

# Monthly Report (00)

## 2020.03 Data Set

Sunday 12<sup>th</sup> April, 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.

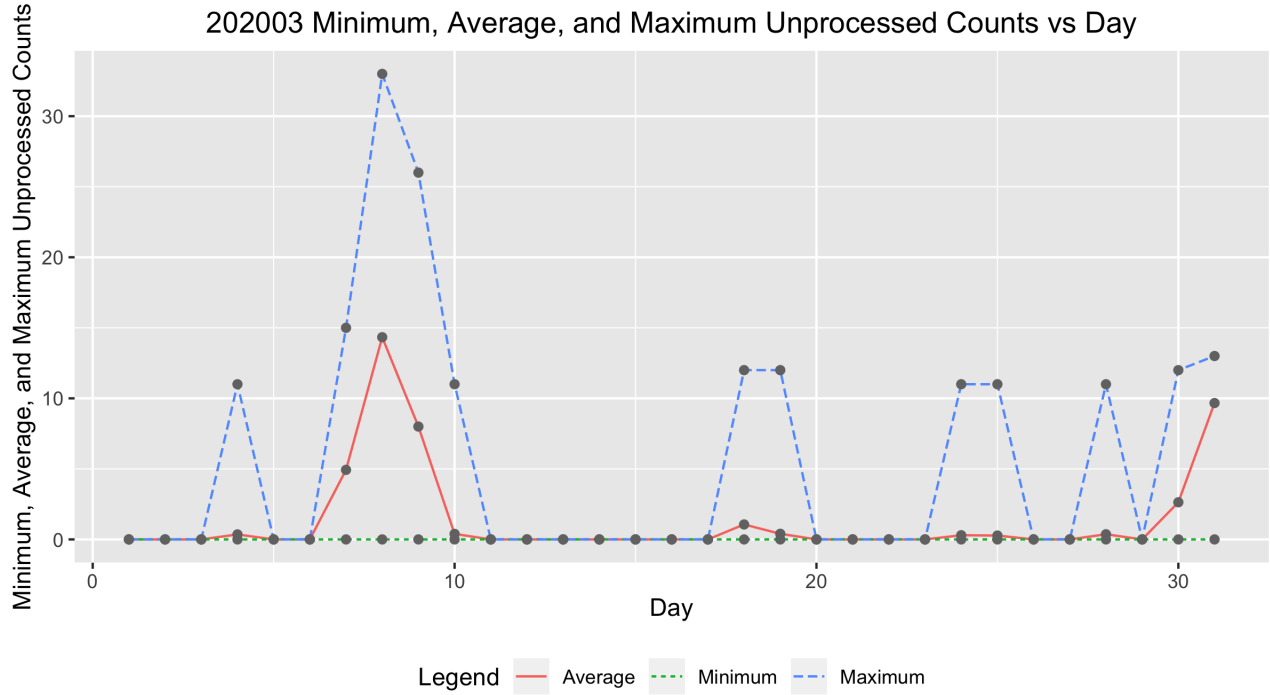


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202003 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	35.0000	0.0000	0.0000	0.0000
2.0000	31.0000	0.0000	0.0000	0.0000
3.0000	32.0000	0.0000	0.0000	0.0000
4.0000	31.0000	0.0000	0.3548	11.0000
5.0000	33.0000	0.0000	0.0000	0.0000
6.0000	36.0000	0.0000	0.0000	0.0000
7.0000	44.0000	0.0000	4.9318	15.0000
8.0000	39.0000	0.0000	14.3333	33.0000
9.0000	36.0000	0.0000	8.0000	26.0000
10.0000	28.0000	0.0000	0.3929	11.0000
11.0000	37.0000	0.0000	0.0000	0.0000
12.0000	39.0000	0.0000	0.0000	0.0000
13.0000	38.0000	0.0000	0.0000	0.0000
14.0000	38.0000	0.0000	0.0000	0.0000
15.0000	38.0000	0.0000	0.0000	0.0000
16.0000	33.0000	0.0000	0.0000	0.0000
17.0000	39.0000	0.0000	0.0000	0.0000
18.0000	33.0000	0.0000	1.0606	12.0000
19.0000	30.0000	0.0000	0.4000	12.0000
20.0000	33.0000	0.0000	0.0000	0.0000
21.0000	43.0000	0.0000	0.0000	0.0000
22.0000	34.0000	0.0000	0.0000	0.0000
23.0000	31.0000	0.0000	0.0000	0.0000
24.0000	37.0000	0.0000	0.2973	11.0000
25.0000	40.0000	0.0000	0.2750	11.0000
26.0000	34.0000	0.0000	0.0000	0.0000
27.0000	42.0000	0.0000	0.0000	0.0000
28.0000	30.0000	0.0000	0.3667	11.0000
29.0000	35.0000	0.0000	0.0000	0.0000
30.0000	30.0000	0.0000	2.6333	12.0000
31.0000	33.0000	0.0000	9.6667	13.0000

### 3 Error Tables

Data are for the month of March 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 25<sup>th</sup> through the 75<sup>th</sup> quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25<sup>th</sup> quartile, and 1.5 times the IQR above the 75<sup>th</sup> 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	2.4039	3.1371	0.5000	1.0000
2009.01	5.9170	5.2691	6.5650	1.3000	1.3000
2009.02	5.0715	4.5010	5.6420	0.7000	1.2000
2009.03	6.6965	6.4306	6.9624	0.3000	0.6000
2009.04	7.5257	7.2498	7.8016	0.4000	1.2000
2009.05	7.6420	7.3323	7.9517	1.6000	2.9000
2009.06	6.6744	6.3307	7.0181	3.2000	6.3000
2009.07	6.3571	6.0970	6.6173	3.6000	5.5000
2009.08	7.0354	6.7505	7.3202	0.0000	0.0000
2009.09	7.5253	7.2521	7.7984	4.5000	7.1000
2009.10	7.0288	6.6526	7.4049	4.5000	7.7000
2009.11	6.9892	6.7956	7.1829	3.3000	6.9000
2009.12	6.5057	6.3192	6.6922	10.4000	16.3000
2010.01	21.8650	19.3486	24.3814	13.3000	19.5000
2010.02	17.0075	14.6673	19.3477	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	18.6597	16.3183	21.0010	15.4000	24.0000
2010.04	20.7123	18.2430	23.1817	7.0000	10.4000
2010.05	24.8855	24.4419	25.3291	8.4000	8.7000
2010.06	20.3939	20.0542	20.7335	11.0000	13.6000
2010.07	21.2899	20.9802	21.5995	15.2000	16.1000
2010.08	22.7819	22.4074	23.1563	18.3000	19.6000
2010.09	25.2974	24.8796	25.7152	22.8000	25.2000
2010.10	23.9074	23.4936	24.3211	21.0000	23.5000
2010.11	24.3503	23.9070	24.7936	20.9000	21.6000
2010.12	21.7380	21.2982	22.1778	13.9000	14.5000
2011.01	77.6152	76.0020	79.2284	17.7000	18.7000
2011.02	65.6657	64.2581	67.0733	29.1000	29.6000
2011.03	70.1149	68.7721	71.4576	48.0000	55.8000
2011.04	78.6821	77.2668	80.0975	47.3000	54.4000
2011.05	80.0419	78.6850	81.3988	37.3000	41.5000
2011.06	65.5596	64.4088	66.7104	35.2000	37.0000
2011.07	67.7565	66.5953	68.9176	41.5000	43.8000
2011.08	73.3573	72.1747	74.5399	42.4000	50.5000
2011.09	80.0938	78.7062	81.4814	73.8000	78.0000
2011.10	75.7090	74.4324	76.9855	78.9000	88.0000
2011.11	76.8947	75.2866	78.5028	84.6000	96.7000
2011.12	67.5586	66.1647	68.9525	65.8000	73.0000
2012.01	83.2910	81.6493	84.9327	55.8000	58.2000
2012.02	69.2902	67.8785	70.7018	29.2000	33.1000
2012.03	74.6540	73.3294	75.9786	53.1000	64.1000
2012.04	82.5329	81.0880	83.9777	51.4000	55.2000
2012.05	85.5767	84.1640	86.9894	61.8000	69.0000
2012.06	69.3829	68.2024	70.5634	59.7000	64.5000
2012.07	72.0927	70.9088	73.2766	64.2000	51.3000
2012.08	75.2850	74.0755	76.4945	57.7000	63.1000
2012.09	82.7114	81.2753	84.1475	57.7000	61.5000
2012.10	79.0431	77.5958	80.4905	48.3000	53.3000
2012.11	80.2556	78.6428	81.8684	56.7000	61.4000
2012.12	70.6940	69.1580	72.2299	37.4000	40.8000
2013.01	92.6247	90.8520	94.3975	63.8000	62.9000
2013.02	77.1989	75.6435	78.7544	37.8000	38.0000
2013.03	80.5535	78.9145	82.1926	50.6000	57.9000
2013.04	90.0021	88.4182	91.5860	70.6000	72.4000
2013.05	91.2040	89.5802	92.8278	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	75.4669	74.1318	76.8019	51.0000	52.5000
2013.07	77.4394	76.1955	78.6834	57.0000	57.0000
2013.08	82.3947	81.0689	83.7204	60.0000	66.0000
2013.09	89.2469	87.6536	90.8401	34.6000	36.9000
2013.10	84.2389	82.6754	85.8025	74.5000	85.6000
2013.11	83.9951	82.1089	85.8814	73.9000	77.6000
2013.12	76.0874	74.4605	77.7144	77.8000	90.3000
2014.01	107.8989	105.6258	110.1719	77.4000	82.0000
2014.02	91.7252	89.9157	93.5347	93.9000	102.8000
2014.03	97.9461	96.1600	99.7321	80.9000	92.2000
2014.04	109.6016	107.6854	111.5177	76.9000	84.7000
2014.05	111.7566	109.8473	113.6659	72.3000	75.2000
2014.06	92.2783	90.7171	93.8395	67.2000	71.0000
2014.07	94.3857	92.8133	95.9580	72.5000	72.5000
2014.08	100.5995	99.0261	102.1728	71.2000	74.7000
2014.09	110.1029	108.1598	112.0459	83.2000	87.6000
2014.10	103.5899	101.6801	105.4998	59.5000	60.6000
2014.11	104.3473	102.1717	106.5230	65.8000	71.1000
2014.12	92.5644	90.4148	94.7140	75.8000	78.0000
2015.01	66.7069	65.3696	68.0442	65.9000	67.0000
2015.02	55.3292	54.1094	56.5491	42.4000	44.8000
2015.03	59.8630	58.7659	60.9601	38.0000	38.4000
2015.04	66.5433	65.3488	67.7379	49.0000	54.4000
2015.05	68.1804	67.0516	69.3093	56.3000	58.8000
2015.06	56.1650	55.1499	57.1800	50.2000	68.3000
2015.07	56.9677	55.9934	57.9419	47.9000	65.8000
2015.08	61.9382	60.8954	62.9810	39.5000	57.2000
2015.09	66.9101	65.6912	68.1290	49.2000	72.1000
2015.10	63.4565	62.2285	64.6844	39.3000	48.3000
2015.11	64.6256	63.2200	66.0313	39.6000	55.9000
2015.12	57.4031	56.1398	58.6664	36.4000	44.8000
2016.01	36.5342	35.7708	37.2976	33.7000	43.3000
2016.02	30.4351	29.7996	31.0706	38.3000	46.8000
2016.03	32.3979	31.7505	33.0454	30.5000	38.9000
2016.04	35.9231	35.2374	36.6087	26.6000	30.9000
2016.05	36.8855	36.2106	37.5603	33.7000	48.4000
2016.06	30.0607	29.5471	30.5742	13.1000	19.5000
2016.07	31.0355	30.5359	31.5351	21.2000	27.5000
2016.08	33.3894	32.8013	33.9775	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	36.9287	36.2537	37.6038	27.7000	37.1000
2016.10	34.6216	33.9530	35.2902	22.7000	31.7000
2016.11	34.8643	34.1344	35.5941	14.0000	22.2000
2016.12	31.3562	30.6849	32.0274	11.1000	20.0000
2017.01	19.8728	19.4541	20.2914	18.4000	26.2000
2017.02	16.6225	16.2569	16.9880	14.4000	20.6000
2017.03	17.8487	17.5082	18.1892	11.3000	15.5000
2017.04	20.0015	19.6481	20.3549	21.6000	33.2000
2017.05	20.2076	19.8583	20.5568	12.5000	18.1000
2017.06	16.4798	16.2045	16.7550	15.5000	19.3000
2017.07	17.0988	16.8266	17.3710	11.5000	16.3000
2017.08	18.3383	18.0194	18.6572	22.8000	35.7000
2017.09	20.6057	20.1772	21.0341	34.6000	42.9000
2017.10	18.8488	18.4667	19.2310	10.5000	11.0000
2017.11	18.8242	18.4299	19.2186	4.2000	5.6000
2017.12	16.8521	16.5965	17.1076	4.0000	4.6000
2018.01	5.5111	5.3931	5.6291	3.1000	6.3000
2018.02	4.5765	4.4650	4.6880	6.8000	11.8000
2018.03	4.8258	4.7302	4.9213	1.1000	1.2000
2018.04	5.3628	5.2559	5.4697	4.7000	7.5000
2018.05	5.5079	5.4038	5.6119	8.4000	14.0000
2018.06	4.4954	4.4161	4.5748	10.2000	13.6000
2018.07	4.6602	4.6080	4.7124	0.5000	1.7000
2018.08	4.9416	4.8561	5.0271	5.9000	9.5000
2018.09	5.3474	5.2477	5.4472	1.6000	2.9000
2018.10	5.1578	5.0580	5.2575	2.5000	5.6000
2018.11	5.1872	5.0813	5.2932	3.1000	4.2000
2018.12	4.7399	4.6482	4.8317	1.6000	2.3000
2019.01	3.6571	3.5888	3.7255	5.4000	2.3000
2019.02	3.1023	3.0420	3.1627	0.1000	1.2000
2019.03	3.2290	3.1739	3.2841	6.1000	12.1000
2019.04	3.6059	3.5379	3.6739	6.2000	9.3000
2019.05	3.5743	3.5107	3.6379	7.0000	11.9000
2019.06	2.9139	2.8627	2.9650	0.7000	1.5000
2019.07	3.0339	2.9868	3.0811	0.4000	2.2000
2019.08	3.2761	3.2256	3.3266	0.3000	0.8000
2019.09	3.6208	3.5618	3.6798	0.5000	1.0000
2019.10	3.3887	3.3290	3.4484	0.2000	0.5000
2019.11	3.4700	3.4024	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	3.0706	3.0086	3.1326	0.8000	1.0000
2020.01	2.5447	2.4941	2.5954	4.0000	5.3000
2020.02	2.1325	2.0892	2.1759	0.1000	0.0000
2020.03	2.2479	2.2054	2.2903	1.2000	1.5000

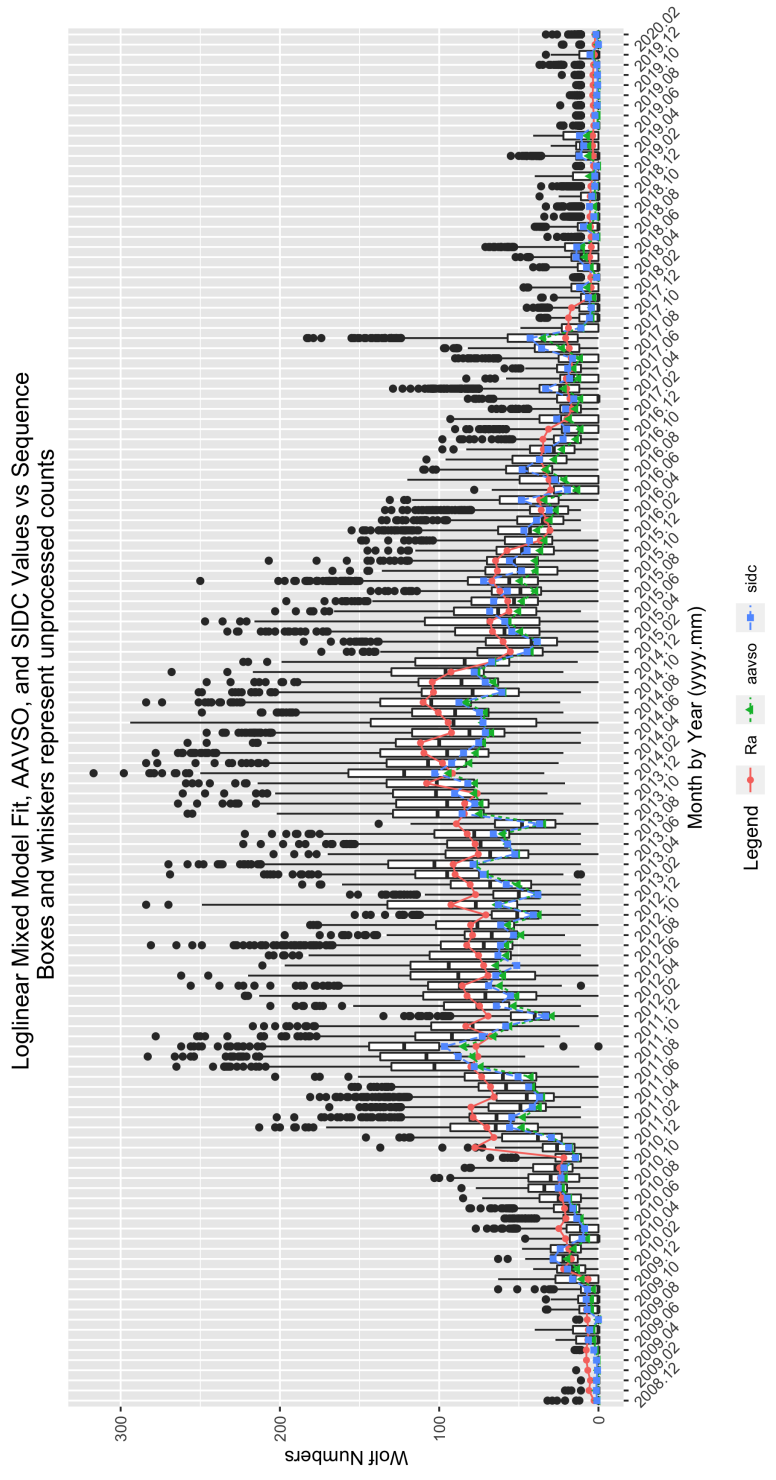


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202003 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4628	0.3079	4.7514	0.0000
seeF	-0.2187	0.0058	-37.6963	0.0000
seeG	-0.1170	0.0051	-23.1488	0.0000
seeM	-0.2025	0.0239	-8.4755	0.0000
seeP	-0.3241	0.0083	-39.0254	0.0000
sidc1	0.1307	0.0688	1.9009	0.0573
year2009	0.6373	0.3088	2.0642	0.0390
year2010	1.8476	0.3066	6.0255	0.0000
year2011	2.9650	0.3065	9.6728	0.0000
year2012	3.0016	0.3065	9.7924	0.0000
year2013	3.0976	0.3065	10.1056	0.0000
year2014	3.2944	0.3065	10.7480	0.0000
year2015	2.8096	0.3065	9.1658	0.0000
year2016	2.1929	0.3066	7.1532	0.0000
year2017	1.5876	0.3066	5.1783	0.0000
year2018	0.2908	0.3069	0.9476	0.3433
year2019	-0.1327	0.3071	-0.4321	0.6657
year2020	-0.4784	0.3102	-1.5419	0.1231
mon2	-0.1733	0.0091	-18.9814	0.0000
mon3	-0.1152	0.0085	-13.5155	0.0000
mon4	-0.0134	0.0082	-1.6254	0.1041
mon5	0.0002	0.0081	0.0239	0.9809
mon6	-0.2018	0.0085	-23.7558	0.0000
mon7	-0.1776	0.0083	-21.5075	0.0000
mon8	-0.1056	0.0081	-13.0686	0.0000
mon9	-0.0074	0.0081	-0.9063	0.3648
mon10	-0.0620	0.0083	-7.4315	0.0000
mon11	-0.0402	0.0087	-4.6082	0.0000
mon12	-0.1499	0.0089	-16.8795	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: 202003 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:124136	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 : 6.586	Mean :15.73		Mean :0.2589
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: 202003 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.0	Length:124136	Length:124136
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.0	Class :character	Class :character
Median : 2.000	Median : 9.00	Median : 35.0	Mode :character	Mode :character
Mean : 2.914	Mean : 17.35	Mean : 46.5		
3rd Qu.: 5.000	3rd Qu.: 26.00	3rd Qu.: 75.0		
Max. :19.000	Max. :204.00	Max. :317.0		

Table 6: 202003 Summary of Sunspot Numbers

inst	filter	unit
Length:124136	Length:124136	Length:124136
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202003 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.0	Min. : 0	Min. : 0.0
1st Qu.: 60.00	1st Qu.: 3.0	1st Qu.: 150	1st Qu.: 40.0
Median : 80.00	Median : 13.0	Median : 910	Median : 57.5
Mean : 93.46	Mean : 28.5	Mean : 919	Mean : 185.5
3rd Qu.: 114.00	3rd Qu.: 23.0	3rd Qu.:1200	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.0	Max. :4300	Max. :4591.0

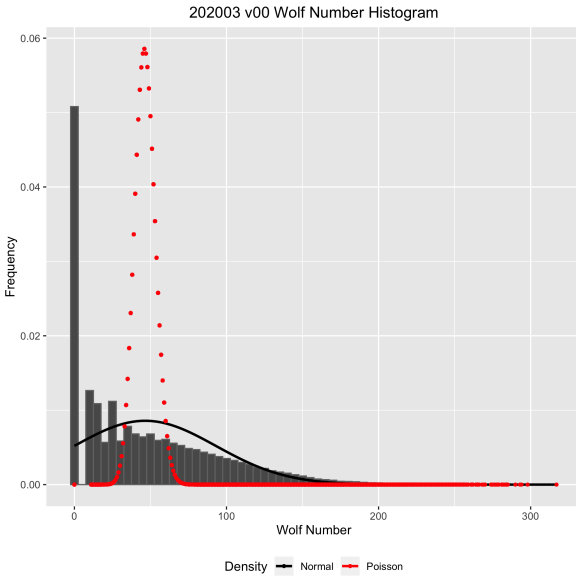


Figure 3: Box plots of raw Wolf number ( $w$ ) by observer rank.

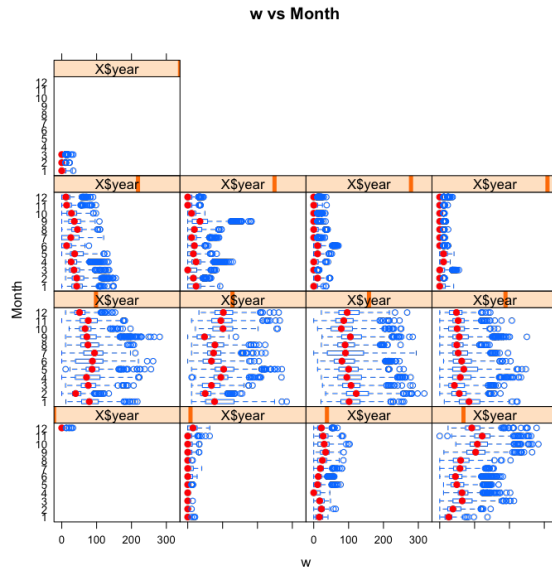


Figure 4: Box plots of raw Wolf number ( $w$ ) by month and year.

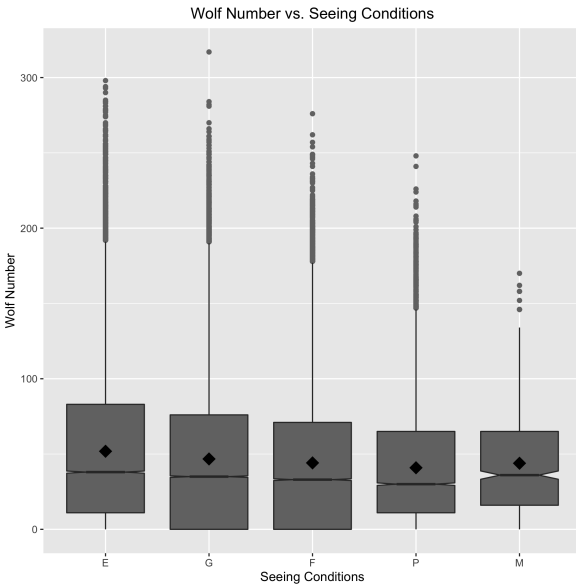


Figure 5: Box plots of raw Wolf number ( $w$ ) by seeing condition.

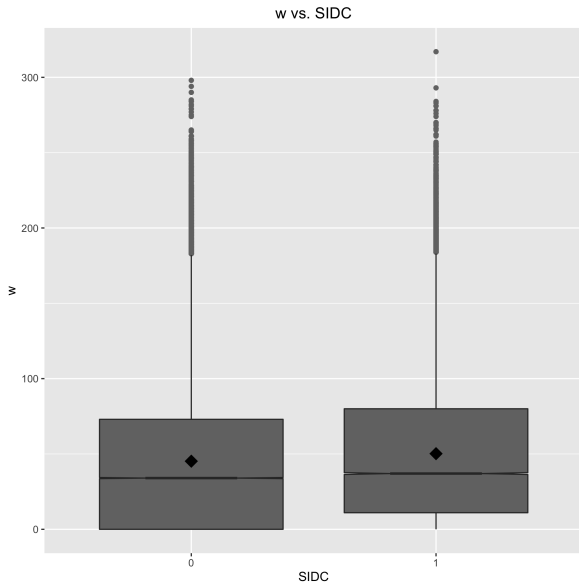


Figure 6: Box plots of raw Wolf number ( $w$ ) by organization.

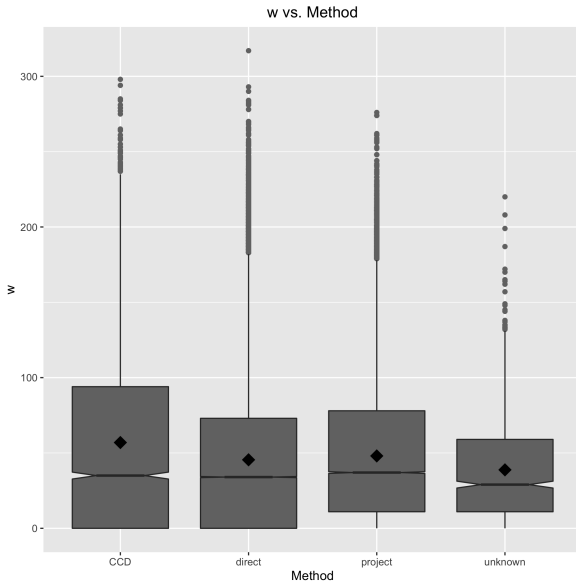


Figure 7: Box plots of raw Wolf number (w) by observer rank.

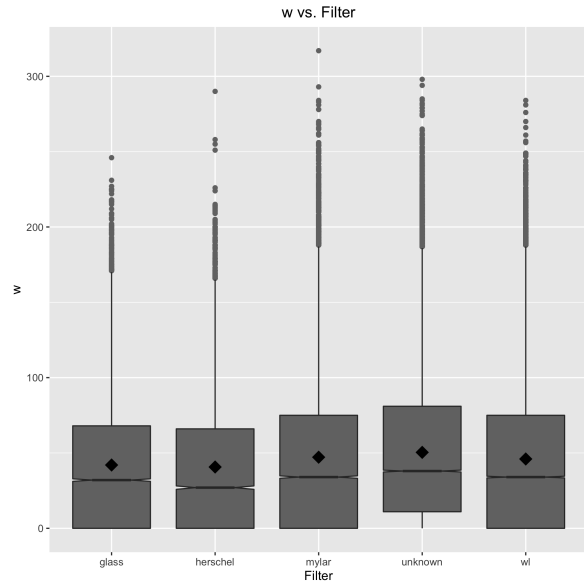


Figure 8: Box plots of raw Wolf number (w) by month and year.

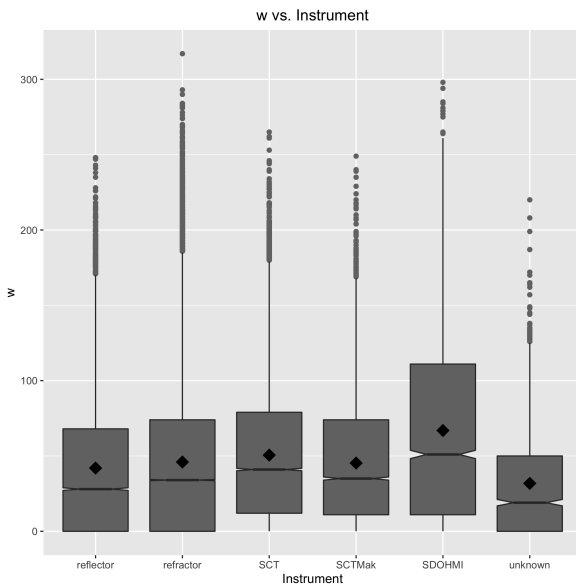


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

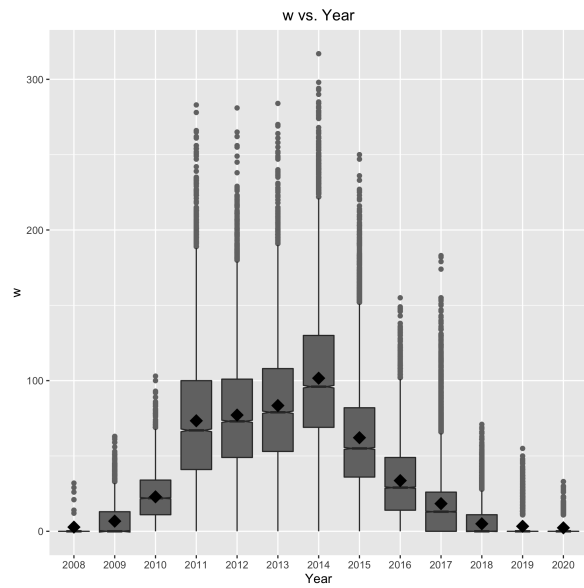


Figure 10: Box plots of raw Wolf number (w) by organization.



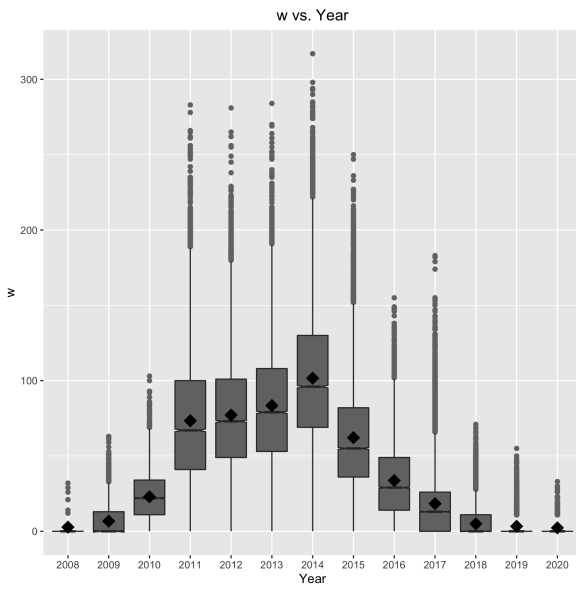


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

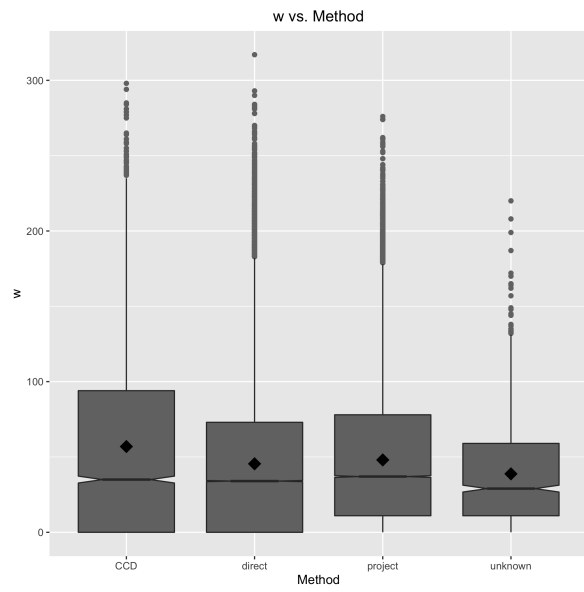


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.