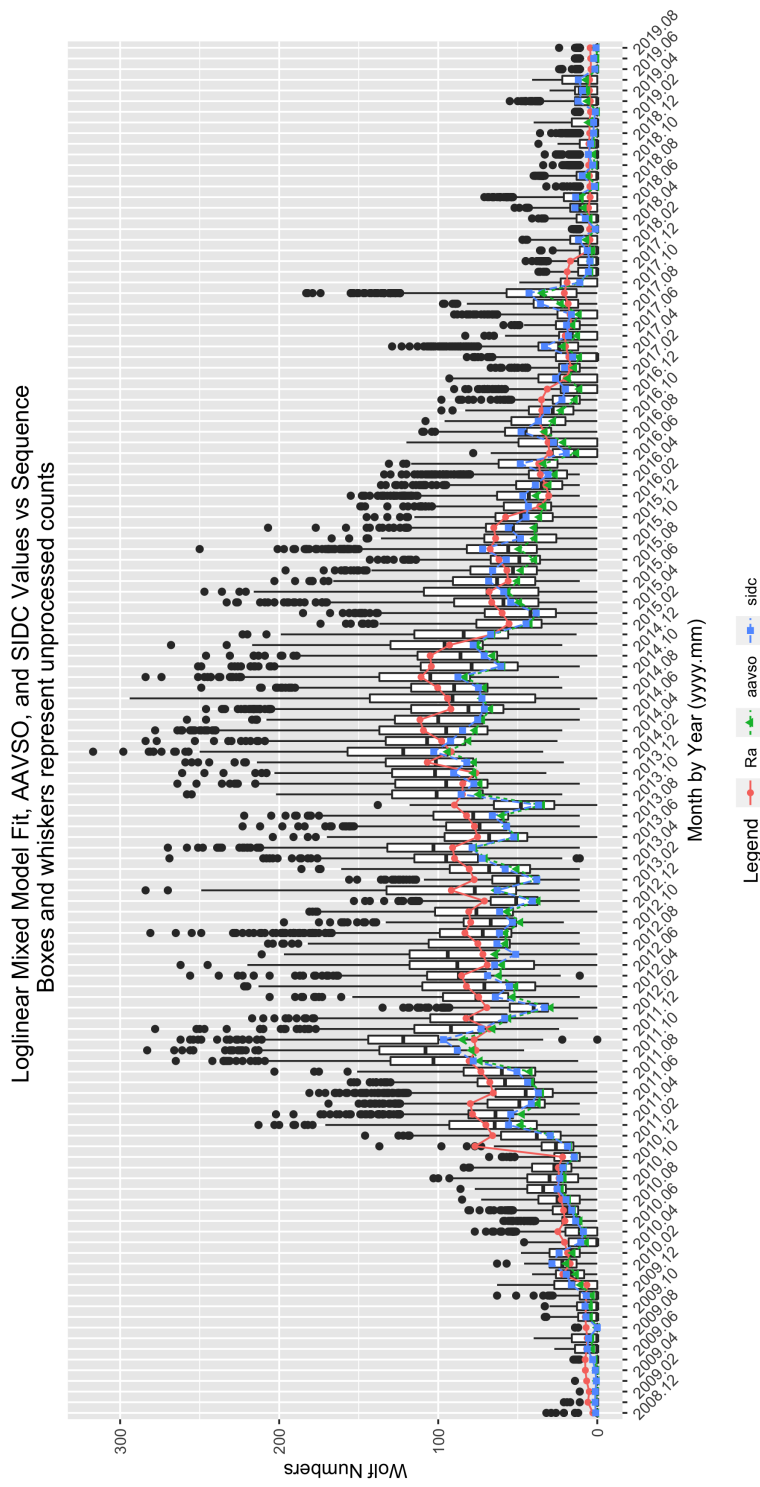


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201908 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4462	0.3124	4.6291	0.0000
seeF	-0.2184	0.0059	-37.0717	0.0000
seeG	-0.1166	0.0051	-22.7150	0.0000
seeM	-0.2005	0.0242	-8.2671	0.0000
seeP	-0.3240	0.0084	-38.4031	0.0000
sidc1	0.1356	0.0684	1.9832	0.0473
year2009	0.6392	0.3134	2.0396	0.0414
year2010	1.8509	0.3112	5.9472	0.0000
year2011	2.9694	0.3111	9.5442	0.0000
year2012	3.0064	0.3111	9.6633	0.0000
year2013	3.1025	0.3111	9.9723	0.0000
year2014	3.2994	0.3111	10.6052	0.0000
year2015	2.8145	0.3111	9.0463	0.0000
year2016	2.1978	0.3112	7.0633	0.0000
year2017	1.5925	0.3112	5.1175	0.0000
year2018	0.2982	0.3115	0.9574	0.3384
year2019	0.1858	0.3118	0.5958	0.5513
mon2	-0.1615	0.0093	-17.3772	0.0000
mon3	-0.1068	0.0087	-12.2920	0.0000
mon4	-0.0069	0.0084	-0.8167	0.4141
mon5	0.0070	0.0082	0.8557	0.3921
mon6	-0.1950	0.0086	-22.5613	0.0000
mon7	-0.1708	0.0084	-20.3272	0.0000
mon8	-0.0988	0.0082	-12.0114	0.0000
mon9	0.0085	0.0083	1.0265	0.3047
mon10	-0.0455	0.0085	-5.3584	0.0000
mon11	-0.0239	0.0089	-2.6937	0.0071
mon12	-0.1371	0.0090	-15.1508	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: 201908 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:116956	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 : 6.571	Mean :15.74		Mean :0.2601
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: 201908 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:116956	Length:116956
1st Qu.: 1.000	1st Qu.: 1.0	1st Qu.: 11.00	Class :character	Class :character
Median : 3.000	Median : 11.0	Median : 38.00	Mode :character	Mode :character
Mean : 3.086	Mean : 18.4	Mean : 49.26		
3rd Qu.: 5.000	3rd Qu.: 27.0	3rd Qu.: 78.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 201908 Summary of Sunspot Numbers

inst	filter	unit
Length:116956	Length:116956	Length:116956
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201908 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 : 85.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 98.36	Mean : 25.83	Mean : 974.4	Mean : 185.5
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1233.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

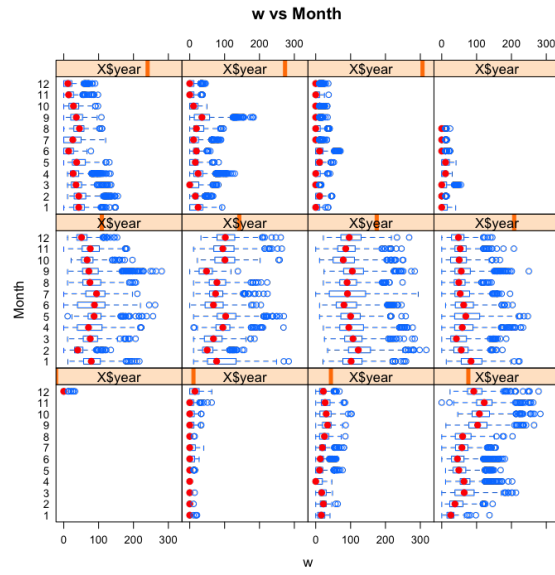
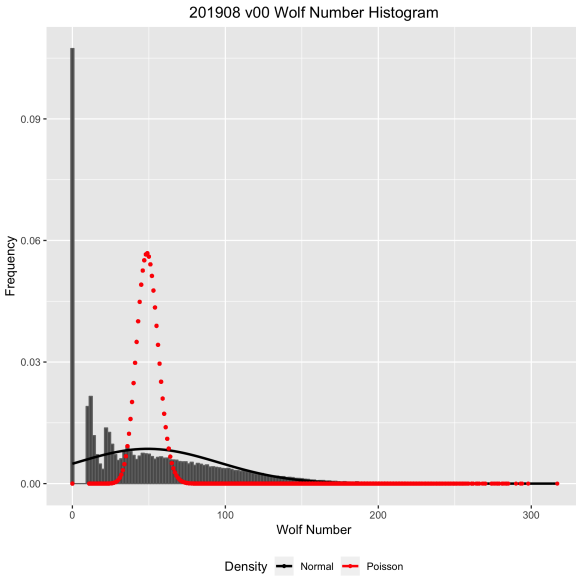


Figure 3: Box plots of raw Wolf number (w) by observer rank.

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

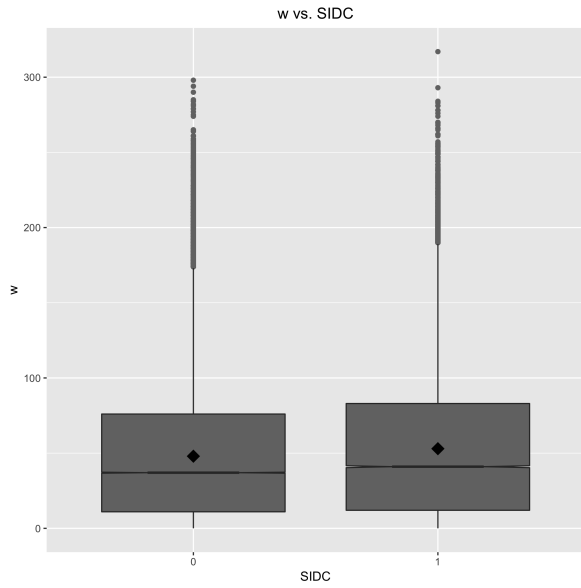
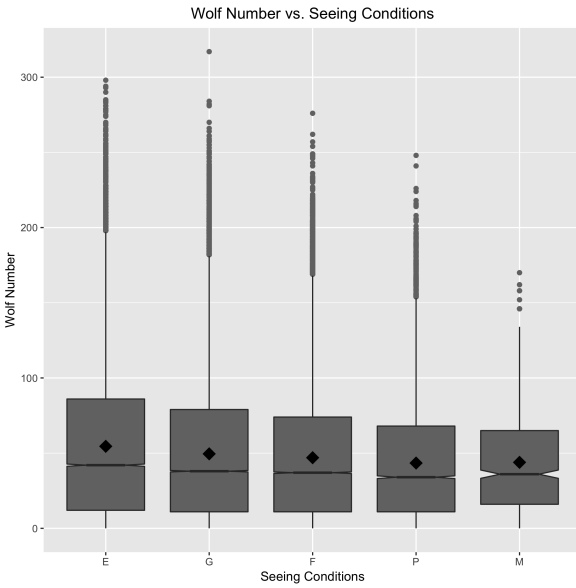


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

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

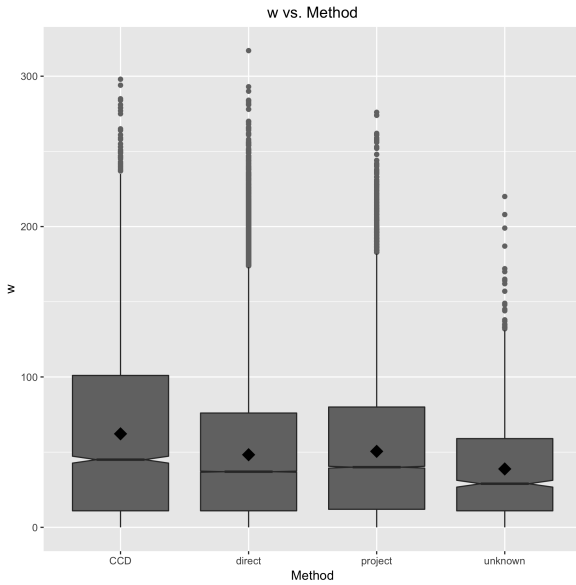


Figure 7: Box plots of raw Wolf number (w) by observer rank.

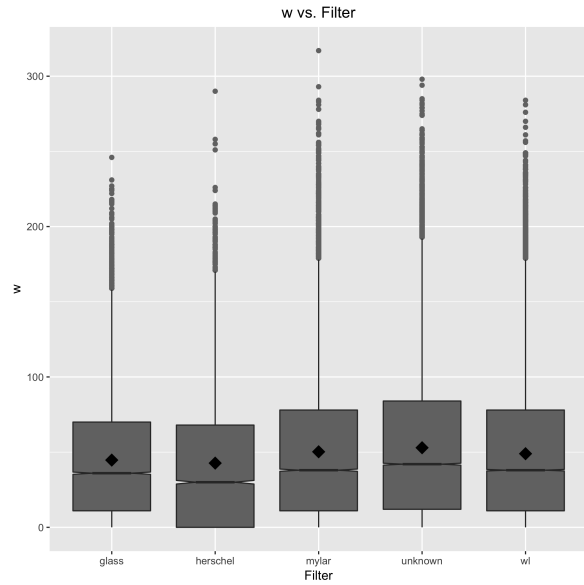


Figure 8: Box plots of raw Wolf number (w) by month and year.

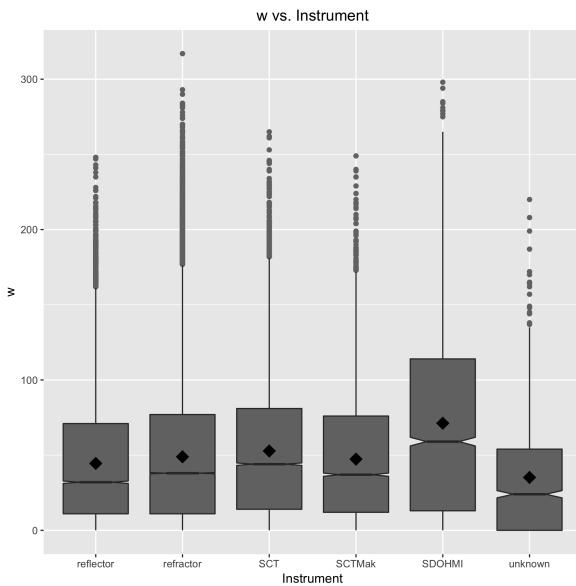


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

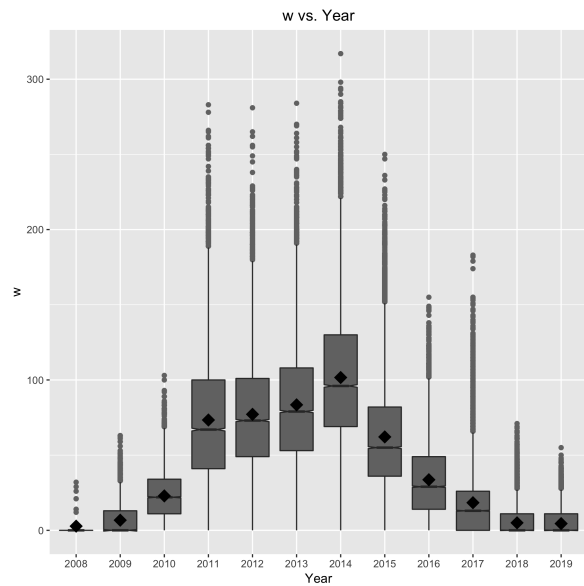


Figure 10: Box plots of raw Wolf number (w) by organization.

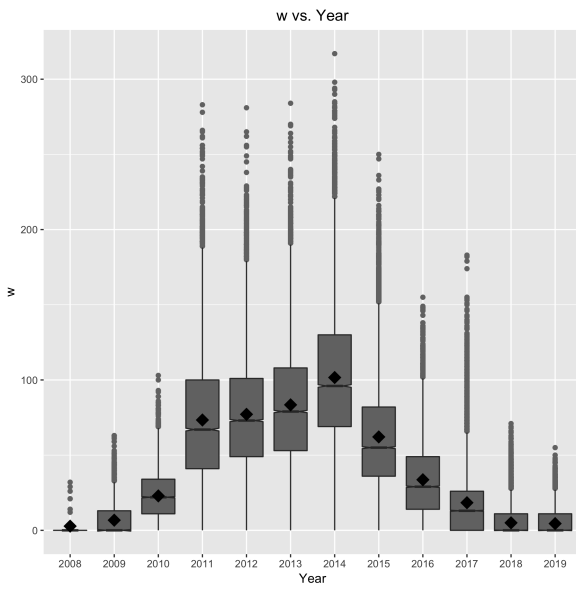


Figure 11: Box plots of raw Wolf number (w) by year.

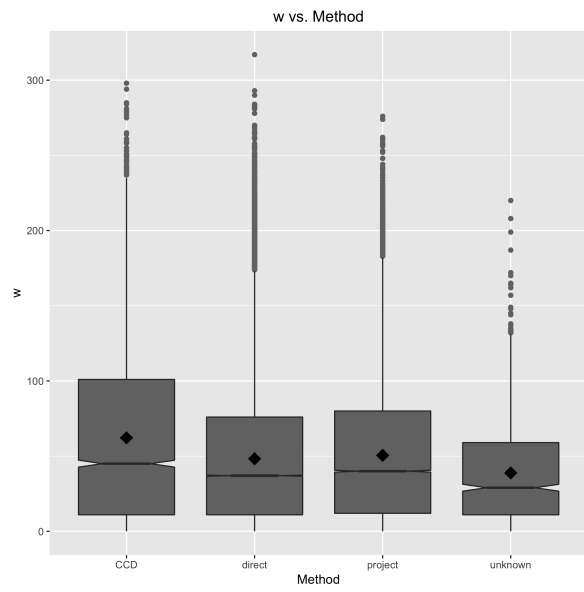


Figure 12: Box plots of raw Wolf number (w) by observing method.