

Monthly Report (00)
2019.12 Data Set

Wednesday 15th January, 2020

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.

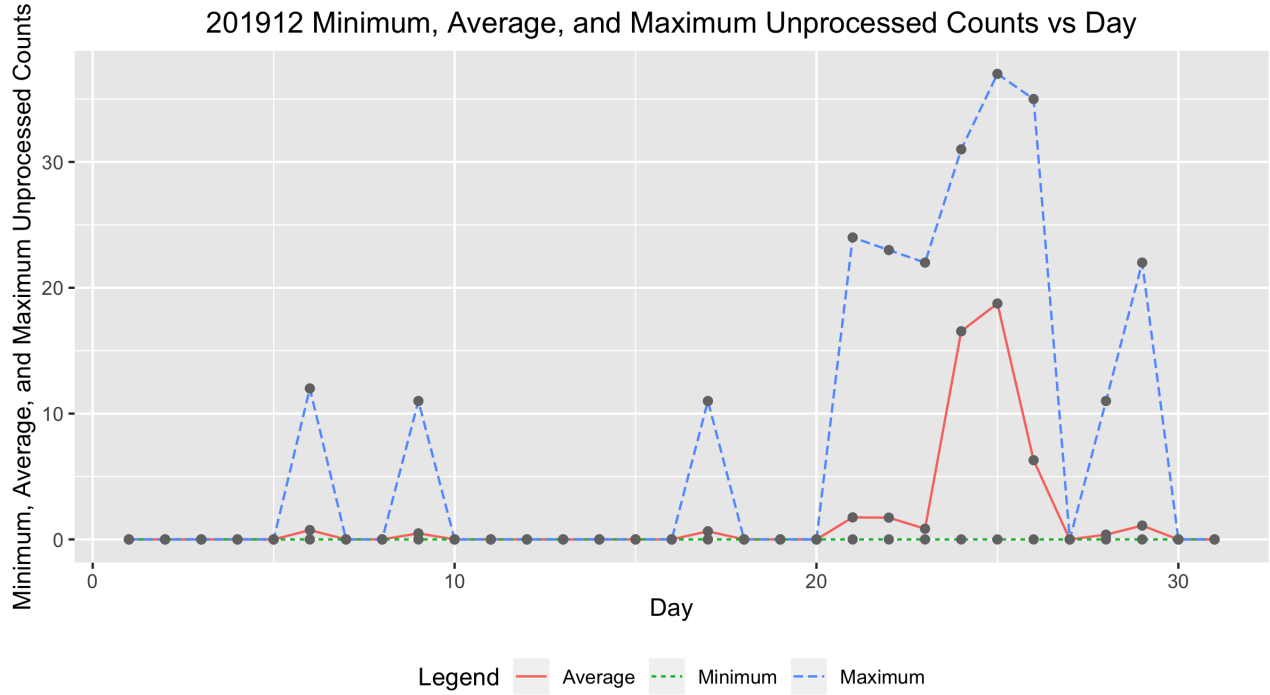


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201912 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	24.0000	0.0000	0.0000	0.0000
2.0000	30.0000	0.0000	0.0000	0.0000
3.0000	36.0000	0.0000	0.0000	0.0000
4.0000	28.0000	0.0000	0.0000	0.0000
5.0000	25.0000	0.0000	0.0000	0.0000
6.0000	31.0000	0.0000	0.7419	12.0000
7.0000	31.0000	0.0000	0.0000	0.0000
8.0000	33.0000	0.0000	0.0000	0.0000
9.0000	23.0000	0.0000	0.4783	11.0000
10.0000	29.0000	0.0000	0.0000	0.0000
11.0000	30.0000	0.0000	0.0000	0.0000
12.0000	31.0000	0.0000	0.0000	0.0000
13.0000	25.0000	0.0000	0.0000	0.0000
14.0000	30.0000	0.0000	0.0000	0.0000
15.0000	37.0000	0.0000	0.0000	0.0000
16.0000	26.0000	0.0000	0.0000	0.0000
17.0000	17.0000	0.0000	0.6471	11.0000
18.0000	32.0000	0.0000	0.0000	0.0000
19.0000	25.0000	0.0000	0.0000	0.0000
20.0000	27.0000	0.0000	0.0000	0.0000
21.0000	28.0000	0.0000	1.7500	24.0000
22.0000	26.0000	0.0000	1.7308	23.0000
23.0000	26.0000	0.0000	0.8462	22.0000
24.0000	35.0000	0.0000	16.5429	31.0000
25.0000	28.0000	0.0000	18.7500	37.0000
26.0000	27.0000	0.0000	6.2963	35.0000
27.0000	25.0000	0.0000	0.0000	0.0000
28.0000	29.0000	0.0000	0.3793	11.0000
29.0000	30.0000	0.0000	1.1000	22.0000
30.0000	28.0000	0.0000	0.0000	0.0000
31.0000	31.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of December 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	2.4037	3.1373	0.5000	1.0000
2009.01	5.8791	5.2350	6.5233	1.3000	1.3000
2009.02	5.0982	4.5244	5.6720	0.7000	1.2000
2009.03	6.7102	6.4437	6.9767	0.3000	0.6000
2009.04	7.5262	7.2503	7.8022	0.4000	1.2000
2009.05	7.6427	7.3329	7.9524	1.6000	2.9000
2009.06	6.6751	6.3313	7.0189	3.2000	6.3000
2009.07	6.3577	6.0975	6.6179	3.6000	5.5000
2009.08	7.0361	6.7512	7.3211	0.0000	0.0000
2009.09	7.5258	7.2526	7.7990	4.5000	7.1000
2009.10	7.0292	6.6529	7.4055	4.5000	7.7000
2009.11	6.9892	6.7954	7.1830	3.3000	6.9000
2009.12	6.5065	6.3198	6.6932	10.4000	16.3000
2010.01	21.7220	19.2209	24.2231	13.3000	19.5000
2010.02	17.0935	14.7402	19.4468	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	18.6934	16.3466	21.0402	15.4000	24.0000
2010.04	20.7083	18.2382	23.1785	7.0000	10.4000
2010.05	24.8863	24.4427	25.3299	8.4000	8.7000
2010.06	20.3935	20.0538	20.7331	11.0000	13.6000
2010.07	21.2905	20.9810	21.6001	15.2000	16.1000
2010.08	22.7824	22.4080	23.1568	18.3000	19.6000
2010.09	25.2977	24.8799	25.7154	22.8000	25.2000
2010.10	23.9066	23.4929	24.3203	21.0000	23.5000
2010.11	24.3492	23.9060	24.7924	20.9000	21.6000
2010.12	21.7389	21.2994	22.1783	13.9000	14.5000
2011.01	77.1299	75.5273	78.7325	17.7000	18.7000
2011.02	66.0143	64.5988	67.4297	29.1000	29.6000
2011.03	70.2562	68.9107	71.6017	48.0000	55.8000
2011.04	78.6817	77.2661	80.0973	47.3000	54.4000
2011.05	80.0384	78.6815	81.3953	37.3000	41.5000
2011.06	65.5583	64.4075	66.7090	35.2000	37.0000
2011.07	67.7572	66.5963	68.9181	41.5000	43.8000
2011.08	73.3537	72.1711	74.5363	42.4000	50.5000
2011.09	80.0917	78.7040	81.4794	73.8000	78.0000
2011.10	75.7069	74.4304	76.9835	78.9000	88.0000
2011.11	76.8911	75.2826	78.4995	84.6000	96.7000
2011.12	67.5594	66.1653	68.9535	65.8000	73.0000
2012.01	82.7619	81.1315	84.3923	55.8000	58.2000
2012.02	69.6557	68.2372	71.0742	29.2000	33.1000
2012.03	74.8013	73.4746	76.1280	53.1000	64.1000
2012.04	82.5311	81.0868	83.9754	51.4000	55.2000
2012.05	85.5744	84.1621	86.9866	61.8000	69.0000
2012.06	69.3807	68.2008	70.5606	59.7000	64.5000
2012.07	72.0921	70.9087	73.2754	64.2000	51.3000
2012.08	75.2848	74.0757	76.4938	57.7000	63.1000
2012.09	82.7117	81.2760	84.1474	57.7000	61.5000
2012.10	79.0434	77.5964	80.4904	48.3000	53.3000
2012.11	80.2536	78.6414	81.8658	56.7000	61.4000
2012.12	70.6950	69.1595	72.2304	37.4000	40.8000
2013.01	92.0403	90.2796	93.8011	63.8000	62.9000
2013.02	77.6092	76.0461	79.1722	37.8000	38.0000
2013.03	80.7182	79.0768	82.3596	50.6000	57.9000
2013.04	90.0049	88.4217	91.5881	70.6000	72.4000
2013.05	91.2080	89.5849	92.8312	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	75.4691	74.1348	76.8035	51.0000	52.5000
2013.07	77.4437	76.2003	78.6872	57.0000	57.0000
2013.08	82.3974	81.0720	83.7228	60.0000	66.0000
2013.09	89.2503	87.6576	90.8430	34.6000	36.9000
2013.10	84.2402	82.6773	85.8031	74.5000	85.6000
2013.11	83.9978	82.1125	85.8831	73.9000	77.6000
2013.12	76.0908	74.4647	77.7170	77.8000	90.3000
2014.01	107.2151	104.9575	109.4726	77.4000	82.0000
2014.02	92.2078	90.3897	94.0259	93.9000	102.8000
2014.03	98.1394	96.3507	99.9281	80.9000	92.2000
2014.04	109.5995	107.6843	111.5147	76.9000	84.7000
2014.05	111.7536	109.8450	113.6623	72.3000	75.2000
2014.06	92.2756	90.7150	93.8363	67.2000	71.0000
2014.07	94.3843	92.8126	95.9560	72.5000	72.5000
2014.08	100.5956	99.0230	102.1682	71.2000	74.7000
2014.09	110.1002	108.1581	112.0423	83.2000	87.6000
2014.10	103.5883	101.6792	105.4974	59.5000	60.6000
2014.11	104.3442	102.1700	106.5185	65.8000	71.1000
2014.12	92.5603	90.4121	94.7085	75.8000	78.0000
2015.01	66.2857	64.9576	67.6138	65.9000	67.0000
2015.02	55.6235	54.3979	56.8491	42.4000	44.8000
2015.03	59.9825	58.8838	61.0812	38.0000	38.4000
2015.04	66.5452	65.3511	67.7392	49.0000	54.4000
2015.05	68.1811	67.0527	69.3096	56.3000	58.8000
2015.06	56.1665	55.1518	57.1812	50.2000	68.3000
2015.07	56.9698	55.9959	57.9436	47.9000	65.8000
2015.08	61.9431	60.9006	62.9856	39.5000	57.2000
2015.09	66.9126	65.6942	68.1310	49.2000	72.1000
2015.10	63.4580	62.2305	64.6854	39.3000	48.3000
2015.11	64.6262	63.2215	66.0310	39.6000	55.9000
2015.12	57.4051	56.1424	58.6678	36.4000	44.8000
2016.01	36.3007	35.5426	37.0588	33.7000	43.3000
2016.02	30.5947	29.9562	31.2331	38.3000	46.8000
2016.03	32.4614	31.8130	33.1098	30.5000	38.9000
2016.04	35.9210	35.2357	36.6063	26.6000	30.9000
2016.05	36.8851	36.2106	37.5597	33.7000	48.4000
2016.06	30.0606	29.5473	30.5739	13.1000	19.5000
2016.07	31.0384	30.5390	31.5378	21.2000	27.5000
2016.08	33.3910	32.8031	33.9789	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	36.9274	36.2528	37.6021	27.7000	37.1000
2016.10	34.6206	33.9524	35.2889	22.7000	31.7000
2016.11	34.8635	34.1341	35.5929	14.0000	22.2000
2016.12	31.3571	30.6862	32.0280	11.1000	20.0000
2017.01	19.7473	19.3315	20.1632	18.4000	26.2000
2017.02	16.7111	16.3438	17.0784	14.4000	20.6000
2017.03	17.8856	17.5446	18.2266	11.3000	15.5000
2017.04	20.0026	19.6494	20.3558	21.6000	33.2000
2017.05	20.2088	19.8596	20.5580	12.5000	18.1000
2017.06	16.4813	16.2063	16.7563	15.5000	19.3000
2017.07	17.0997	16.8277	17.3717	11.5000	16.3000
2017.08	18.3382	18.0195	18.6568	22.8000	35.7000
2017.09	20.6077	20.1793	21.0360	34.6000	42.9000
2017.10	18.8507	18.4689	19.2325	10.5000	11.0000
2017.11	18.8255	18.4315	19.2195	4.2000	5.6000
2017.12	16.8475	16.5921	17.1029	4.0000	4.6000
2018.01	5.4793	5.3621	5.5965	3.1000	6.3000
2018.02	4.6012	4.4893	4.7132	6.8000	11.8000
2018.03	4.8335	4.7381	4.9289	1.1000	1.2000
2018.04	5.3599	5.2530	5.4667	4.7000	7.5000
2018.05	5.5110	5.4065	5.6156	8.4000	14.0000
2018.06	4.4952	4.4156	4.5748	10.2000	13.6000
2018.07	4.6570	4.6051	4.7089	0.5000	1.7000
2018.08	4.9416	4.8561	5.0270	5.9000	9.5000
2018.09	5.3440	5.2446	5.4434	1.6000	2.9000
2018.10	5.1573	5.0579	5.2567	2.5000	5.6000
2018.11	5.1927	5.0865	5.2988	3.1000	4.2000
2018.12	4.7455	4.6533	4.8376	1.6000	2.3000
2019.01	3.6328	3.5648	3.7008	5.4000	2.3000
2019.02	3.1222	3.0613	3.1832	0.1000	1.2000
2019.03	3.2370	3.1816	3.2924	6.1000	12.1000
2019.04	3.6089	3.5408	3.6771	6.2000	9.3000
2019.05	3.5732	3.5094	3.6370	7.0000	11.9000
2019.06	2.9151	2.8635	2.9666	0.7000	1.5000
2019.07	3.0313	2.9837	3.0788	0.4000	2.2000
2019.08	3.2745	3.2235	3.3256	0.3000	0.8000
2019.09	3.6213	3.5616	3.6809	0.5000	1.0000
2019.10	3.3892	3.3288	3.4497	0.2000	0.5000
2019.11	3.4696	3.4016	3.5376	0.3000	0.6000

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Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2019.12	3.0686	3.0059	3.1314	0.8000	1.0000

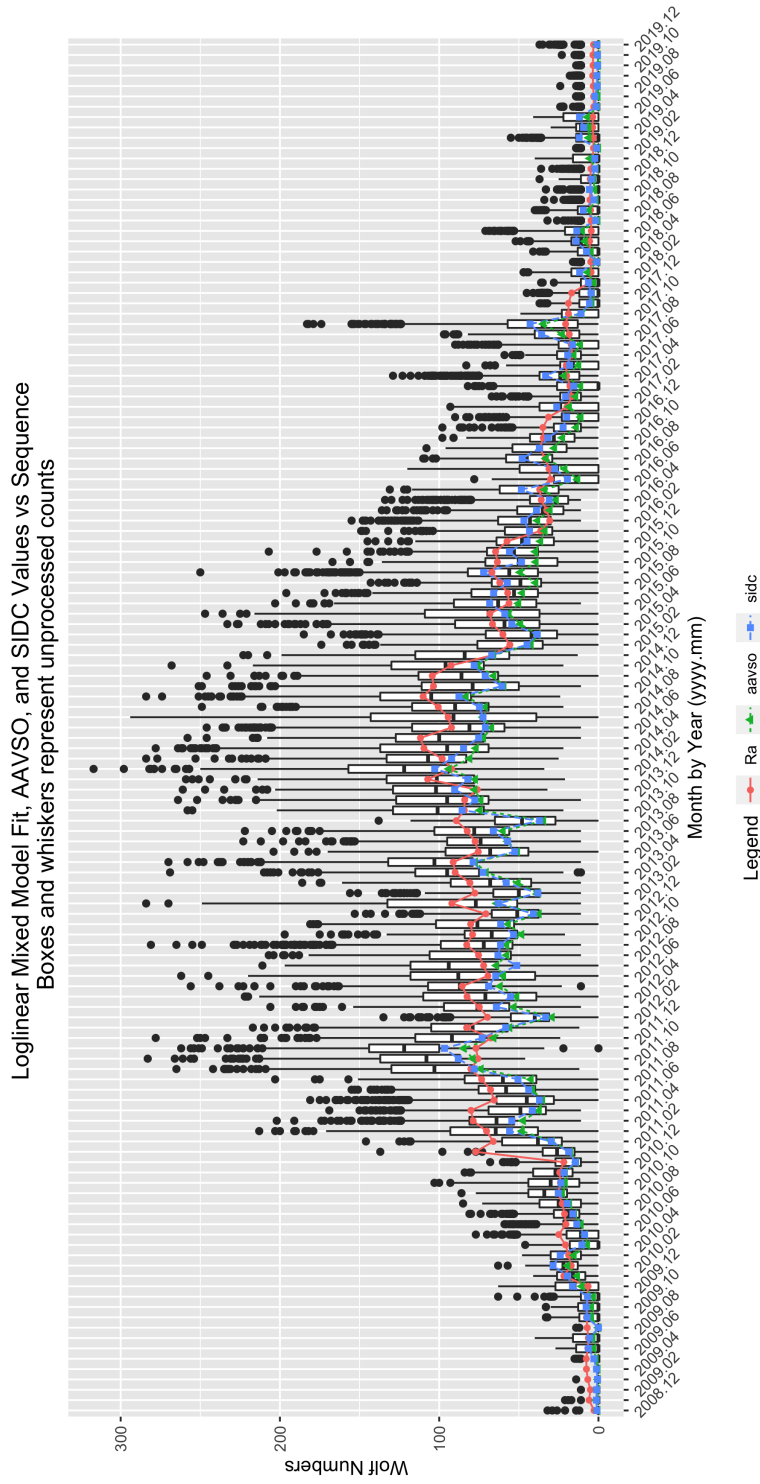


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201912 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4553	0.3099	4.6963	0.0000
seeF	-0.2187	0.0058	-37.4474	0.0000
seeG	-0.1169	0.0051	-22.9865	0.0000
seeM	-0.2020	0.0240	-8.4026	0.0000
seeP	-0.3243	0.0084	-38.7723	0.0000
sidc1	0.1342	0.0697	1.9261	0.0541
year2009	0.6373	0.3108	2.0507	0.0403
year2010	1.8474	0.3086	5.9860	0.0000
year2011	2.9648	0.3085	9.6098	0.0000
year2012	3.0014	0.3085	9.7288	0.0000
year2013	3.0974	0.3085	10.0400	0.0000
year2014	3.2943	0.3085	10.6781	0.0000
year2015	2.8094	0.3085	9.1062	0.0000
year2016	2.1927	0.3085	7.1064	0.0000
year2017	1.5875	0.3086	5.1444	0.0000
year2018	0.2905	0.3089	0.9404	0.3470
year2019	-0.1338	0.3091	-0.4329	0.6651
mon2	-0.1616	0.0092	-17.5388	0.0000
mon3	-0.1068	0.0086	-12.4038	0.0000
mon4	-0.0070	0.0083	-0.8449	0.3981
mon5	0.0066	0.0082	0.8056	0.4205
mon6	-0.1954	0.0086	-22.7971	0.0000
mon7	-0.1712	0.0083	-20.5436	0.0000
mon8	-0.0992	0.0082	-12.1659	0.0000
mon9	-0.0010	0.0082	-0.1199	0.9046
mon10	-0.0556	0.0084	-6.6072	0.0000
mon11	-0.0338	0.0088	-3.8438	0.0001
mon12	-0.1435	0.0090	-16.0179	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: 201912 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.0	Min. : 0.00	Length:121100	Min. :0.0000
1st Qu.:2012	1st Qu.: 4.0	1st Qu.: 8.00	Class :character	1st Qu.:0.0000
Median :2015	Median : 7.0	Median :16.00	Mode :character	Median :0.0000
Mean :2015	Mean : 6.7	Mean :15.73		Mean :0.2593
3rd Qu.:2017	3rd Qu.: 9.0	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2019	Max. :12.0	Max. :31.00		Max. :1.0000

Table 5: 201912 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.0	Length:121100	Length:121100
1st Qu.: 1.000	1st Qu.: 1.00	1st Qu.: 11.0	Class :character	Class :character
Median : 2.000	Median : 10.00	Median : 36.0	Mode :character	Mode :character
Mean : 2.983	Mean : 17.78	Mean : 47.6		
3rd Qu.: 5.000	3rd Qu.: 27.00	3rd Qu.: 76.0		
Max. :19.000	Max. :204.00	Max. :317.0		

Table 6: 201912 Summary of Sunspot Numbers

inst	filter	unit
Length:121100	Length:121100	Length:121100
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201912 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 63.00	1st Qu.: 3.00	1st Qu.: 450.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 95.46	Mean : 27.39	Mean : 941.6	Mean : 185.5
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1203.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

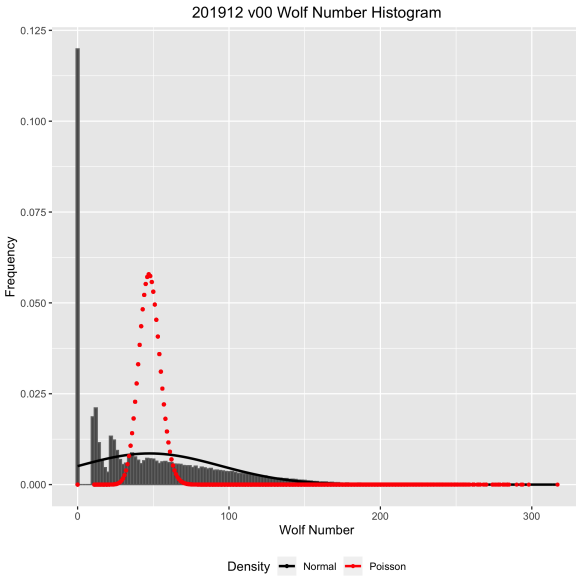


Figure 3: Box plots of raw Wolf number (w) by observer rank.

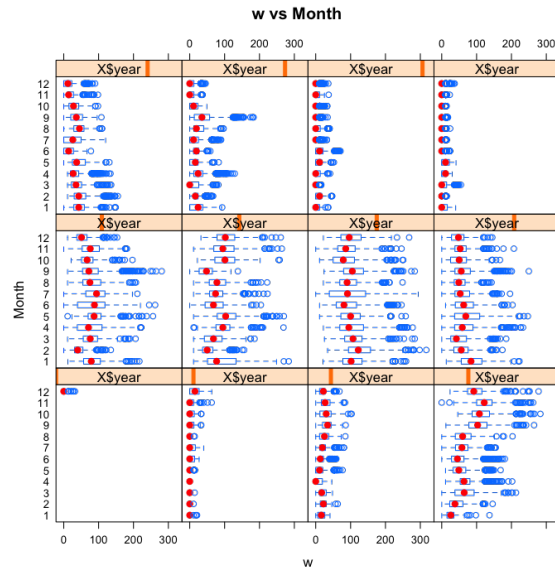


Figure 4: Box plots of raw Wolf number (w) by month and year.

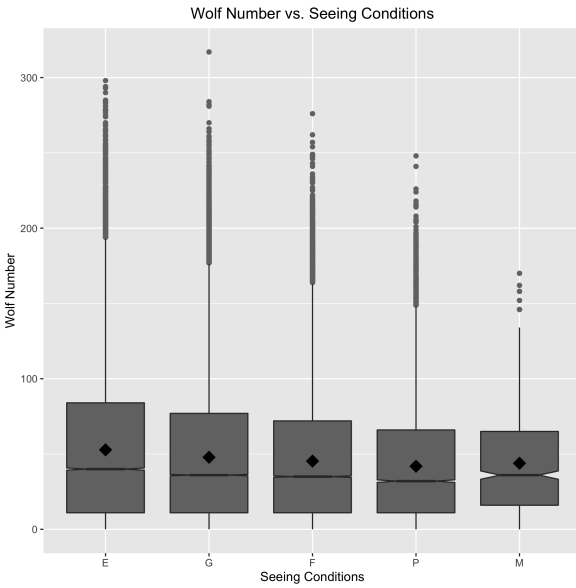


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

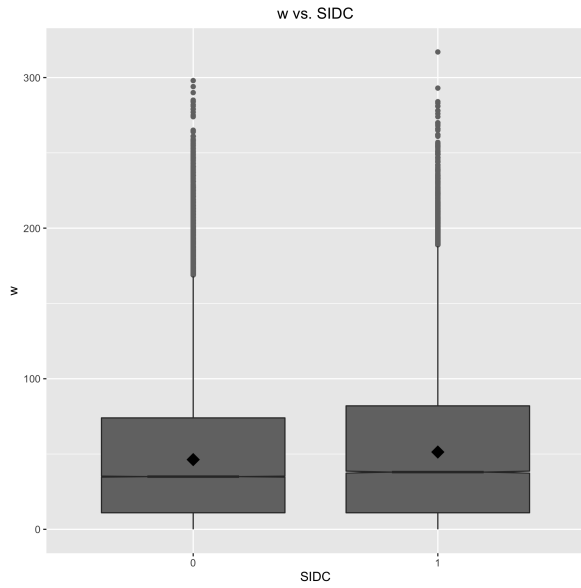


Figure 6: Box plots of raw Wolf number (w) by organization.

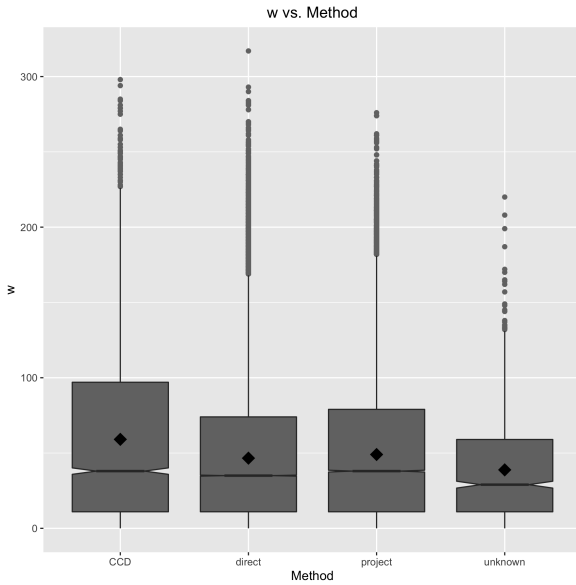


Figure 7: Box plots of raw Wolf number (w) by observer rank.

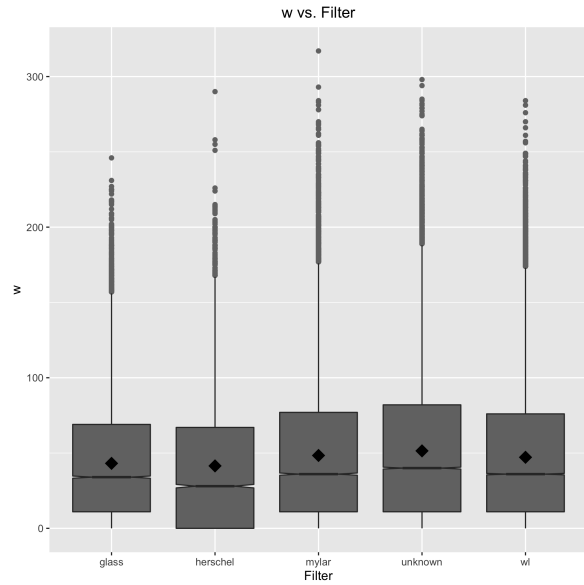


Figure 8: Box plots of raw Wolf number (w) by month and year.

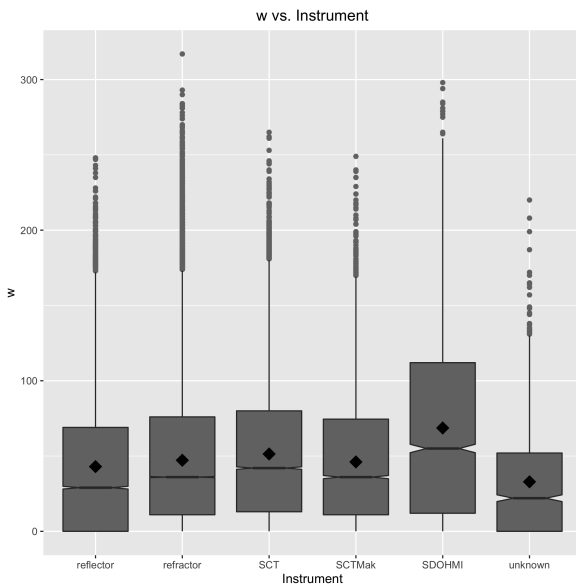


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

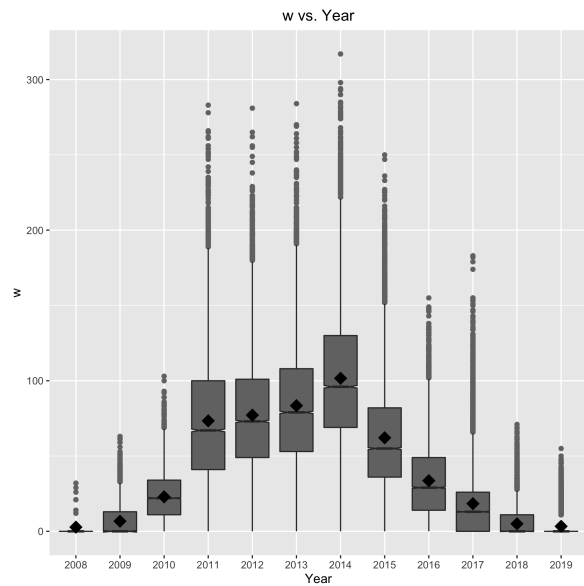


Figure 10: Box plots of raw Wolf number (w) by organization.

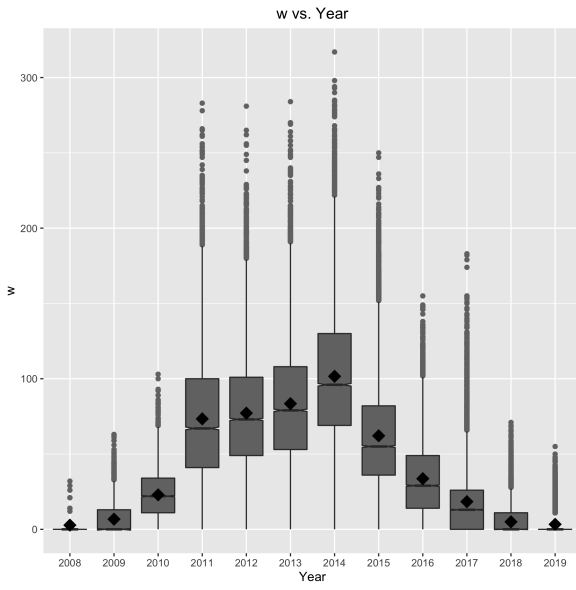


Figure 11: Box plots of raw Wolf number (w) by year.

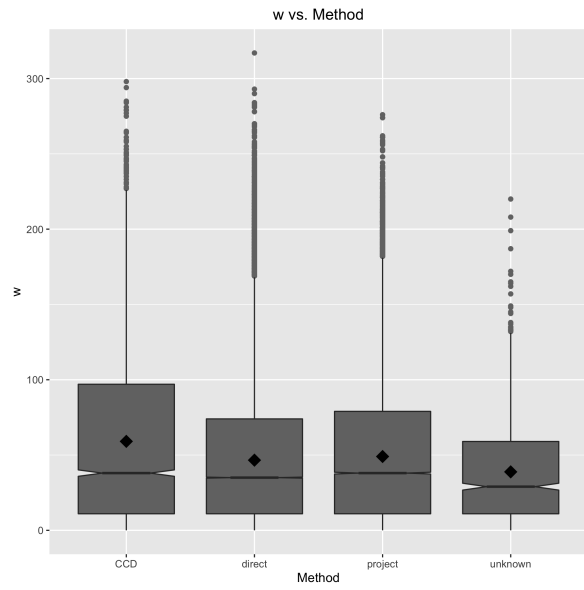


Figure 12: Box plots of raw Wolf number (w) by observing method.