

Monthly Report (00)

201904 Data Set

Sunday 12th May, 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.

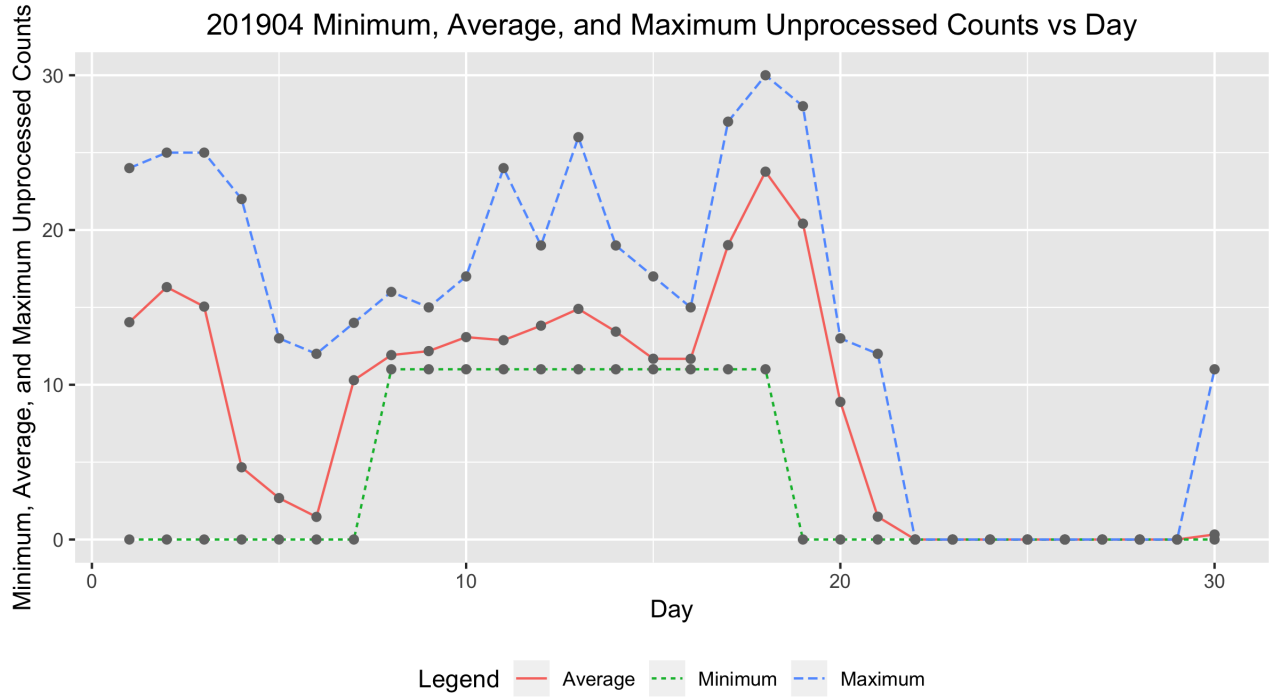


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201904 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	46.0000	0.0000	14.0435	24.0000
2.0000	42.0000	0.0000	16.3095	25.0000
3.0000	40.0000	0.0000	15.0500	25.0000
4.0000	33.0000	0.0000	4.6667	22.0000
5.0000	31.0000	0.0000	2.6774	13.0000
6.0000	39.0000	0.0000	1.4615	12.0000
7.0000	34.0000	0.0000	10.2941	14.0000
8.0000	37.0000	11.0000	11.9189	16.0000
9.0000	40.0000	11.0000	12.1750	15.0000
10.0000	38.0000	11.0000	13.0789	17.0000
11.0000	41.0000	11.0000	12.8780	24.0000
12.0000	33.0000	11.0000	13.8182	19.0000
13.0000	41.0000	11.0000	14.9024	26.0000
14.0000	37.0000	11.0000	13.4324	19.0000
15.0000	47.0000	11.0000	11.6809	17.0000
16.0000	43.0000	11.0000	11.6744	15.0000
17.0000	42.0000	11.0000	19.0238	27.0000
18.0000	39.0000	11.0000	23.7692	30.0000
19.0000	34.0000	0.0000	20.4118	28.0000
20.0000	37.0000	0.0000	8.8919	13.0000
21.0000	38.0000	0.0000	1.4737	12.0000
22.0000	35.0000	0.0000	0.0000	0.0000
23.0000	34.0000	0.0000	0.0000	0.0000
24.0000	36.0000	0.0000	0.0000	0.0000
25.0000	38.0000	0.0000	0.0000	0.0000
26.0000	41.0000	0.0000	0.0000	0.0000
27.0000	42.0000	0.0000	0.0000	0.0000
28.0000	42.0000	0.0000	0.0000	0.0000
29.0000	41.0000	0.0000	0.0000	0.0000
30.0000	34.0000	0.0000	0.3235	11.0000

3 Error Tables

Data are for the month of April 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	3.1326	0.5000	1.0000
2009.01	5.8318	5.2013	6.4622	1.3000	1.3000
2009.02	5.0572	4.4955	5.6188	0.7000	1.2000
2009.03	6.6372	6.3727	6.9016	0.3000	0.6000
2009.04	7.4464	7.1726	7.7202	0.4000	1.2000
2009.05	7.5266	7.2206	7.8326	1.6000	2.9000
2009.06	6.6885	6.3435	7.0335	3.2000	6.3000
2009.07	6.3818	6.1199	6.6437	3.6000	5.5000
2009.08	7.0640	6.7771	7.3508	0.0000	0.0000
2009.09	7.5526	7.2776	7.8276	4.5000	7.1000
2009.10	7.0584	6.6794	7.4374	4.5000	7.7000
2009.11	7.0185	6.8250	7.2119	3.3000	6.9000
2009.12	6.5101	6.3244	6.6957	10.4000	16.3000
2010.01	21.5204	19.0739	23.9668	13.3000	19.5000
2010.02	16.9600	14.6573	19.2628	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	18.5402	16.2425	20.8378	15.4000	24.0000
2010.04	20.5427	18.1236	22.9617	7.0000	10.4000
2010.05	24.5123	24.0779	24.9466	8.4000	8.7000
2010.06	20.4269	20.0872	20.7667	11.0000	13.6000
2010.07	21.3637	21.0538	21.6736	15.2000	16.1000
2010.08	22.8586	22.4834	23.2338	18.3000	19.6000
2010.09	25.3751	24.9567	25.7935	22.8000	25.2000
2010.10	23.9938	23.5796	24.4081	21.0000	23.5000
2010.11	24.4412	23.9972	24.8852	20.9000	21.6000
2010.12	21.7430	21.3048	22.1811	13.9000	14.5000
2011.01	76.5103	74.9270	78.0935	17.7000	18.7000
2011.02	65.5073	64.1084	66.9062	29.1000	29.6000
2011.03	69.6889	68.3593	71.0186	48.0000	55.8000
2011.04	78.0528	76.6508	79.4548	47.3000	54.4000
2011.05	79.0403	77.7039	80.3768	37.3000	41.5000
2011.06	65.8619	64.7076	67.0163	35.2000	37.0000
2011.07	68.1791	67.0118	69.3464	41.5000	43.8000
2011.08	73.8146	72.6255	75.0037	42.4000	50.5000
2011.09	80.5604	79.1677	81.9530	73.8000	78.0000
2011.10	76.2075	74.9249	77.4902	78.9000	88.0000
2011.11	77.3933	75.7768	79.0099	84.6000	96.7000
2011.12	67.7657	66.3696	69.1618	65.8000	73.0000
2012.01	82.1118	80.4979	83.7256	55.8000	58.2000
2012.02	69.1226	67.7174	70.5278	29.2000	33.1000
2012.03	74.2144	72.9004	75.5284	53.1000	64.1000
2012.04	81.9011	80.4699	83.3323	51.4000	55.2000
2012.05	84.5167	83.1237	85.9098	61.8000	69.0000
2012.06	69.7311	68.5465	70.9157	59.7000	64.5000
2012.07	72.5805	71.3905	73.7704	64.2000	51.3000
2012.08	75.7857	74.5697	77.0017	57.7000	63.1000
2012.09	83.2464	81.8026	84.6902	57.7000	61.5000
2012.10	79.5932	78.1379	81.0485	48.3000	53.3000
2012.11	80.8165	79.1958	82.4372	56.7000	61.4000
2012.12	70.9330	69.3944	72.4717	37.4000	40.8000
2013.01	91.2991	89.5553	93.0429	63.8000	62.9000
2013.02	77.0182	75.4696	78.5667	37.8000	38.0000
2013.03	80.0774	78.4515	81.7034	50.6000	57.9000
2013.04	89.3253	87.7572	90.8934	70.6000	72.4000
2013.05	90.0927	88.4912	91.6942	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	75.8466	74.5067	77.1865	51.0000	52.5000
2013.07	77.9662	76.7155	79.2170	57.0000	57.0000
2013.08	82.9590	81.6264	84.2915	60.0000	66.0000
2013.09	89.8347	88.2334	91.4360	34.6000	36.9000
2013.10	84.8411	83.2694	86.4128	74.5000	85.6000
2013.11	84.5776	82.6818	86.4733	73.9000	77.6000
2013.12	76.3445	74.7154	77.9736	77.8000	90.3000
2014.01	106.3617	104.1253	108.5980	77.4000	82.0000
2014.02	91.5113	89.7102	93.3124	93.9000	102.8000
2014.03	97.3808	95.6091	99.1525	80.9000	92.2000
2014.04	108.7938	106.8959	110.6917	76.9000	84.7000
2014.05	110.4095	108.5269	112.2920	72.3000	75.2000
2014.06	92.7459	91.1791	94.3128	67.2000	71.0000
2014.07	95.0401	93.4596	96.6207	72.5000	72.5000
2014.08	101.2923	99.7109	102.8737	71.2000	74.7000
2014.09	110.8287	108.8763	112.7811	83.2000	87.6000
2014.10	104.3442	102.4238	106.2646	59.5000	60.6000
2014.11	105.0720	102.8853	107.2587	65.8000	71.1000
2014.12	92.8918	90.7391	95.0445	75.8000	78.0000
2015.01	65.7789	64.4622	67.0955	65.9000	67.0000
2015.02	55.2037	53.9877	56.4197	42.4000	44.8000
2015.03	59.5186	58.4289	60.6083	38.0000	38.4000
2015.04	66.0479	64.8629	67.2328	49.0000	54.4000
2015.05	67.3447	66.2301	68.4594	56.3000	58.8000
2015.06	56.4607	55.4411	57.4803	50.2000	68.3000
2015.07	57.3598	56.3794	58.3403	47.9000	65.8000
2015.08	62.3789	61.3295	63.4284	39.5000	57.2000
2015.09	67.3598	66.1341	68.5855	49.2000	72.1000
2015.10	63.9240	62.6884	65.1596	39.3000	48.3000
2015.11	65.0802	63.6663	66.4940	39.6000	55.9000
2015.12	57.6131	56.3474	58.8789	36.4000	44.8000
2016.01	36.0077	35.2559	36.7594	33.7000	43.3000
2016.02	30.3572	29.7240	30.9903	38.3000	46.8000
2016.03	32.2061	31.5631	32.8490	30.5000	38.9000
2016.04	35.6430	34.9630	36.3230	26.6000	30.9000
2016.05	36.4283	35.7618	37.0948	33.7000	48.4000
2016.06	30.2087	29.6928	30.7246	13.1000	19.5000
2016.07	31.2504	30.7473	31.7534	21.2000	27.5000
2016.08	33.6167	33.0246	34.2088	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	37.1656	36.4863	37.8450	27.7000	37.1000
2016.10	34.8666	34.1933	35.5399	22.7000	31.7000
2016.11	35.0991	34.3646	35.8336	14.0000	22.2000
2016.12	31.4690	30.7963	32.1418	11.1000	20.0000
2017.01	19.5915	19.1793	20.0037	18.4000	26.2000
2017.02	16.5831	16.2188	16.9475	14.4000	20.6000
2017.03	17.7467	17.4085	18.0850	11.3000	15.5000
2017.04	19.8545	19.5040	20.2049	21.6000	33.2000
2017.05	19.9624	19.6175	20.3073	12.5000	18.1000
2017.06	16.5662	16.2895	16.8430	15.5000	19.3000
2017.07	17.2179	16.9438	17.4919	11.5000	16.3000
2017.08	18.4592	18.1403	18.7781	22.8000	35.7000
2017.09	20.6921	20.2780	21.1063	34.6000	42.9000
2017.10	18.9709	18.5902	19.3517	10.5000	11.0000
2017.11	18.9469	18.5502	19.3435	4.2000	5.6000
2017.12	16.8958	16.6392	17.1524	4.0000	4.6000
2018.01	5.4278	5.3101	5.5455	3.1000	6.3000
2018.02	4.5515	4.4401	4.6629	6.8000	11.8000
2018.03	4.7850	4.6885	4.8814	1.1000	1.2000
2018.04	5.3084	5.2013	5.4154	4.7000	7.5000
2018.05	5.4558	5.3505	5.5611	8.4000	14.0000
2018.06	4.5217	4.4395	4.6038	10.2000	13.6000
2018.07	4.6879	4.6342	4.7415	0.5000	1.7000
2018.08	4.9746	4.8860	5.0631	5.9000	9.5000
2018.09	5.3708	5.2685	5.4731	1.6000	2.9000
2018.10	5.1912	5.0891	5.2933	2.5000	5.6000
2018.11	5.2175	5.1079	5.3271	3.1000	4.2000
2018.12	4.7617	4.6658	4.8575	1.6000	2.3000
2019.01	7.0549	6.9192	7.1905	5.4000	2.3000
2019.02	6.0774	5.9542	6.2007	0.1000	1.2000
2019.03	6.2999	6.1887	6.4111	6.1000	12.1000
2019.04	7.0318	6.8974	7.1662	6.2000	9.3000

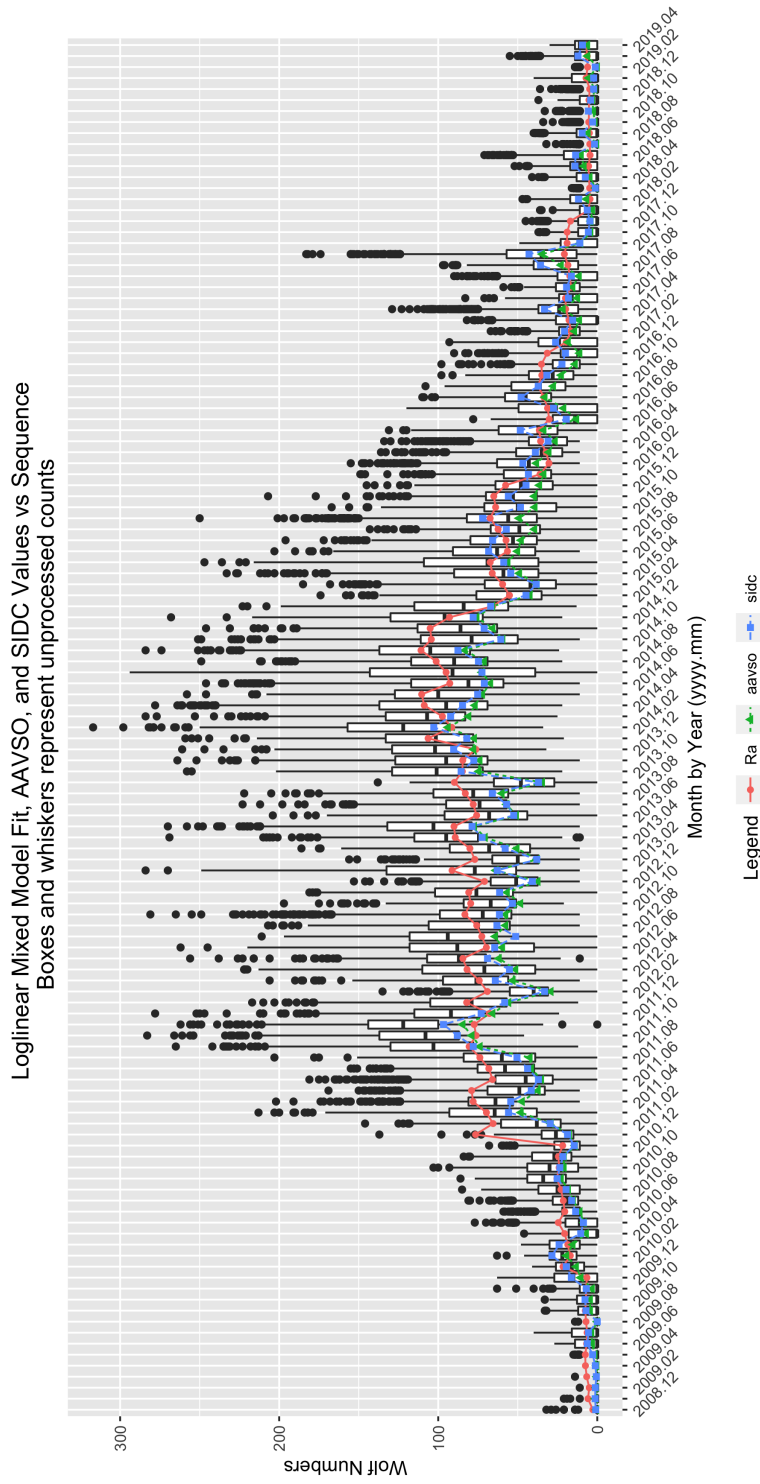


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201904 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4369	0.3145	4.5695	0.0000
seeF	-0.2181	0.0059	-36.7310	0.0000
seeG	-0.1161	0.0052	-22.4576	0.0000
seeM	-0.1976	0.0244	-8.0923	0.0000
seeP	-0.3242	0.0085	-38.1301	0.0000
sidc1	0.1556	0.0683	2.2777	0.0227
year2009	0.6407	0.3155	2.0308	0.0423
year2010	1.8504	0.3133	5.9062	0.0000
year2011	2.9709	0.3132	9.4859	0.0000
year2012	3.0084	0.3132	9.6057	0.0000
year2013	3.1044	0.3132	9.9123	0.0000
year2014	3.3014	0.3132	10.5414	0.0000
year2015	2.8166	0.3132	8.9932	0.0000
year2016	2.1998	0.3132	7.0229	0.0000
year2017	1.5948	0.3133	5.0908	0.0000
year2018	0.3024	0.3136	0.9645	0.3348
year2019	0.5560	0.3142	1.7697	0.0768
mon2	-0.1613	0.0094	-17.2422	0.0000
mon3	-0.1067	0.0087	-12.2025	0.0000
mon4	-0.0066	0.0084	-0.7824	0.4340
mon5	0.0023	0.0083	0.2742	0.7840
mon6	-0.1823	0.0087	-20.9151	0.0000
mon7	-0.1563	0.0085	-18.4498	0.0000
mon8	-0.0843	0.0083	-10.1689	0.0000
mon9	0.0137	0.0083	1.6438	0.1002
mon10	-0.0404	0.0086	-4.7219	0.0000
mon11	-0.0188	0.0089	-2.1019	0.0356
mon12	-0.1320	0.0091	-14.4829	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: 201904 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:111963	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 : 6.571	Mean :15.73		Mean :0.2612
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: 201904 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:111963	Length:111963
1st Qu.: 1.000	1st Qu.: 2.0	1st Qu.: 13.00	Class :character	Class :character
Median : 3.000	Median : 12.0	Median : 41.00	Mode :character	Mode :character
Mean : 3.214	Mean : 19.2	Mean : 51.34		
3rd Qu.: 5.000	3rd Qu.: 28.0	3rd Qu.: 80.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 201904 Summary of Sunspot Numbers

inst	filter	unit
Length:111963	Length:111963	Length:111963
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201904 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.0	Min. : 0.00	Min. : 0	Min. : 0.0
1st Qu.: 70.0	1st Qu.: 3.00	1st Qu.: 600	1st Qu.: 40.0
Median : 89.0	Median : 13.00	Median : 910	Median : 57.5
Mean : 102.2	Mean : 24.17	Mean :1017	Mean : 186.4
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

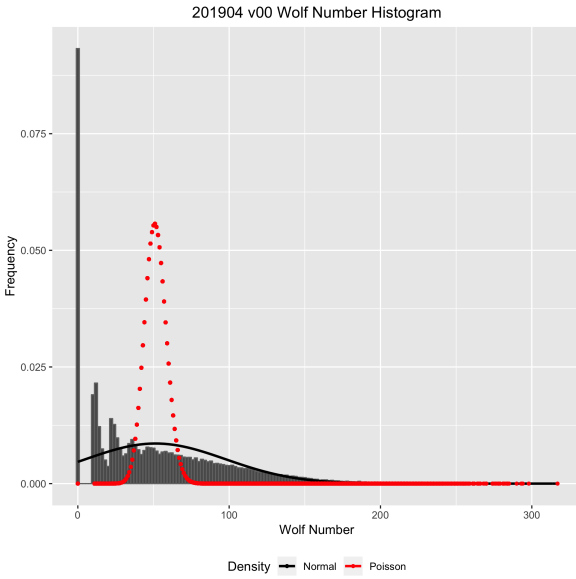


Figure 3: Box plots of raw Wolf number (w) by observer rank.

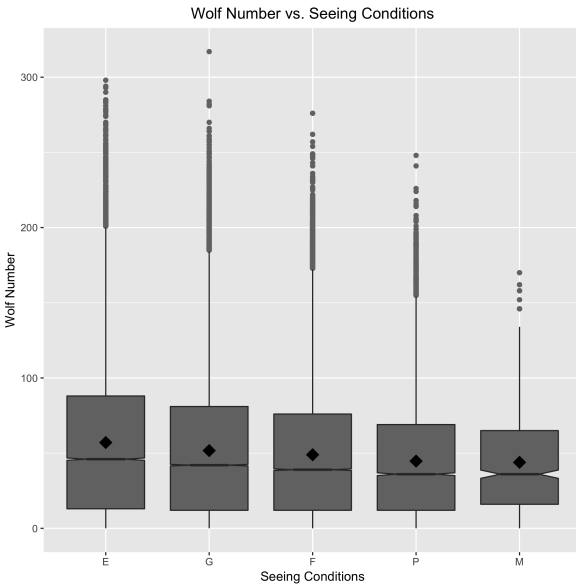


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

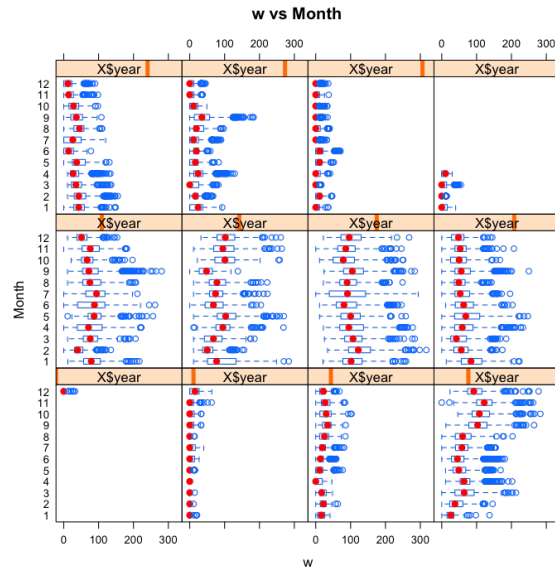


Figure 4: Box plots of raw Wolf number (w) by month and year.

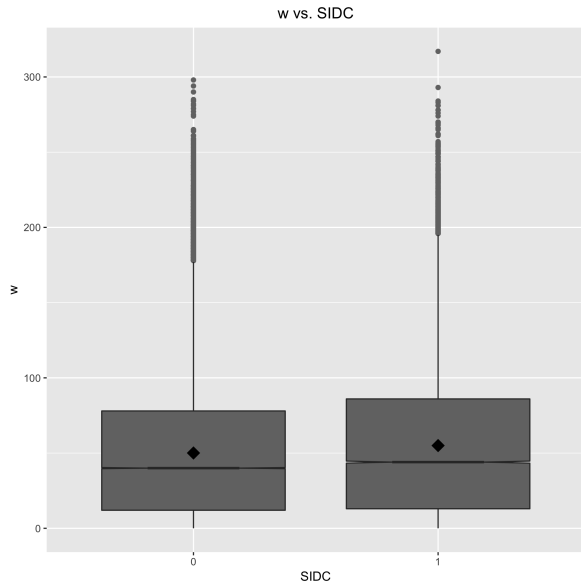


Figure 6: Box plots of raw Wolf number (w) by organization.

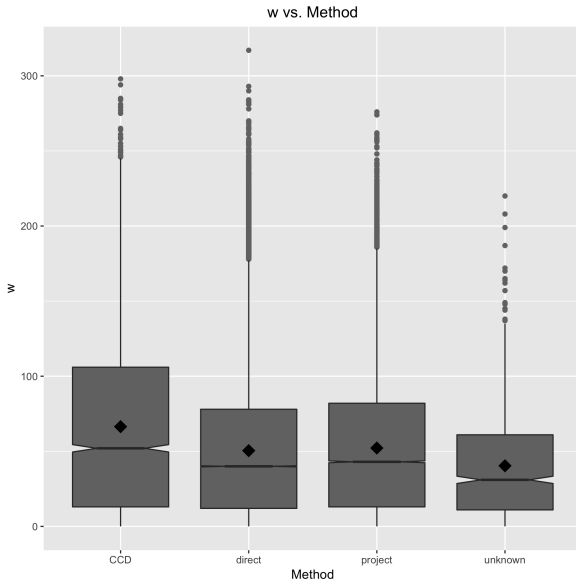


Figure 7: Box plots of raw Wolf number (w) by observer rank.

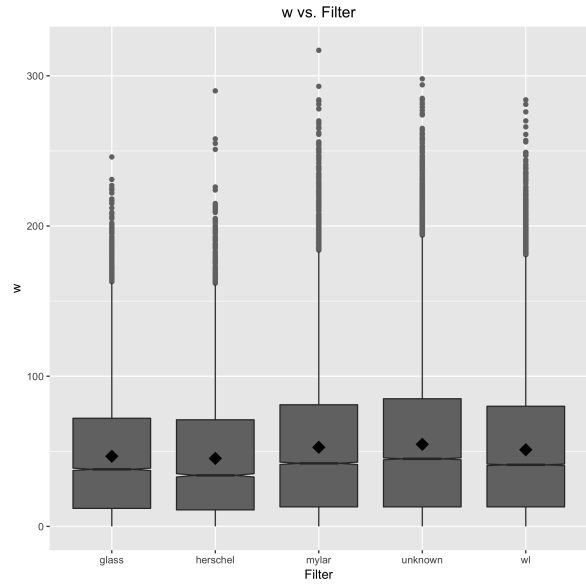


Figure 8: Box plots of raw Wolf number (w) by month and year.

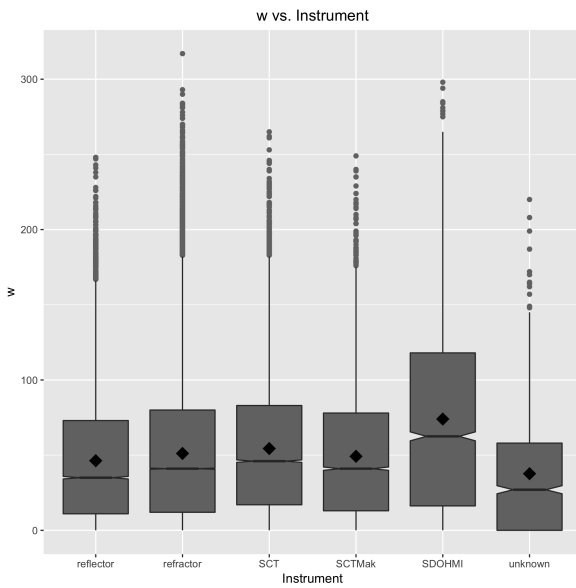


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

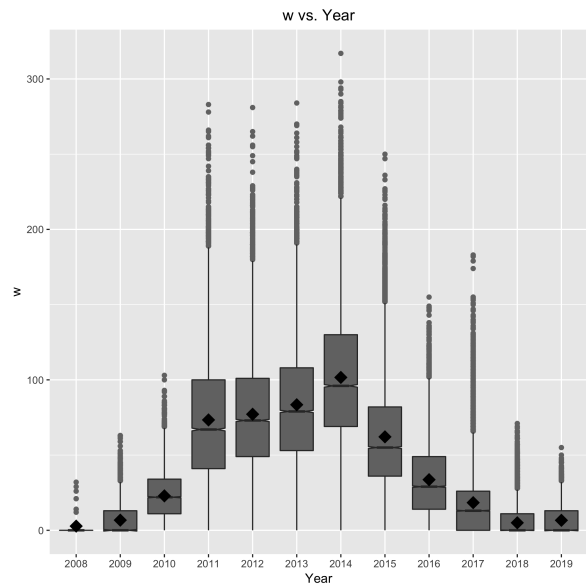


Figure 10: Box plots of raw Wolf number (w) by organization.

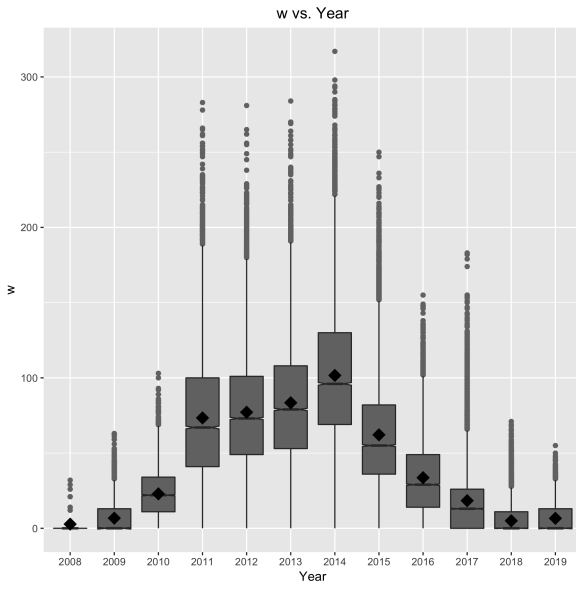


Figure 11: Box plots of raw Wolf number (w) by year.

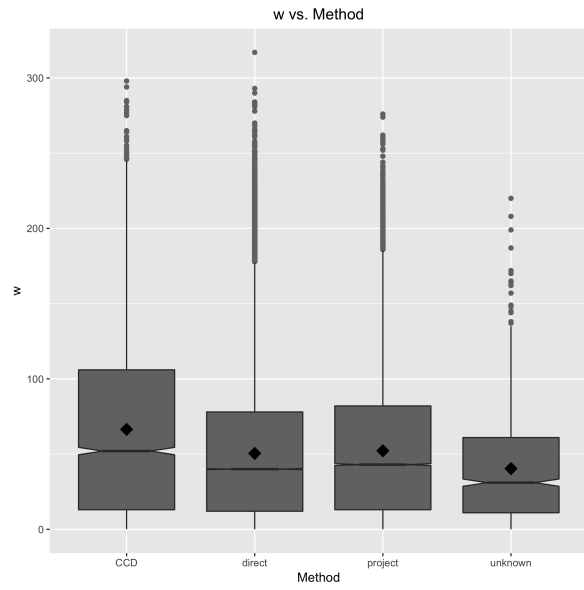


Figure 12: Box plots of raw Wolf number (w) by observing method.