

Monthly Report (00)

201901 Data Set

Sunday 17th February, 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.

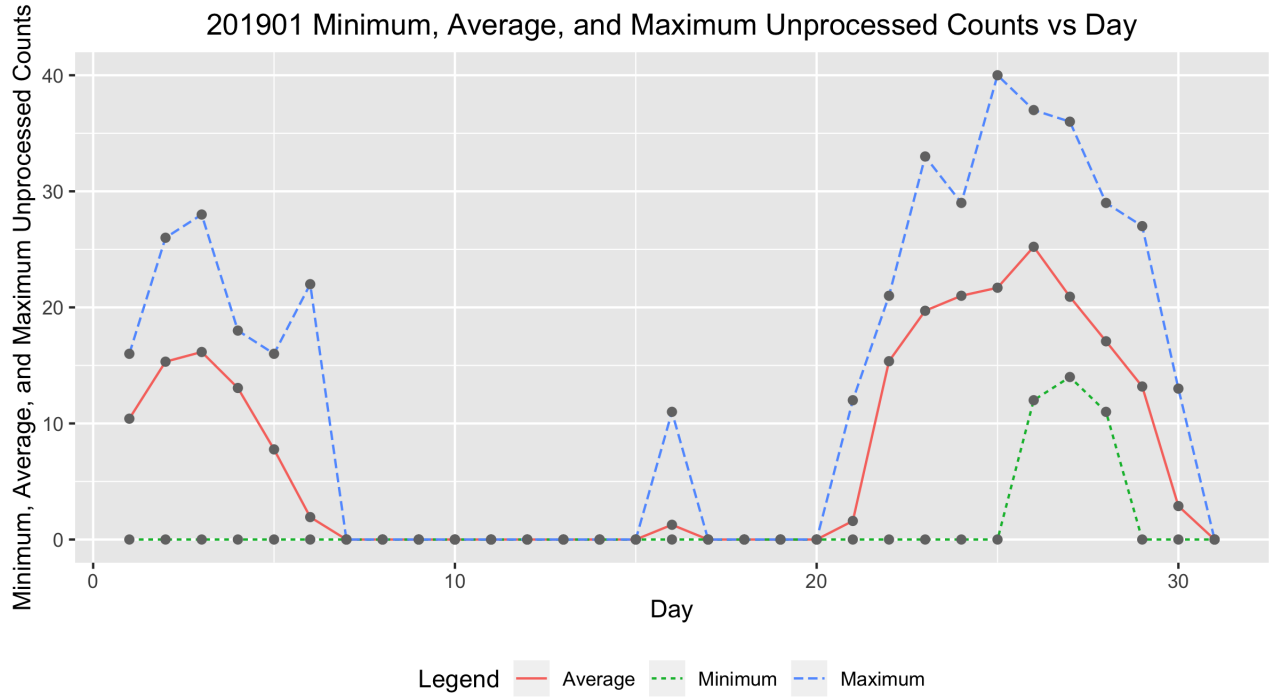


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201901 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	34.0000	0.0000	10.4118	16.0000
2.0000	28.0000	0.0000	15.3214	26.0000
3.0000	32.0000	0.0000	16.1562	28.0000
4.0000	36.0000	0.0000	13.0556	18.0000
5.0000	34.0000	0.0000	7.7647	16.0000
6.0000	29.0000	0.0000	1.9310	22.0000
7.0000	31.0000	0.0000	0.0000	0.0000
8.0000	30.0000	0.0000	0.0000	0.0000
9.0000	33.0000	0.0000	0.0000	0.0000
10.0000	29.0000	0.0000	0.0000	0.0000
11.0000	30.0000	0.0000	0.0000	0.0000
12.0000	26.0000	0.0000	0.0000	0.0000
13.0000	36.0000	0.0000	0.0000	0.0000
14.0000	36.0000	0.0000	0.0000	0.0000
15.0000	25.0000	0.0000	0.0000	0.0000
16.0000	26.0000	0.0000	1.2692	11.0000
17.0000	29.0000	0.0000	0.0000	0.0000
18.0000	26.0000	0.0000	0.0000	0.0000
19.0000	32.0000	0.0000	0.0000	0.0000
20.0000	35.0000	0.0000	0.0000	0.0000
21.0000	35.0000	0.0000	1.6000	12.0000
22.0000	25.0000	0.0000	15.3600	21.0000
23.0000	24.0000	0.0000	19.7083	33.0000
24.0000	30.0000	0.0000	21.0000	29.0000
25.0000	39.0000	0.0000	21.6923	40.0000
26.0000	41.0000	12.0000	25.2195	37.0000
27.0000	36.0000	14.0000	20.9167	36.0000
28.0000	38.0000	11.0000	17.0789	29.0000
29.0000	33.0000	0.0000	13.1818	27.0000
30.0000	34.0000	0.0000	2.8824	13.0000
31.0000	24.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of January 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	2.4074	3.1335	0.5000	1.0000
2009.01	5.8180	5.1874	6.4486	1.3000	1.3000
2009.02	5.1293	4.5583	5.7004	0.7000	1.2000
2009.03	6.5956	6.3333	6.8580	0.3000	0.6000
2009.04	7.4183	7.1459	7.6906	0.4000	1.2000
2009.05	7.5245	7.2187	7.8303	1.6000	2.9000
2009.06	6.6878	6.3431	7.0325	3.2000	6.3000
2009.07	6.3805	6.1189	6.6422	3.6000	5.5000
2009.08	7.0634	6.7765	7.3503	0.0000	0.0000
2009.09	7.5515	7.2769	7.8261	4.5000	7.1000
2009.10	7.0566	6.6779	7.4353	4.5000	7.7000
2009.11	7.0189	6.8248	7.2131	3.3000	6.9000
2009.12	6.5108	6.3245	6.6972	10.4000	16.3000
2010.01	21.4635	19.0178	23.9093	13.3000	19.5000
2010.02	17.1911	14.8510	19.5312	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	18.4066	16.1195	20.6937	15.4000	24.0000
2010.04	20.4428	18.0292	22.8563	7.0000	10.4000
2010.05	24.5100	24.0747	24.9454	8.4000	8.7000
2010.06	20.4253	20.0851	20.7655	11.0000	13.6000
2010.07	21.3654	21.0551	21.6758	15.2000	16.1000
2010.08	22.8594	22.4837	23.2352	18.3000	19.6000
2010.09	25.3783	24.9593	25.7973	22.8000	25.2000
2010.10	23.9940	23.5791	24.4090	21.0000	23.5000
2010.11	24.4470	24.0024	24.8915	20.9000	21.6000
2010.12	21.7441	21.3050	22.1831	13.9000	14.5000
2011.01	76.3852	74.8014	77.9690	17.7000	18.7000
2011.02	66.4774	65.0535	67.9013	29.1000	29.6000
2011.03	69.2755	67.9517	70.5994	48.0000	55.8000
2011.04	77.7769	76.3784	79.1753	47.3000	54.4000
2011.05	79.0449	77.7067	80.3831	37.3000	41.5000
2011.06	65.8634	64.7073	67.0195	35.2000	37.0000
2011.07	68.1844	67.0152	69.3537	41.5000	43.8000
2011.08	73.8223	72.6311	75.0135	42.4000	50.5000
2011.09	80.5704	79.1753	81.9655	73.8000	78.0000
2011.10	76.2137	74.9292	77.4982	78.9000	88.0000
2011.11	77.3989	75.7798	79.0181	84.6000	96.7000
2011.12	67.7759	66.3779	69.1739	65.8000	73.0000
2012.01	81.9985	80.3855	83.6116	55.8000	58.2000
2012.02	70.1671	68.7393	71.5949	29.2000	33.1000
2012.03	73.7750	72.4673	75.0827	53.1000	64.1000
2012.04	81.6072	80.1796	83.0347	51.4000	55.2000
2012.05	84.5145	83.1200	85.9090	61.8000	69.0000
2012.06	69.7312	68.5448	70.9175	59.7000	64.5000
2012.07	72.5825	71.3908	73.7743	64.2000	51.3000
2012.08	75.7809	74.5632	76.9985	57.7000	63.1000
2012.09	83.2412	81.7956	84.6868	57.7000	61.5000
2012.10	79.5888	78.1317	81.0459	48.3000	53.3000
2012.11	80.8179	79.1953	82.4404	56.7000	61.4000
2012.12	70.9336	69.3932	72.4740	37.4000	40.8000
2013.01	91.1736	89.4304	92.9169	63.8000	62.9000
2013.02	78.1799	76.6061	79.7538	37.8000	38.0000
2013.03	79.5943	77.9767	81.2119	50.6000	57.9000
2013.04	89.0059	87.4417	90.5700	70.6000	72.4000
2013.05	90.0896	88.4865	91.6928	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	75.8446	74.5031	77.1861	51.0000	52.5000
2013.07	77.9639	76.7119	79.2159	57.0000	57.0000
2013.08	82.9601	81.6264	84.2938	60.0000	66.0000
2013.09	89.8367	88.2342	91.4392	34.6000	36.9000
2013.10	84.8393	83.2664	86.4122	74.5000	85.6000
2013.11	84.5817	82.6848	86.4787	73.9000	77.6000
2013.12	76.3510	74.7206	77.9813	77.8000	90.3000
2014.01	106.2021	103.9666	108.4375	77.4000	82.0000
2014.02	92.8837	91.0536	94.7137	93.9000	102.8000
2014.03	96.7960	95.0332	98.5587	80.9000	92.2000
2014.04	108.4044	106.5116	110.2972	76.9000	84.7000
2014.05	110.4036	108.5193	112.2878	72.3000	75.2000
2014.06	92.7364	91.1678	94.3049	67.2000	71.0000
2014.07	95.0367	93.4547	96.6187	72.5000	72.5000
2014.08	101.2870	99.7039	102.8702	71.2000	74.7000
2014.09	110.8254	108.8711	112.7797	83.2000	87.6000
2014.10	104.3432	102.4212	106.2653	59.5000	60.6000
2014.11	105.0598	102.8705	107.2490	65.8000	71.1000
2014.12	92.8913	90.7364	95.0462	75.8000	78.0000
2015.01	65.6965	64.3799	67.0132	65.9000	67.0000
2015.02	56.0340	54.7978	57.2702	42.4000	44.8000
2015.03	59.1630	58.0779	60.2480	38.0000	38.4000
2015.04	65.8188	64.6359	67.0017	49.0000	54.4000
2015.05	67.3444	66.2272	68.4615	56.3000	58.8000
2015.06	56.4652	55.4435	57.4869	50.2000	68.3000
2015.07	57.3598	56.3775	58.3421	47.9000	65.8000
2015.08	62.3819	61.3301	63.4336	39.5000	57.2000
2015.09	67.3651	66.1372	68.5930	49.2000	72.1000
2015.10	63.9273	62.6893	65.1653	39.3000	48.3000
2015.11	65.0890	63.6722	66.5057	39.6000	55.9000
2015.12	57.6238	56.3555	58.8921	36.4000	44.8000
2016.01	35.9542	35.2023	36.7062	33.7000	43.3000
2016.02	30.8132	30.1696	31.4569	38.3000	46.8000
2016.03	32.0087	31.3686	32.6489	30.5000	38.9000
2016.04	35.5087	34.8299	36.1876	26.6000	30.9000
2016.05	36.4212	35.7532	37.0891	33.7000	48.4000
2016.06	30.2033	29.6864	30.7202	13.1000	19.5000
2016.07	31.2530	30.7488	31.7571	21.2000	27.5000
2016.08	33.6175	33.0242	34.2108	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	37.1646	36.4839	37.8452	27.7000	37.1000
2016.10	34.8647	34.1900	35.5394	22.7000	31.7000
2016.11	35.0981	34.3623	35.8339	14.0000	22.2000
2016.12	31.4670	30.7935	32.1405	11.1000	20.0000
2017.01	19.5652	19.1529	19.9775	18.4000	26.2000
2017.02	16.8344	16.4640	17.2048	14.4000	20.6000
2017.03	17.6417	17.3049	17.9784	11.3000	15.5000
2017.04	19.7874	19.4375	20.1373	21.6000	33.2000
2017.05	19.9649	19.6192	20.3105	12.5000	18.1000
2017.06	16.5722	16.2948	16.8497	15.5000	19.3000
2017.07	17.2214	16.9467	17.4962	11.5000	16.3000
2017.08	18.4606	18.1415	18.7797	22.8000	35.7000
2017.09	20.6859	20.2759	21.0959	34.6000	42.9000
2017.10	18.9715	18.5912	19.3517	10.5000	11.0000
2017.11	18.9519	18.5547	19.3490	4.2000	5.6000
2017.12	16.8871	16.6295	17.1447	4.0000	4.6000
2018.01	5.4211	5.3036	5.5385	3.1000	6.3000
2018.02	4.6227	4.5099	4.7356	6.8000	11.8000
2018.03	4.7597	4.6636	4.8559	1.1000	1.2000
2018.04	5.2924	5.1850	5.3998	4.7000	7.5000
2018.05	5.4692	5.3612	5.5771	8.4000	14.0000
2018.06	4.5277	4.4436	4.6118	10.2000	13.6000
2018.07	4.6839	4.6289	4.7388	0.5000	1.7000
2018.08	4.9718	4.8805	5.0630	5.9000	9.5000
2018.09	5.3679	5.2636	5.4723	1.6000	2.9000
2018.10	5.1909	5.0877	5.2941	2.5000	5.6000
2018.11	5.2019	5.0898	5.3140	3.1000	4.2000
2018.12	4.7544	4.6547	4.8541	1.6000	2.3000
2019.01	7.6650	7.5126	7.8173	5.4000	2.3000

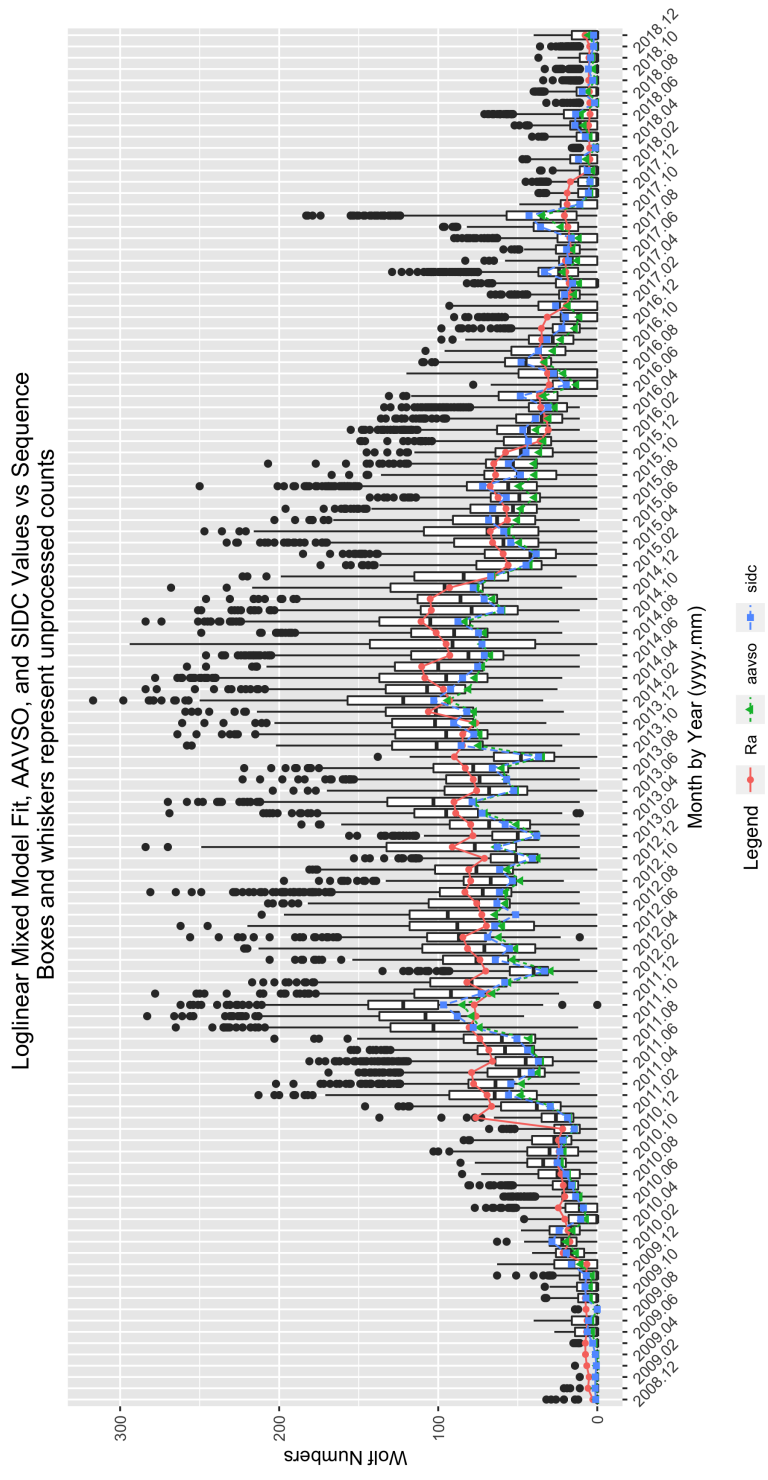


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201901 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4319	0.3157	4.5361	0.0000
seeF	-0.2186	0.0060	-36.6174	0.0000
seeG	-0.1159	0.0052	-22.2926	0.0000
seeM	-0.1972	0.0245	-8.0464	0.0000
seeP	-0.3249	0.0086	-37.9988	0.0000
sidc1	0.1648	0.0700	2.3526	0.0186
year2009	0.6397	0.3167	2.0203	0.0434
year2010	1.8491	0.3145	5.8802	0.0000
year2011	2.9695	0.3144	9.4461	0.0000
year2012	3.0069	0.3144	9.5653	0.0000
year2013	3.1030	0.3144	9.8710	0.0000
year2014	3.2999	0.3143	10.4976	0.0000
year2015	2.8154	0.3144	8.9561	0.0000
year2016	2.1984	0.3144	6.9925	0.0000
year2017	1.5937	0.3144	5.0687	0.0000
year2018	0.3011	0.3147	0.9567	0.3387
year2019	0.6409	0.3180	2.0152	0.0439
mon2	-0.1449	0.0094	-15.3658	0.0000
mon3	-0.1113	0.0089	-12.5602	0.0000
mon4	-0.0089	0.0086	-1.0381	0.2992
mon5	0.0035	0.0084	0.4233	0.6721
mon6	-0.1810	0.0088	-20.6206	0.0000
mon7	-0.1550	0.0085	-18.1601	0.0000
mon8	-0.0830	0.0084	-9.9345	0.0000
mon9	0.0150	0.0084	1.7927	0.0730
mon10	-0.0390	0.0086	-4.5287	0.0000
mon11	-0.0173	0.0090	-1.9267	0.0540
mon12	-0.1305	0.0092	-14.2189	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: 201901 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:108789	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 : 6.673	Mean :15.73		Mean :0.2621
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: 201901 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:108789	Length:108789
1st Qu.: 1.000	1st Qu.: 3.00	1st Qu.: 13.00	Class :character	Class :character
Median : 3.000	Median : 12.00	Median : 43.00	Mode :character	Mode :character
Mean : 3.295	Mean : 19.71	Mean : 52.65		
3rd Qu.: 5.000	3rd Qu.: 29.00	3rd Qu.: 81.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 201901 Summary of Sunspot Numbers

inst	filter	unit
Length:108789	Length:108789	Length:108789
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201901 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.0	Min. : 0.00	Min. : 0	Min. : 0.0
1st Qu.: 76.0	1st Qu.: 3.00	1st Qu.: 630	1st Qu.: 40.0
Median : 89.0	Median : 13.00	Median : 912	Median : 57.5
Mean : 104.8	Mean : 22.84	Mean :1046	Mean : 186.6
3rd Qu.: 120.0	3rd Qu.: 23.00	3rd Qu.:1250	3rd Qu.: 76.0
Max. :1524.0	Max. :2010.00	Max. :4300	Max. :4591.0

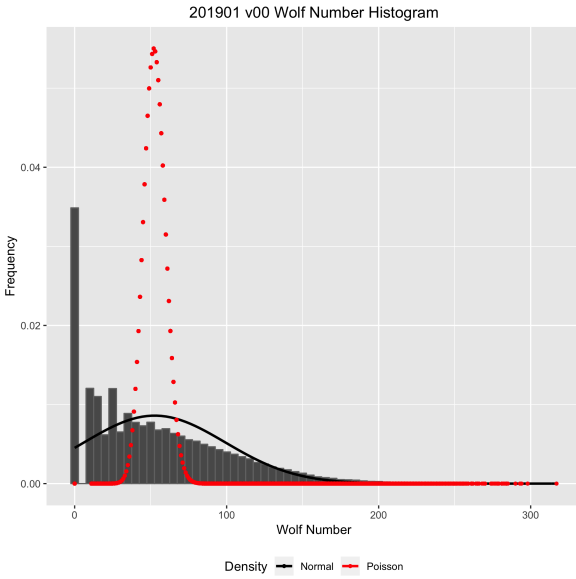


Figure 3: Box plots of raw Wolf number (w) by observer rank.

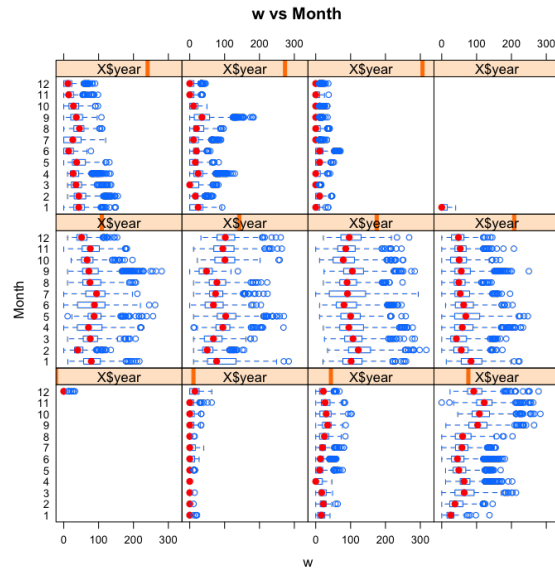


Figure 4: Box plots of raw Wolf number (w) by month and year.

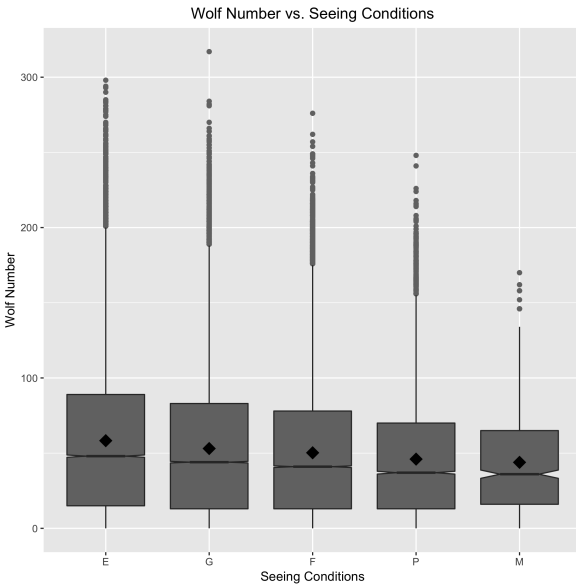


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

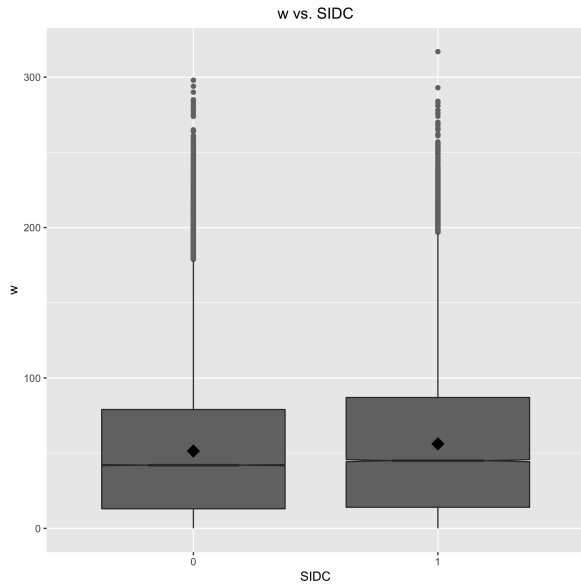


Figure 6: Box plots of raw Wolf number (w) by organization.

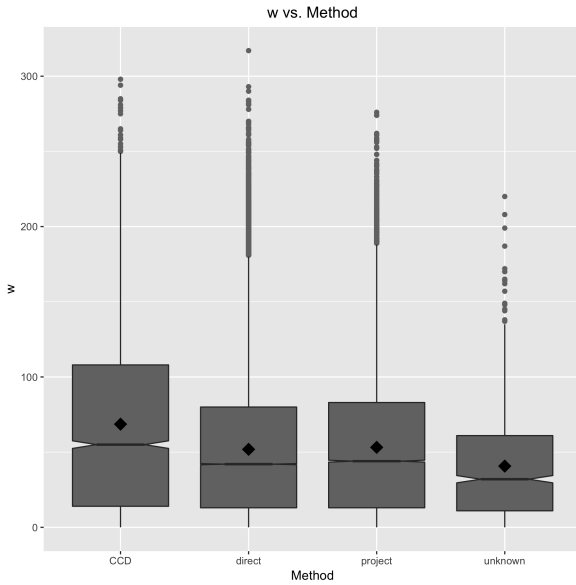


Figure 7: Box plots of raw Wolf number (w) by observer rank.

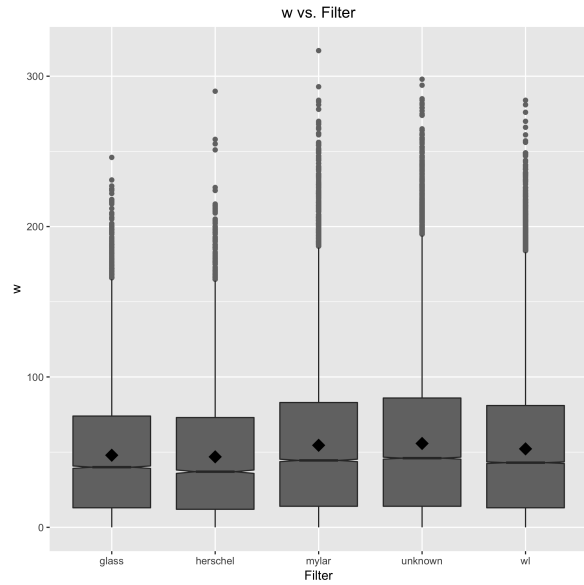


Figure 8: Box plots of raw Wolf number (w) by month and year.

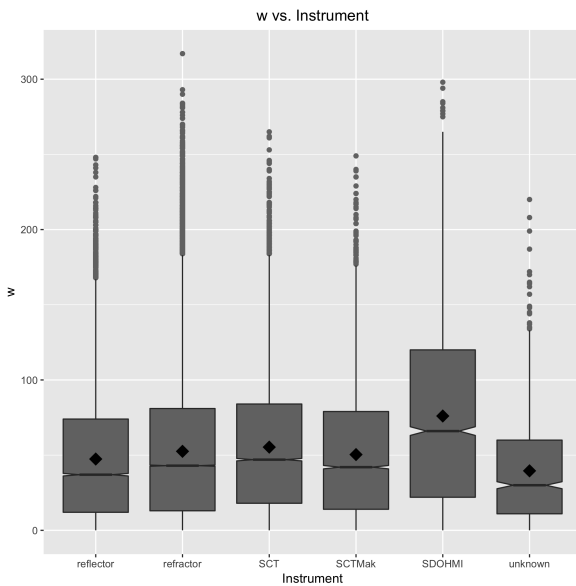


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

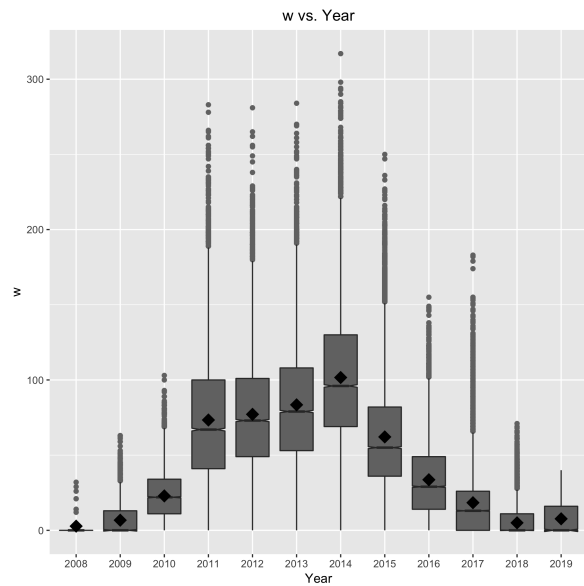


Figure 10: Box plots of raw Wolf number (w) by organization.

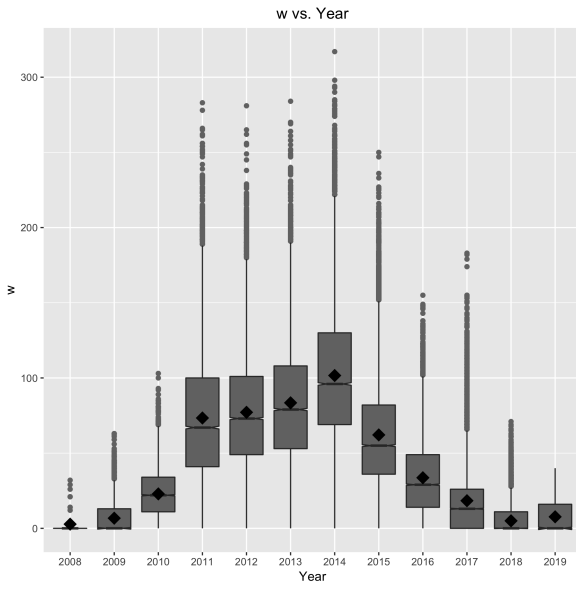


Figure 11: Box plots of raw Wolf number (w) by year.

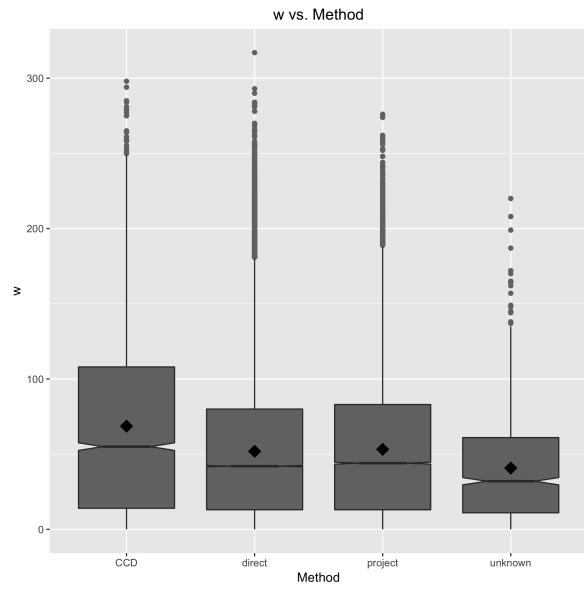


Figure 12: Box plots of raw Wolf number (w) by observing method.