

Monthly Report (00)
202010 Data Set

Sunday 15th November, 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.

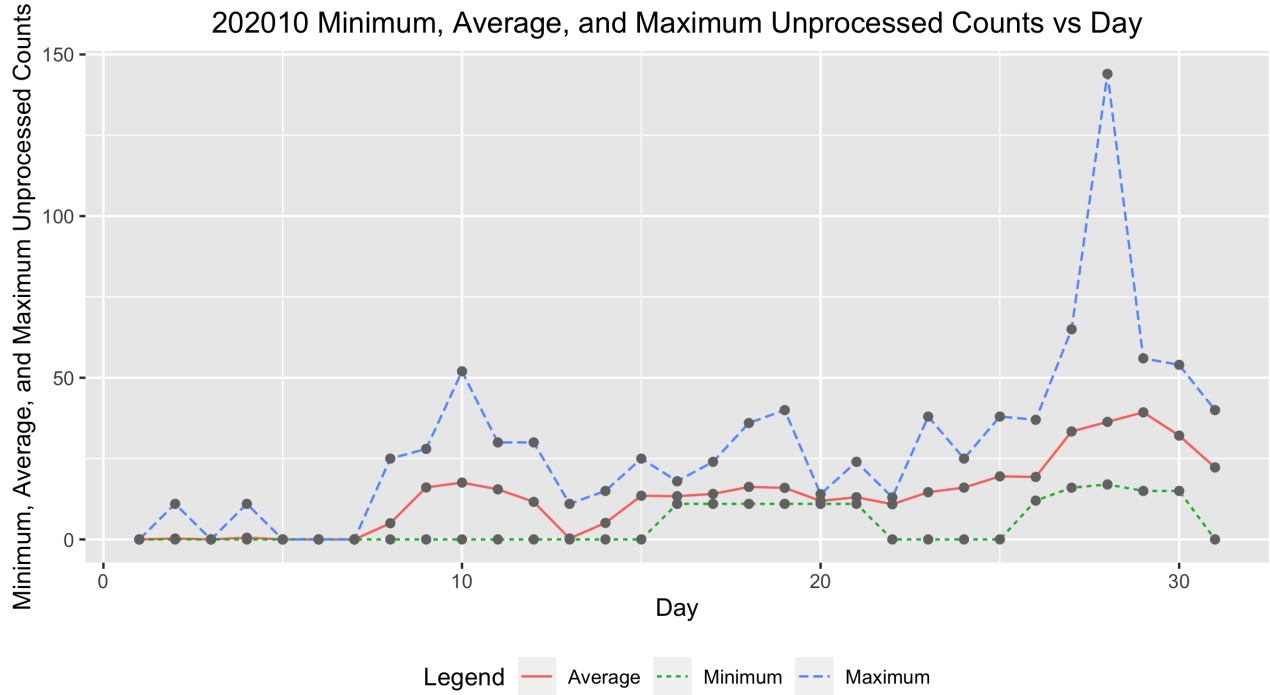


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202010 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	47.0000	0.0000	0.0000	0.0000
2.0000	39.0000	0.0000	0.2821	11.0000
3.0000	38.0000	0.0000	0.0000	0.0000
4.0000	41.0000	0.0000	0.5366	11.0000
5.0000	39.0000	0.0000	0.0000	0.0000
6.0000	38.0000	0.0000	0.0000	0.0000
7.0000	41.0000	0.0000	0.0000	0.0000
8.0000	36.0000	0.0000	5.0000	25.0000
9.0000	39.0000	0.0000	16.0769	28.0000
10.0000	42.0000	0.0000	17.5714	52.0000
11.0000	43.0000	0.0000	15.4884	30.0000
12.0000	39.0000	0.0000	11.6154	30.0000
13.0000	38.0000	0.0000	0.2895	11.0000
14.0000	39.0000	0.0000	5.1026	15.0000
15.0000	35.0000	0.0000	13.5143	25.0000
16.0000	41.0000	11.0000	13.3659	18.0000
17.0000	40.0000	11.0000	14.0750	24.0000
18.0000	38.0000	11.0000	16.2368	36.0000
19.0000	39.0000	11.0000	15.9487	40.0000
20.0000	33.0000	11.0000	11.9091	14.0000
21.0000	34.0000	11.0000	13.0588	24.0000
22.0000	37.0000	0.0000	10.8649	13.0000
23.0000	33.0000	0.0000	14.6061	38.0000
24.0000	36.0000	0.0000	16.0278	25.0000
25.0000	28.0000	0.0000	19.5000	38.0000
26.0000	40.0000	12.0000	19.3250	37.0000
27.0000	29.0000	16.0000	33.3793	65.0000
28.0000	37.0000	17.0000	36.3514	144.0000
29.0000	36.0000	15.0000	39.3056	56.0000
30.0000	41.0000	15.0000	32.0976	54.0000
31.0000	45.0000	0.0000	22.2667	40.0000

3 Error Tables

Data are for the month of October 2020. 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	2.4021	3.1389	0.5000	1.0000
2009.01	5.8833	5.2355	6.5310	1.3000	1.3000
2009.02	5.0415	4.4712	5.6119	0.7000	1.2000
2009.03	6.6669	6.4028	6.9310	0.3000	0.6000
2009.04	7.5156	7.2406	7.7906	0.4000	1.2000
2009.05	7.5653	7.2600	7.8705	1.6000	2.9000
2009.06	6.6986	6.3549	7.0423	3.2000	6.3000
2009.07	6.3951	6.1341	6.6560	3.6000	5.5000
2009.08	7.0787	6.7936	7.3638	0.0000	0.0000
2009.09	7.4565	7.1866	7.7265	4.5000	7.1000
2009.10	7.1734	6.7912	7.5557	4.5000	7.7000
2009.11	6.9909	6.7973	7.1846	3.3000	6.9000
2009.12	6.5089	6.3225	6.6954	10.4000	16.3000
2010.01	21.7176	19.2049	24.2304	13.3000	19.5000
2010.02	16.8805	14.5441	19.2169	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	18.5238	16.1880	20.8595	15.4000	24.0000
2010.04	20.6320	18.1600	23.1040	7.0000	10.4000
2010.05	24.5928	24.1547	25.0309	8.4000	8.7000
2010.06	20.4431	20.1035	20.7827	11.0000	13.6000
2010.07	21.3788	21.0684	21.6892	15.2000	16.1000
2010.08	22.8866	22.5111	23.2621	18.3000	19.6000
2010.09	25.0224	24.6102	25.4346	22.8000	25.2000
2010.10	24.3525	23.9321	24.7729	21.0000	23.5000
2010.11	24.3185	23.8770	24.7600	20.9000	21.6000
2010.12	21.7112	21.2730	22.1493	13.9000	14.5000
2011.01	77.2405	75.6414	78.8395	17.7000	18.7000
2011.02	65.3321	63.9384	66.7259	29.1000	29.6000
2011.03	69.7892	68.4543	71.1241	48.0000	55.8000
2011.04	78.5527	77.1429	79.9626	47.3000	54.4000
2011.05	79.2102	77.8728	80.5477	37.3000	41.5000
2011.06	65.7840	64.6331	66.9348	35.2000	37.0000
2011.07	68.0956	66.9319	69.2593	41.5000	43.8000
2011.08	73.7640	72.5791	74.9489	42.4000	50.5000
2011.09	79.3303	77.9561	80.7044	73.8000	78.0000
2011.10	77.1976	75.8995	78.4958	78.9000	88.0000
2011.11	76.8602	75.2588	78.4616	84.6000	96.7000
2011.12	67.5349	66.1459	68.9239	65.8000	73.0000
2012.01	82.8948	81.2633	84.5264	55.8000	58.2000
2012.02	68.9359	67.5331	70.3387	29.2000	33.1000
2012.03	74.2983	72.9824	75.6142	53.1000	64.1000
2012.04	82.4110	80.9704	83.8516	51.4000	55.2000
2012.05	84.7046	83.3097	86.0995	61.8000	69.0000
2012.06	69.6385	68.4570	70.8199	59.7000	64.5000
2012.07	72.5011	71.3133	73.6888	64.2000	51.3000
2012.08	75.7398	74.5250	76.9545	57.7000	63.1000
2012.09	81.9417	80.5204	83.3631	57.7000	61.5000
2012.10	80.6294	79.1549	82.1039	48.3000	53.3000
2012.11	80.2696	78.6584	81.8808	56.7000	61.4000
2012.12	70.7195	69.1852	72.2539	37.4000	40.8000
2013.01	92.1562	90.3941	93.9183	63.8000	62.9000
2013.02	76.7890	75.2428	78.3352	37.8000	38.0000
2013.03	80.1631	78.5316	81.7945	50.6000	57.9000
2013.04	89.8529	88.2717	91.4341	70.6000	72.4000
2013.05	90.2740	88.6661	91.8820	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	75.7478	74.4095	77.0862	51.0000	52.5000
2013.07	77.8702	76.6200	79.1203	57.0000	57.0000
2013.08	82.9122	81.5785	84.2458	60.0000	66.0000
2013.09	88.4159	86.8378	89.9940	34.6000	36.9000
2013.10	85.9432	84.3483	87.5381	74.5000	85.6000
2013.11	84.0043	82.1175	85.8912	73.9000	77.6000
2013.12	76.0998	74.4723	77.7273	77.8000	90.3000
2014.01	107.3547	105.0928	109.6165	77.4000	82.0000
2014.02	91.2434	89.4428	93.0441	93.9000	102.8000
2014.03	97.4881	95.7099	99.2662	80.9000	92.2000
2014.04	109.4419	107.5283	111.3555	76.9000	84.7000
2014.05	110.6219	108.7328	112.5111	72.3000	75.2000
2014.06	92.6385	91.0717	94.2052	67.2000	71.0000
2014.07	94.9169	93.3361	96.4977	72.5000	72.5000
2014.08	101.2199	99.6371	102.8028	71.2000	74.7000
2014.09	109.0619	107.1374	110.9864	83.2000	87.6000
2014.10	105.6702	103.7227	107.6177	59.5000	60.6000
2014.11	104.3687	102.1931	106.5443	65.8000	71.1000
2014.12	92.5868	90.4373	94.7364	75.8000	78.0000
2015.01	66.3634	65.0328	67.6939	65.9000	67.0000
2015.02	55.0509	53.8374	56.2645	42.4000	44.8000
2015.03	59.5887	58.4973	60.6801	38.0000	38.4000
2015.04	66.4651	65.2745	67.6558	49.0000	54.4000
2015.05	67.4948	66.3784	68.6112	56.3000	58.8000
2015.06	56.3913	55.3743	57.4083	50.2000	68.3000
2015.07	57.3086	56.3302	58.2869	47.9000	65.8000
2015.08	62.3130	61.2655	63.3605	39.5000	57.2000
2015.09	66.2994	65.0932	67.5055	49.2000	72.1000
2015.10	64.7499	63.4982	66.0016	39.3000	48.3000
2015.11	64.6295	63.2243	66.0347	39.6000	55.9000
2015.12	57.3971	56.1335	58.6607	36.4000	44.8000
2016.01	36.3551	35.5962	37.1140	33.7000	43.3000
2016.02	30.2783	29.6462	30.9104	38.3000	46.8000
2016.03	32.2455	31.6014	32.8895	30.5000	38.9000
2016.04	35.8741	35.1901	36.5582	26.6000	30.9000
2016.05	36.5043	35.8370	37.1716	33.7000	48.4000
2016.06	30.1747	29.6596	30.6899	13.1000	19.5000
2016.07	31.1988	30.6967	31.7009	21.2000	27.5000
2016.08	33.5897	32.9986	34.1807	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	36.5840	35.9162	37.2519	27.7000	37.1000
2016.10	35.3200	34.6389	36.0011	22.7000	31.7000
2016.11	34.8708	34.1416	35.6001	14.0000	22.2000
2016.12	31.3544	30.6834	32.0253	11.1000	20.0000
2017.01	19.7772	19.3608	20.1935	18.4000	26.2000
2017.02	16.5380	16.1746	16.9015	14.4000	20.6000
2017.03	17.7648	17.4261	18.1035	11.3000	15.5000
2017.04	19.9712	19.6185	20.3238	21.6000	33.2000
2017.05	20.0040	19.6585	20.3495	12.5000	18.1000
2017.06	16.5364	16.2604	16.8124	15.5000	19.3000
2017.07	17.1900	16.9164	17.4637	11.5000	16.3000
2017.08	18.4478	18.1260	18.7696	22.8000	35.7000
2017.09	20.4308	19.9980	20.8637	34.6000	42.9000
2017.10	19.2289	18.8360	19.6219	10.5000	11.0000
2017.11	18.8263	18.4308	19.2218	4.2000	5.6000
2017.12	16.8485	16.5928	17.1042	4.0000	4.6000
2018.01	5.4762	5.3579	5.5945	3.1000	6.3000
2018.02	4.5488	4.4364	4.6613	6.8000	11.8000
2018.03	4.7993	4.7034	4.8953	1.1000	1.2000
2018.04	5.3517	5.2430	5.4604	4.7000	7.5000
2018.05	5.4444	5.3404	5.5484	8.4000	14.0000
2018.06	4.5106	4.4307	4.5905	10.2000	13.6000
2018.07	4.6865	4.6334	4.7396	0.5000	1.7000
2018.08	4.9708	4.8844	5.0571	5.9000	9.5000
2018.09	5.2994	5.1998	5.3991	1.6000	2.9000
2018.10	5.2595	5.1569	5.3622	2.5000	5.6000
2018.11	5.1845	5.0780	5.2910	3.1000	4.2000
2018.12	4.7351	4.6432	4.8270	1.6000	2.3000
2019.01	3.6319	3.5633	3.7005	5.4000	2.3000
2019.02	3.0775	3.0172	3.1379	0.1000	1.2000
2019.03	3.2066	3.1514	3.2617	6.1000	12.1000
2019.04	3.5953	3.5272	3.6633	6.2000	9.3000
2019.05	3.5414	3.4790	3.6038	7.0000	11.9000
2019.06	2.9321	2.8819	2.9824	0.7000	1.5000
2019.07	3.0610	3.0145	3.1076	0.4000	2.2000
2019.08	3.3011	3.2511	3.3511	0.3000	0.8000
2019.09	3.5898	3.5320	3.6476	0.5000	1.0000
2019.10	3.4526	3.3919	3.5133	0.2000	0.5000
2019.11	3.4681	3.4005	3.5356	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	3.0710	3.0096	3.1325	0.8000	1.0000
2020.01	4.7393	4.6446	4.8340	4.0000	5.3000
2020.02	3.9590	3.8783	4.0396	0.1000	0.0000
2020.03	4.1846	4.1051	4.2641	1.2000	1.5000
2020.04	4.7349	4.6567	4.8131	3.0000	5.1000
2020.05	4.7123	4.6370	4.7876	0.1000	0.4000
2020.06	3.9349	3.8723	3.9975	3.9000	6.4000
2020.07	4.0350	3.9736	4.0965	4.2000	7.7000
2020.08	4.2908	4.2307	4.3510	5.3000	7.8000
2020.09	4.6731	4.5986	4.7476	0.4000	0.9000
2020.10	4.6072	4.5313	4.6831	9.9000	13.6000

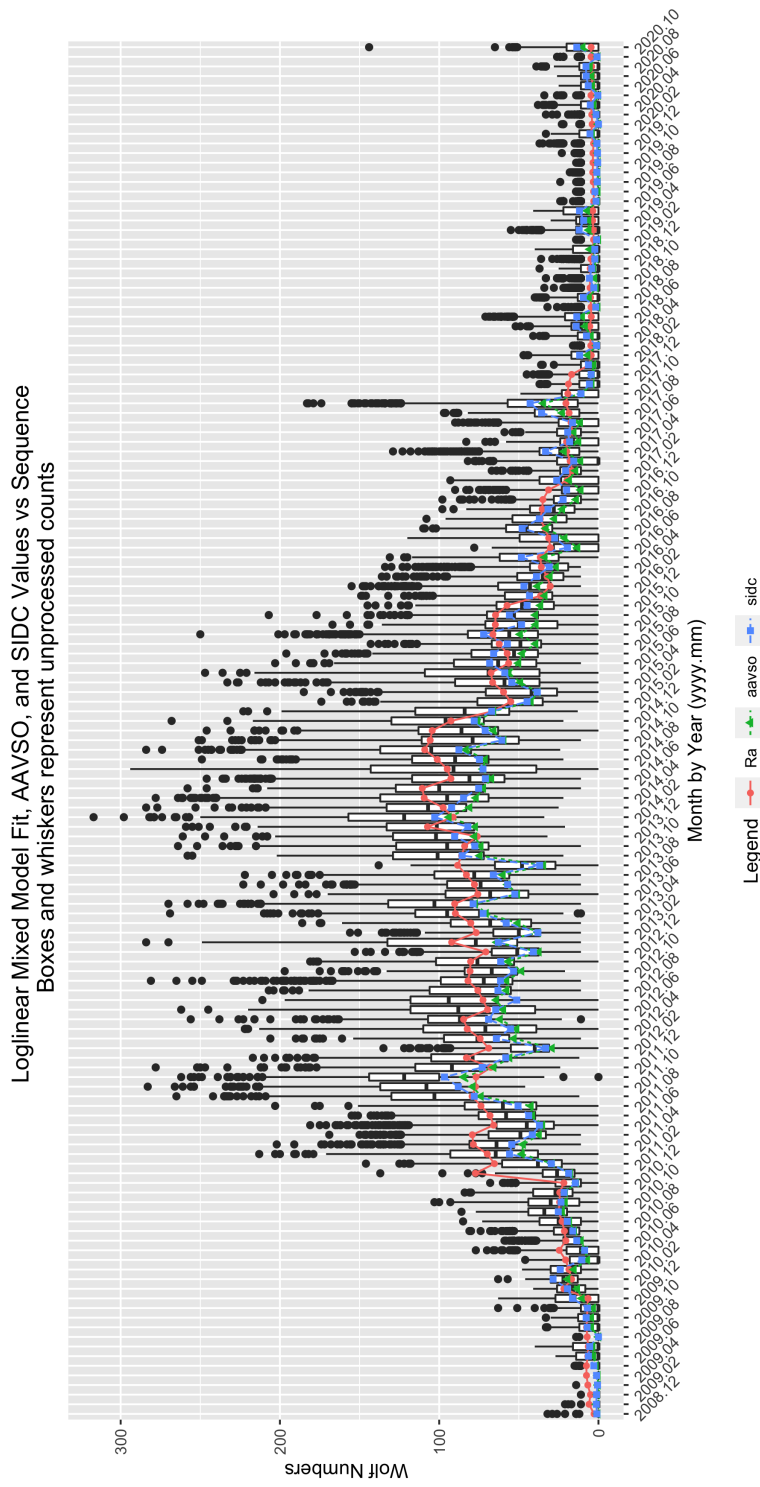


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202010 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4702	0.3059	4.8059	0.0000
seeF	-0.2171	0.0057	-37.8235	0.0000
seeG	-0.1169	0.0050	-23.3877	0.0000
seeM	-0.2000	0.0237	-8.4352	0.0000
seeP	-0.3202	0.0082	-38.9865	0.0000
sidc1	0.1302	0.0690	1.8867	0.0592
year2009	0.6368	0.3067	2.0765	0.0379
year2010	1.8454	0.3045	6.0596	0.0000
year2011	2.9642	0.3045	9.7363	0.0000
year2012	3.0013	0.3044	9.8584	0.0000
year2013	3.0971	0.3044	10.1732	0.0000
year2014	3.2940	0.3044	10.8199	0.0000
year2015	2.8093	0.3045	9.2274	0.0000
year2016	2.1925	0.3045	7.2009	0.0000
year2017	1.5874	0.3045	5.2127	0.0000
year2018	0.2910	0.3048	0.9548	0.3397
year2019	-0.1345	0.3050	-0.4408	0.6594
year2020	0.1457	0.3050	0.4779	0.6327
mon2	-0.1735	0.0091	-19.1403	0.0000
mon3	-0.1148	0.0085	-13.5665	0.0000
mon4	-0.0097	0.0082	-1.1902	0.2340
mon5	-0.0049	0.0080	-0.6139	0.5393
mon6	-0.1926	0.0084	-22.9221	0.0000
mon7	-0.1666	0.0082	-20.3969	0.0000
mon8	-0.0941	0.0080	-11.7789	0.0000
mon9	-0.0115	0.0081	-1.4303	0.1526
mon10	-0.0368	0.0082	-4.4772	0.0000
mon11	-0.0351	0.0087	-4.0519	0.0001
mon12	-0.1449	0.0088	-16.4246	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: 202010 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:133203	Min. :0.0000
1st Qu.:2013	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 : 6.613	Mean :15.72		Mean :0.2571
3rd Qu.:2018	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2020	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202010 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:133203	Length:133203
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 8.00	Median : 29.00	Mode :character	Mode :character
Mean : 2.743	Mean : 16.25	Mean : 43.68		
3rd Qu.: 5.000	3rd Qu.: 24.00	3rd Qu.: 71.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202010 Summary of Sunspot Numbers

inst	filter	unit
Length:133203	Length:133203	Length:133203
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202010 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 50.00	1st Qu.: 4.00	1st Qu.: 32.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 89.78	Mean : 30.75	Mean : 875.3	Mean : 183.9
3rd Qu.: 104.00	3rd Qu.: 23.00	3rd Qu.:1200.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :9990.0	Max. :4591.0

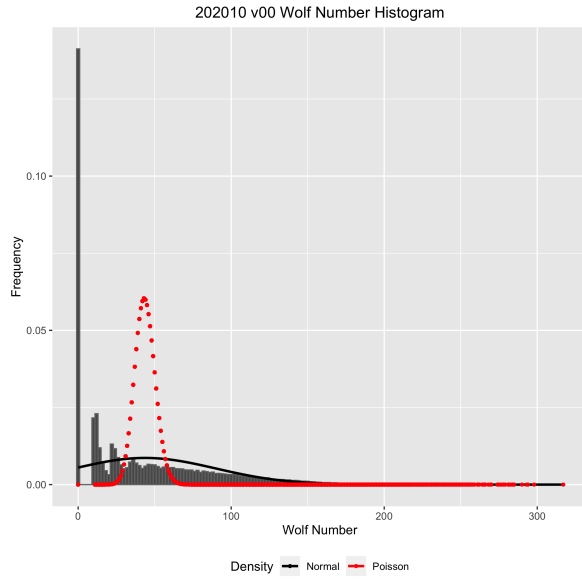


Figure 3: Box plots of raw Wolf number (w) by observer rank.

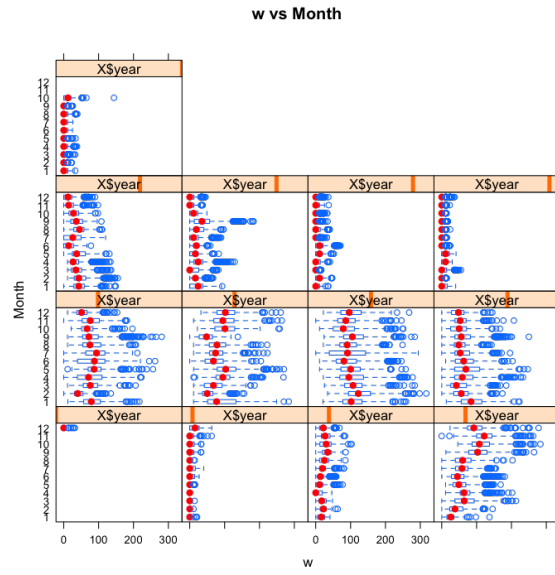


Figure 4: Box plots of raw Wolf number (w) by month and year.

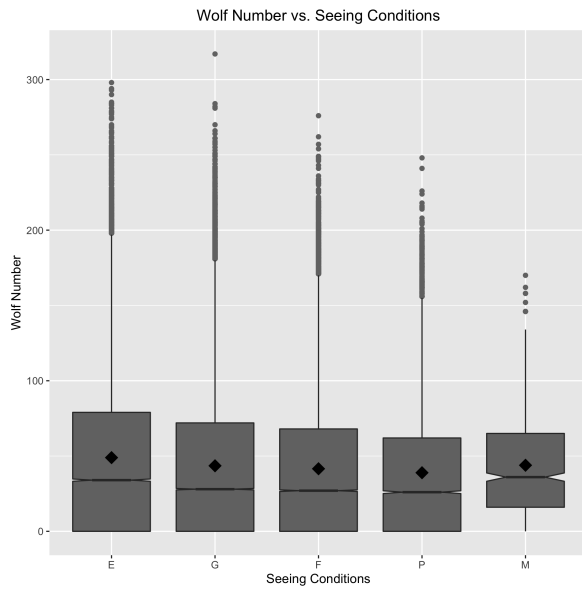


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

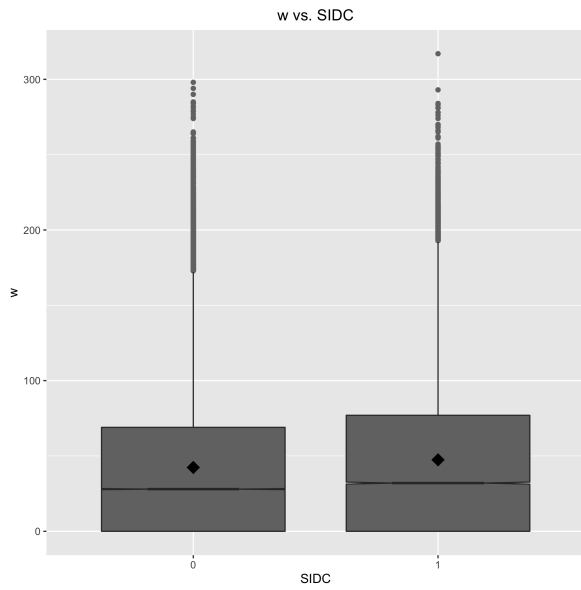


Figure 6: Box plots of raw Wolf number (w) by organization.

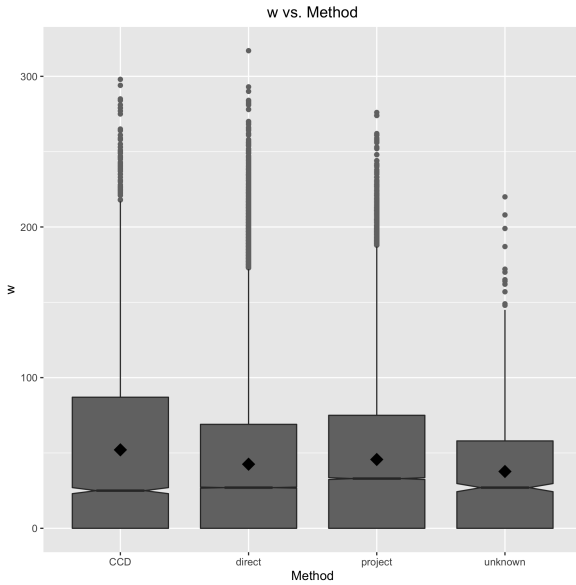


Figure 7: Box plots of raw Wolf number (w) by observer rank.

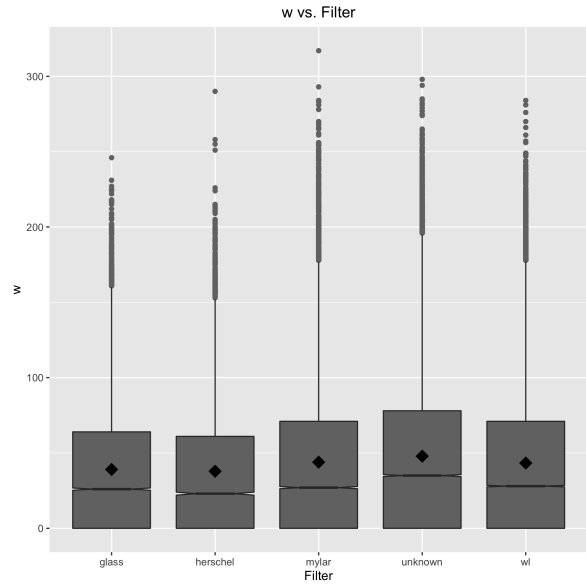


Figure 8: Box plots of raw Wolf number (w) by month and year.

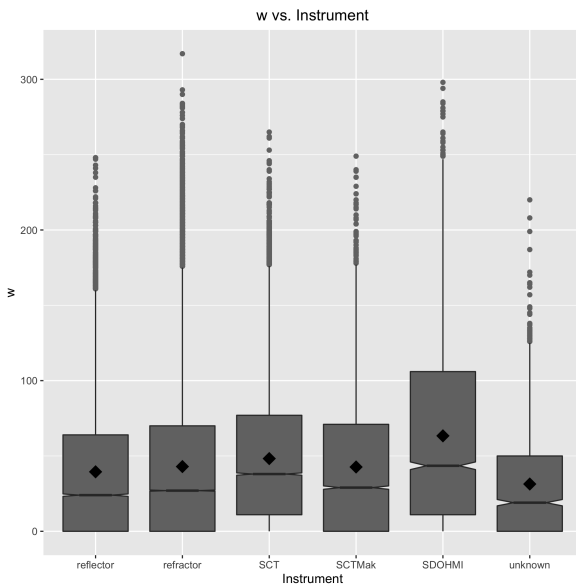


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

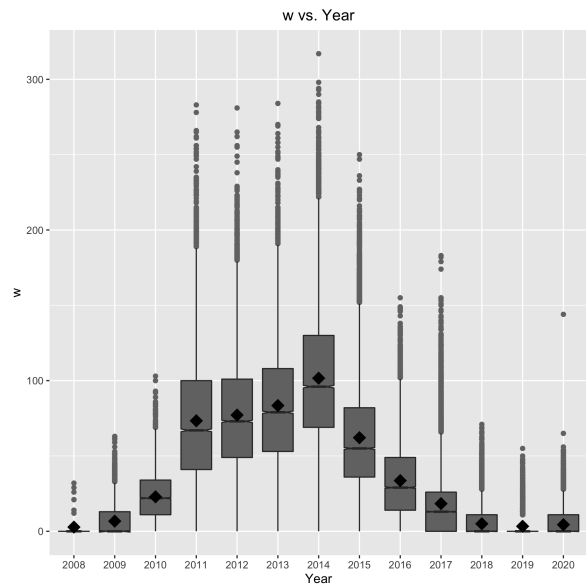


Figure 10: Box plots of raw Wolf number (w) by organization.

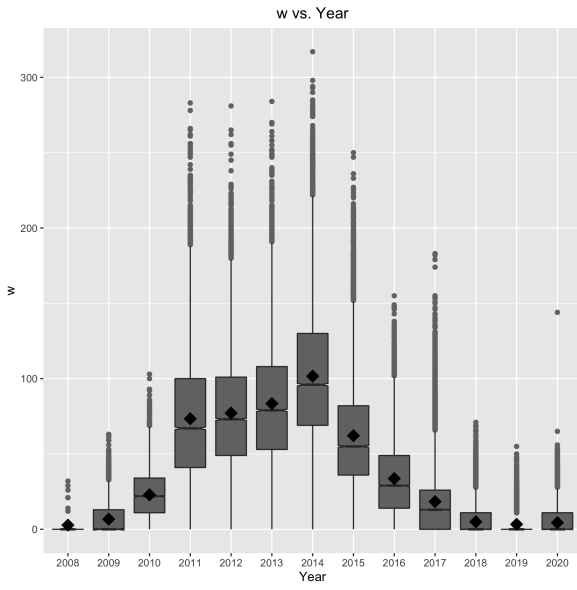


Figure 11: Box plots of raw Wolf number (w) by year.

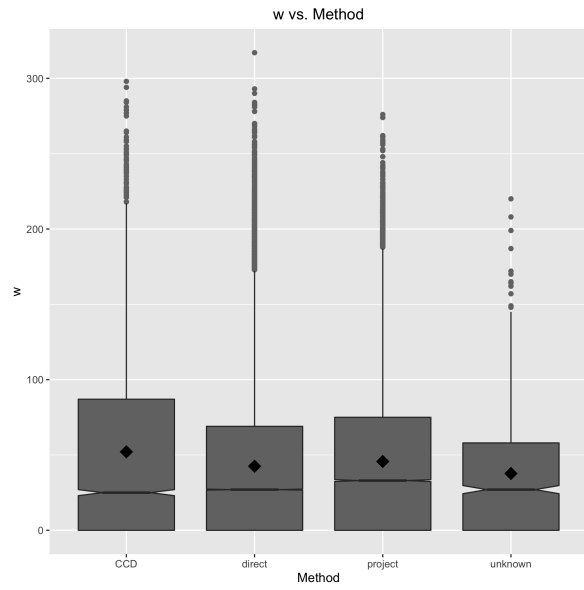


Figure 12: Box plots of raw Wolf number (w) by observing method.