

Monthly Report (00)

2020.04 Data Set

Tuesday 12th May, 2020

Prepared for

Statistics for Physical and Engineering Sciences

by

Jamie Riggs, Ph.D.

Principal Statistician
Statistics for Physical and Engineering Sciences Institute

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.

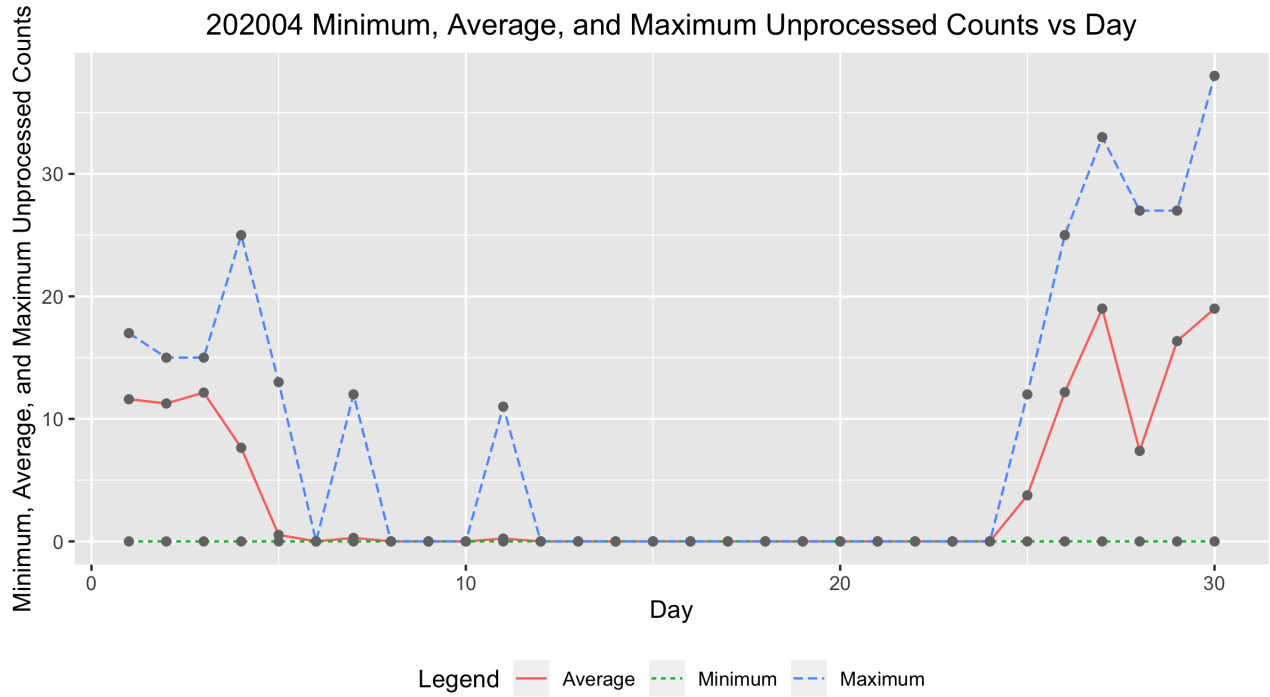


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202004 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	38.0000	0.0000	11.6053	17.0000
2.0000	46.0000	0.0000	11.2609	15.0000
3.0000	41.0000	0.0000	12.1463	15.0000
4.0000	45.0000	0.0000	7.6444	25.0000
5.0000	45.0000	0.0000	0.5333	13.0000
6.0000	46.0000	0.0000	0.0000	0.0000
7.0000	42.0000	0.0000	0.2857	12.0000
8.0000	43.0000	0.0000	0.0000	0.0000
9.0000	42.0000	0.0000	0.0000	0.0000
10.0000	46.0000	0.0000	0.0000	0.0000
11.0000	48.0000	0.0000	0.2292	11.0000
12.0000	37.0000	0.0000	0.0000	0.0000
13.0000	35.0000	0.0000	0.0000	0.0000
14.0000	41.0000	0.0000	0.0000	0.0000
15.0000	40.0000	0.0000	0.0000	0.0000
16.0000	45.0000	0.0000	0.0000	0.0000
17.0000	38.0000	0.0000	0.0000	0.0000
18.0000	37.0000	0.0000	0.0000	0.0000
19.0000	32.0000	0.0000	0.0000	0.0000
20.0000	40.0000	0.0000	0.0000	0.0000
21.0000	39.0000	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	38.0000	0.0000	0.0000	0.0000
25.0000	50.0000	0.0000	3.7600	12.0000
26.0000	44.0000	0.0000	12.1818	25.0000
27.0000	44.0000	0.0000	19.0000	33.0000
28.0000	39.0000	0.0000	7.3846	27.0000
29.0000	40.0000	0.0000	16.3500	27.0000
30.0000	37.0000	0.0000	19.0000	38.0000

3 Error Tables

Data are for the month of April 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	2.4041	3.1368	0.5000	1.0000
2009.01	5.9115	5.2646	6.5584	1.3000	1.3000
2009.02	5.0664	4.4969	5.6360	0.7000	1.2000
2009.03	6.6895	6.4238	6.9552	0.3000	0.6000
2009.04	7.5445	7.2678	7.8212	0.4000	1.2000
2009.05	7.6420	7.3323	7.9518	1.6000	2.9000
2009.06	6.6742	6.3305	7.0179	3.2000	6.3000
2009.07	6.3571	6.0969	6.6173	3.6000	5.5000
2009.08	7.0353	6.7504	7.3202	0.0000	0.0000
2009.09	7.5252	7.2520	7.7984	4.5000	7.1000
2009.10	7.0289	6.6528	7.4050	4.5000	7.7000
2009.11	6.9895	6.7959	7.1831	3.3000	6.9000
2009.12	6.5058	6.3194	6.6922	10.4000	16.3000
2010.01	21.8446	19.3322	24.3571	13.3000	19.5000
2010.02	16.9923	14.6558	19.3288	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	18.6438	16.3061	20.9816	15.4000	24.0000
2010.04	20.7686	18.2942	23.2430	7.0000	10.4000
2010.05	24.8863	24.4429	25.3297	8.4000	8.7000
2010.06	20.3939	20.0544	20.7335	11.0000	13.6000
2010.07	21.2893	20.9798	21.5989	15.2000	16.1000
2010.08	22.7806	22.4062	23.1550	18.3000	19.6000
2010.09	25.2967	24.8789	25.7145	22.8000	25.2000
2010.10	23.9082	23.4946	24.3218	21.0000	23.5000
2010.11	24.3500	23.9067	24.7933	20.9000	21.6000
2010.12	21.7382	21.2985	22.1778	13.9000	14.5000
2011.01	77.5367	75.9257	79.1476	17.7000	18.7000
2011.02	65.5921	64.1863	66.9979	29.1000	29.6000
2011.03	70.0432	68.7020	71.3844	48.0000	55.8000
2011.04	78.8760	77.4571	80.2949	47.3000	54.4000
2011.05	80.0421	78.6854	81.3988	37.3000	41.5000
2011.06	65.5585	64.4079	66.7091	35.2000	37.0000
2011.07	67.7525	66.5917	68.9134	41.5000	43.8000
2011.08	73.3555	72.1733	74.5377	42.4000	50.5000
2011.09	80.0912	78.7039	81.4784	73.8000	78.0000
2011.10	75.7077	74.4313	76.9842	78.9000	88.0000
2011.11	76.8934	75.2857	78.5012	84.6000	96.7000
2011.12	67.5545	66.1609	68.9481	65.8000	73.0000
2012.01	83.2027	81.5627	84.8427	55.8000	58.2000
2012.02	69.2134	67.8032	70.6236	29.2000	33.1000
2012.03	74.5783	73.2551	75.9014	53.1000	64.1000
2012.04	82.7422	81.2937	84.1907	51.4000	55.2000
2012.05	85.5795	84.1670	86.9921	61.8000	69.0000
2012.06	69.3835	68.2031	70.5638	59.7000	64.5000
2012.07	72.0943	70.9105	73.2781	64.2000	51.3000
2012.08	75.2844	74.0749	76.4939	57.7000	63.1000
2012.09	82.7125	81.2764	84.1487	57.7000	61.5000
2012.10	79.0445	77.5971	80.4918	48.3000	53.3000
2012.11	80.2575	78.6449	81.8702	56.7000	61.4000
2012.12	70.6939	69.1580	72.2298	37.4000	40.8000
2013.01	92.5224	90.7517	94.2932	63.8000	62.9000
2013.02	77.1115	75.5578	78.6653	37.8000	38.0000
2013.03	80.4693	78.8318	82.1067	50.6000	57.9000
2013.04	90.2274	88.6395	91.8152	70.6000	72.4000
2013.05	91.2010	89.5772	92.8248	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	75.4650	74.1300	76.8000	51.0000	52.5000
2013.07	77.4376	76.1935	78.6817	57.0000	57.0000
2013.08	82.3942	81.0683	83.7200	60.0000	66.0000
2013.09	89.2470	87.6537	90.8404	34.6000	36.9000
2013.10	84.2387	82.6751	85.8023	74.5000	85.6000
2013.11	83.9938	82.1073	85.8803	73.9000	77.6000
2013.12	76.0848	74.4577	77.7119	77.8000	90.3000
2014.01	107.7799	105.5090	110.0508	77.4000	82.0000
2014.02	91.6204	89.8128	93.4281	93.9000	102.8000
2014.03	97.8446	96.0603	99.6290	80.9000	92.2000
2014.04	109.8749	107.9537	111.7960	76.9000	84.7000
2014.05	111.7553	109.8458	113.6647	72.3000	75.2000
2014.06	92.2799	90.7187	93.8412	67.2000	71.0000
2014.07	94.3865	92.8141	95.9589	72.5000	72.5000
2014.08	100.6012	99.0277	102.1747	71.2000	74.7000
2014.09	110.1048	108.1616	112.0481	83.2000	87.6000
2014.10	103.5906	101.6807	105.5005	59.5000	60.6000
2014.11	104.3490	102.1733	106.5247	65.8000	71.1000
2014.12	92.5635	90.4136	94.7133	75.8000	78.0000
2015.01	66.6335	65.2976	67.9695	65.9000	67.0000
2015.02	55.2662	54.0476	56.4847	42.4000	44.8000
2015.03	59.8015	58.7054	60.8976	38.0000	38.4000
2015.04	66.7109	65.5134	67.9084	49.0000	54.4000
2015.05	68.1827	67.0539	69.3115	56.3000	58.8000
2015.06	56.1641	55.1490	57.1792	50.2000	68.3000
2015.07	56.9676	55.9932	57.9419	47.9000	65.8000
2015.08	61.9368	60.8940	62.9796	39.5000	57.2000
2015.09	66.9108	65.6920	68.1297	49.2000	72.1000
2015.10	63.4568	62.2287	64.6848	39.3000	48.3000
2015.11	64.6249	63.2191	66.0306	39.6000	55.9000
2015.12	57.4012	56.1379	58.6644	36.4000	44.8000
2016.01	36.4969	35.7342	37.2595	33.7000	43.3000
2016.02	30.4025	29.7676	31.0374	38.3000	46.8000
2016.03	32.3662	31.7193	33.0130	30.5000	38.9000
2016.04	36.0156	35.3281	36.7031	26.6000	30.9000
2016.05	36.8849	36.2100	37.5598	33.7000	48.4000
2016.06	30.0619	29.5483	30.5755	13.1000	19.5000
2016.07	31.0330	30.5332	31.5327	21.2000	27.5000
2016.08	33.3891	32.8009	33.9773	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	36.9294	36.2543	37.6046	27.7000	37.1000
2016.10	34.6211	33.9524	35.2897	22.7000	31.7000
2016.11	34.8643	34.1344	35.5943	14.0000	22.2000
2016.12	31.3548	30.6834	32.0261	11.1000	20.0000
2017.01	19.8517	19.4334	20.2700	18.4000	26.2000
2017.02	16.6041	16.2389	16.9693	14.4000	20.6000
2017.03	17.8305	17.4903	18.1707	11.3000	15.5000
2017.04	20.0514	19.6970	20.4057	21.6000	33.2000
2017.05	20.2078	19.8584	20.5572	12.5000	18.1000
2017.06	16.4787	16.2033	16.7541	15.5000	19.3000
2017.07	17.0983	16.8260	17.3706	11.5000	16.3000
2017.08	18.3381	18.0192	18.6571	22.8000	35.7000
2017.09	20.6024	20.1745	21.0302	34.6000	42.9000
2017.10	18.8473	18.4650	19.2295	10.5000	11.0000
2017.11	18.8241	18.4295	19.2187	4.2000	5.6000
2017.12	16.8553	16.5997	17.1110	4.0000	4.6000
2018.01	5.5031	5.3850	5.6212	3.1000	6.3000
2018.02	4.5706	4.4589	4.6824	6.8000	11.8000
2018.03	4.8203	4.7246	4.9159	1.1000	1.2000
2018.04	5.3772	5.2696	5.4848	4.7000	7.5000
2018.05	5.5061	5.4018	5.6104	8.4000	14.0000
2018.06	4.4955	4.4162	4.5749	10.2000	13.6000
2018.07	4.6611	4.6087	4.7135	0.5000	1.7000
2018.08	4.9416	4.8559	5.0273	5.9000	9.5000
2018.09	5.3478	5.2478	5.4477	1.6000	2.9000
2018.10	5.1579	5.0579	5.2579	2.5000	5.6000
2018.11	5.1883	5.0823	5.2943	3.1000	4.2000
2018.12	4.7408	4.6491	4.8324	1.6000	2.3000
2019.01	3.6493	3.5812	3.7175	5.4000	2.3000
2019.02	3.0946	3.0344	3.1548	0.1000	1.2000
2019.03	3.2217	3.1668	3.2767	6.1000	12.1000
2019.04	3.6121	3.5442	3.6800	6.2000	9.3000
2019.05	3.5750	3.5119	3.6381	7.0000	11.9000
2019.06	2.9151	2.8647	2.9656	0.7000	1.5000
2019.07	3.0382	2.9917	3.0848	0.4000	2.2000
2019.08	3.2794	3.2298	3.3291	0.3000	0.8000
2019.09	3.6220	3.5637	3.6803	0.5000	1.0000
2019.10	3.3891	3.3303	3.4479	0.2000	0.5000
2019.11	3.4687	3.4016	3.5358	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	3.0734	3.0123	3.1345	0.8000	1.0000
2020.01	3.0223	2.9628	3.0818	4.0000	5.3000
2020.02	2.5307	2.4798	2.5816	0.1000	0.0000
2020.03	2.6712	2.6216	2.7209	1.2000	1.5000
2020.04	3.0304	2.9809	3.0799	3.0000	5.1000

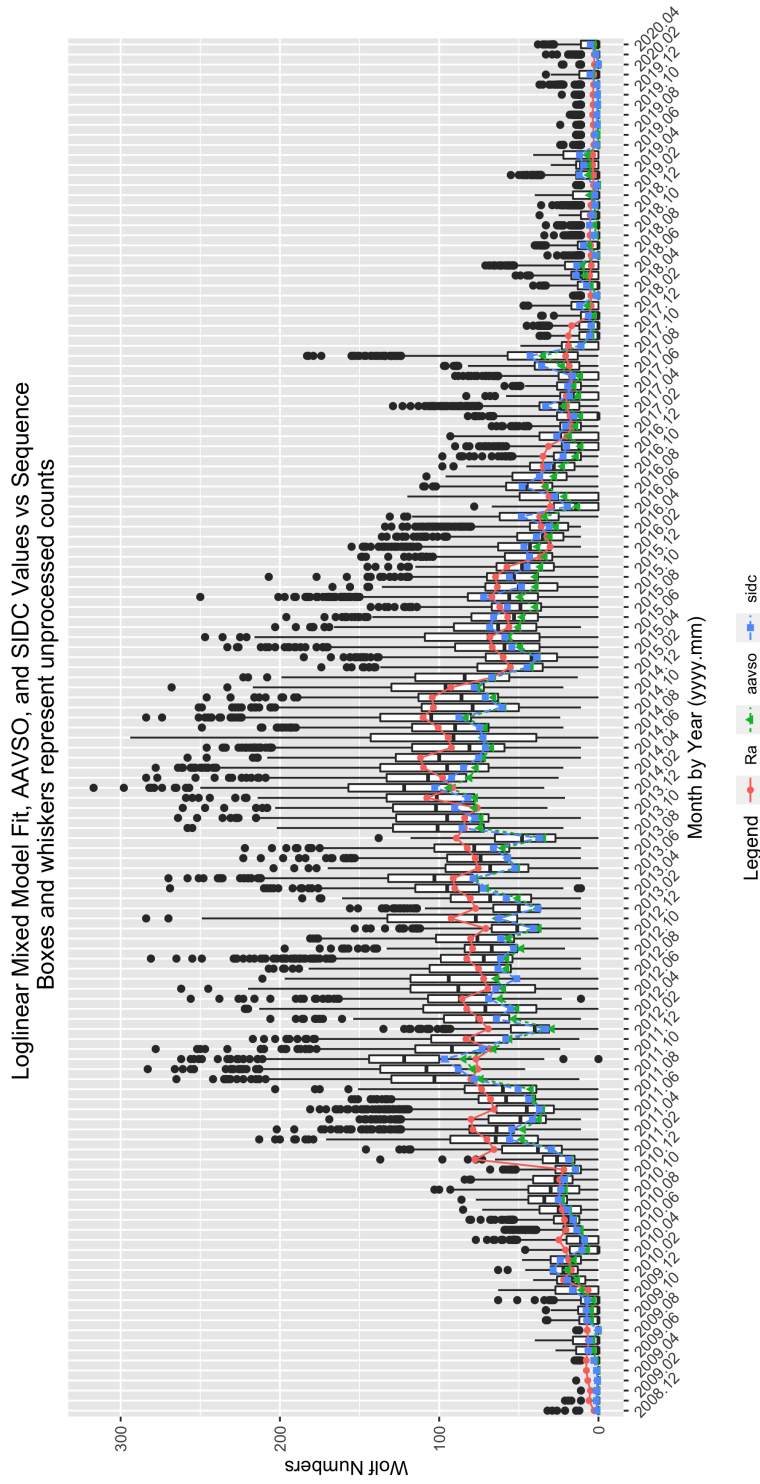


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202004 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4616	0.3075	4.7535	0.0000
seeF	-0.2184	0.0058	-37.7220	0.0000
seeG	-0.1168	0.0050	-23.1608	0.0000
seeM	-0.2023	0.0239	-8.4784	0.0000
seeP	-0.3236	0.0083	-39.0299	0.0000
sidc1	0.1424	0.0679	2.0975	0.0360
year2009	0.6375	0.3084	2.0671	0.0387
year2010	1.8477	0.3062	6.0334	0.0000
year2011	2.9651	0.3062	9.6852	0.0000
year2012	3.0018	0.3061	9.8050	0.0000
year2013	3.0977	0.3061	10.1185	0.0000
year2014	3.2946	0.3061	10.7617	0.0000
year2015	2.8098	0.3062	9.1776	0.0000
year2016	2.1931	0.3062	7.1627	0.0000
year2017	1.5879	0.3062	5.1854	0.0000
year2018	0.2908	0.3065	0.9487	0.3428
year2019	-0.1340	0.3067	-0.4368	0.6623
year2020	-0.3071	0.3083	-0.9962	0.3192
mon2	-0.1733	0.0091	-19.0089	0.0000
mon3	-0.1151	0.0085	-13.5234	0.0000
mon4	-0.0098	0.0082	-1.1894	0.2343
mon5	0.0013	0.0081	0.1636	0.8701
mon6	-0.2006	0.0085	-23.6534	0.0000
mon7	-0.1764	0.0082	-21.3992	0.0000
mon8	-0.1045	0.0081	-12.9461	0.0000
mon9	-0.0062	0.0081	-0.7693	0.4417
mon10	-0.0609	0.0083	-7.3081	0.0000
mon11	-0.0391	0.0087	-4.4886	0.0000
mon12	-0.1489	0.0089	-16.7826	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: 202004 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:125370	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 : 6.561	Mean :15.73		Mean :0.2586
3rd Qu.:2017	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: 202004 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:125370	Length:125370
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 9.00	Median : 34.00	Mode :character	Mode :character
Mean : 2.889	Mean : 17.19	Mean : 46.08		
3rd Qu.: 5.000	3rd Qu.: 26.00	3rd Qu.: 74.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202004 Summary of Sunspot Numbers

inst	filter	unit
Length:125370	Length:125370	Length:125370
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202004 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 60.00	1st Qu.: 3.00	1st Qu.: 150.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 92.69	Mean : 28.84	Mean : 910.1	Mean : 185.3
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1200.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

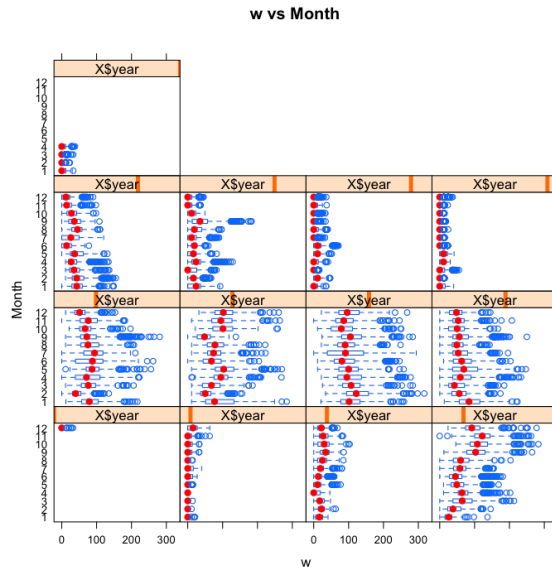
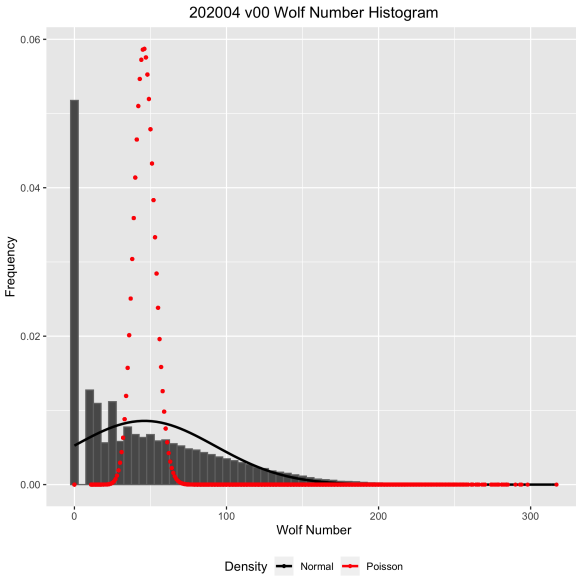


Figure 3: Box plots of raw Wolf number (w) by observer rank.

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

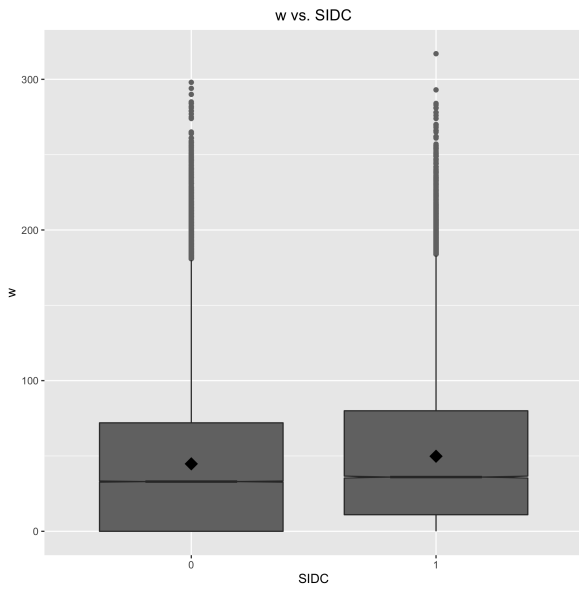
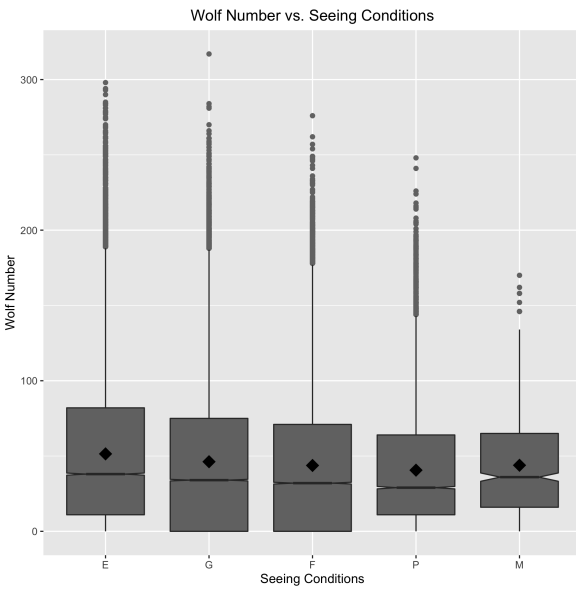


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

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

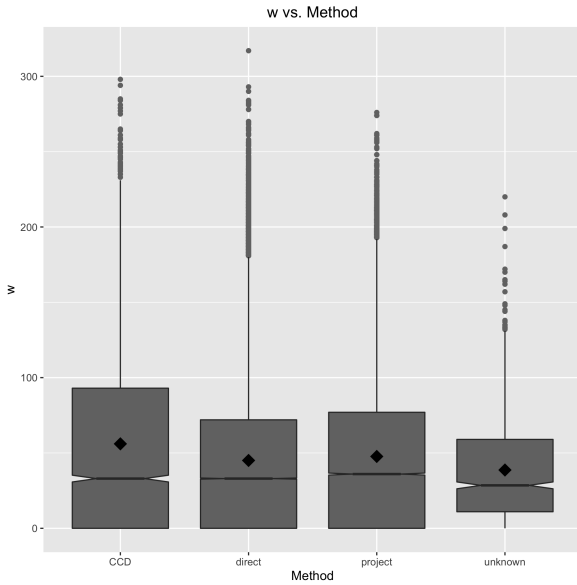


Figure 7: Box plots of raw Wolf number (w) by observer rank.

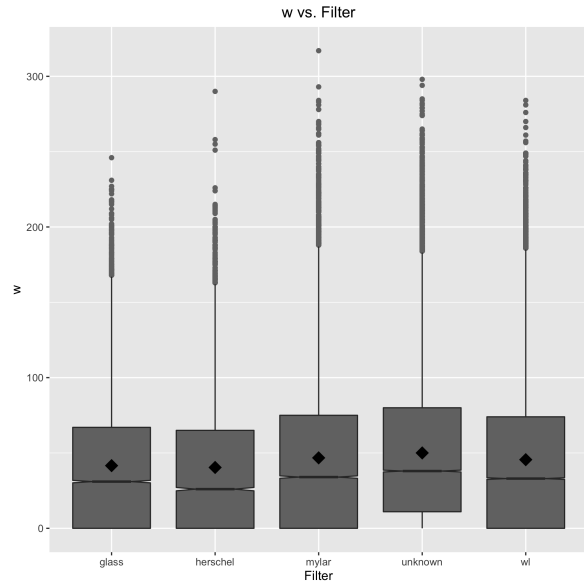


Figure 8: Box plots of raw Wolf number (w) by month and year.

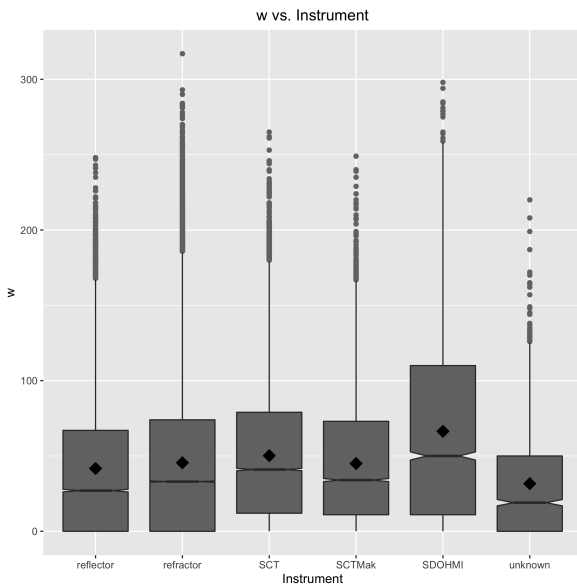


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

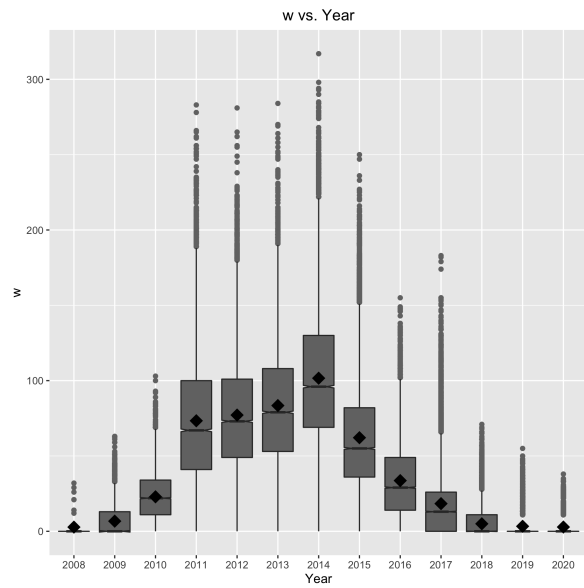


Figure 10: Box plots of raw Wolf number (w) by organization.

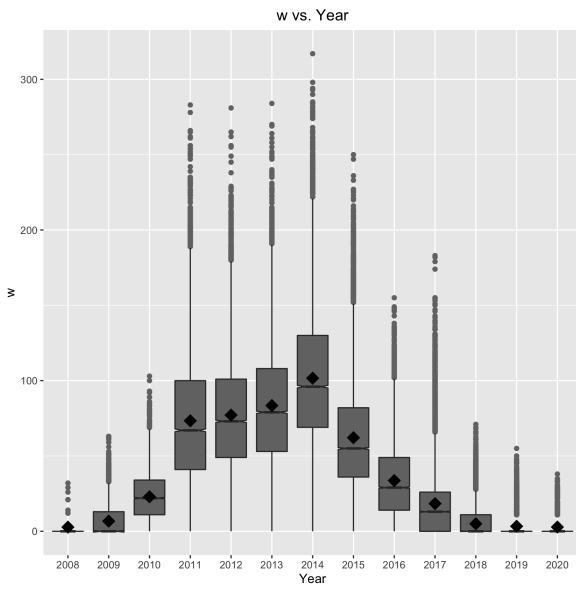


Figure 11: Box plots of raw Wolf number (w) by year.

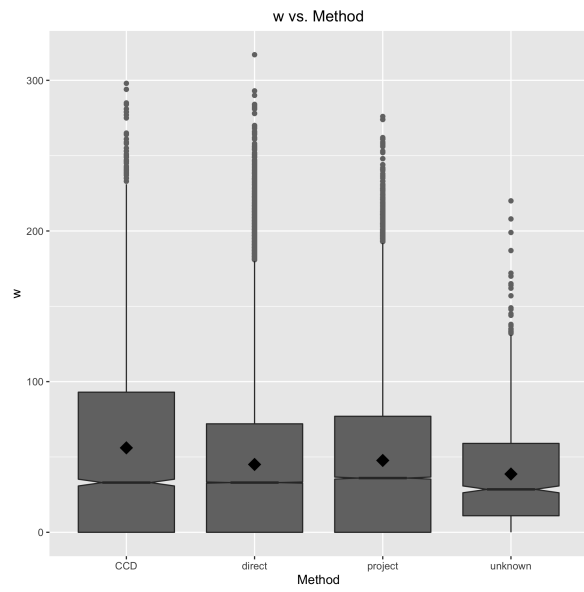


Figure 12: Box plots of raw Wolf number (w) by observing method.