

# Monthly Report (00)

## 2020.05 Data Set

Sunday 14<sup>th</sup> June, 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.

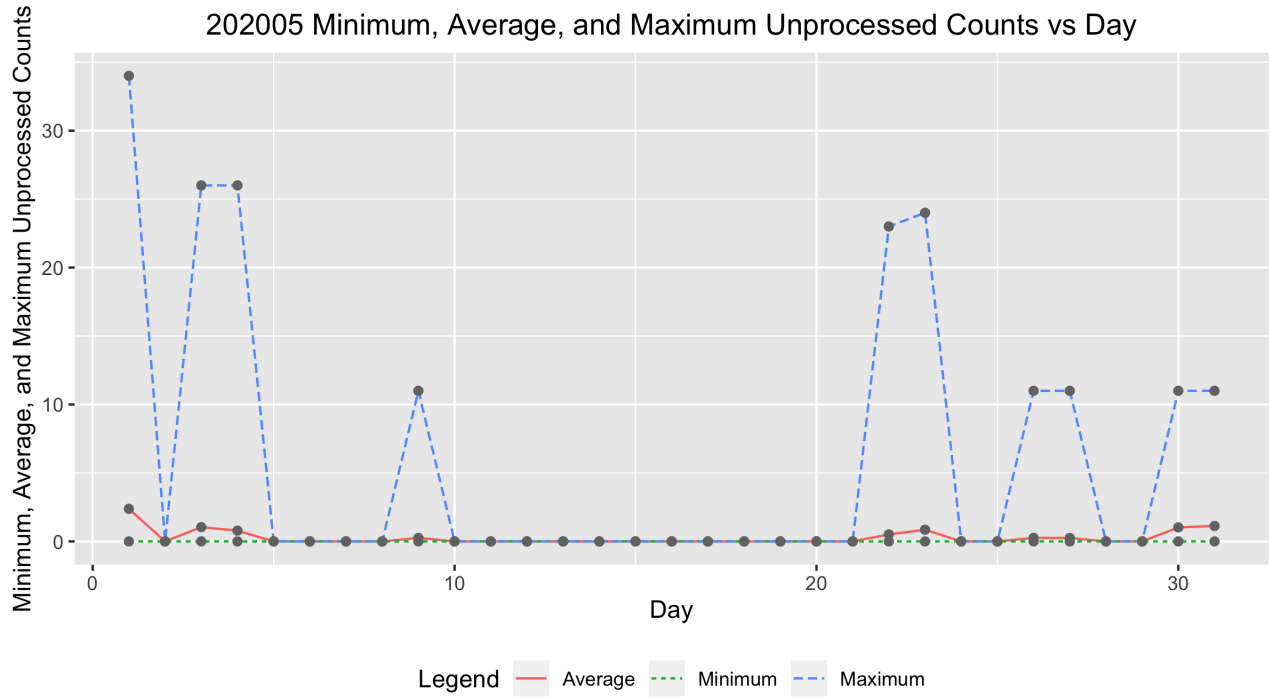


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202005 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	50.0000	0.0000	2.3800	34.0000
2.0000	48.0000	0.0000	0.0000	0.0000
3.0000	46.0000	0.0000	1.0435	26.0000
4.0000	47.0000	0.0000	0.7872	26.0000
5.0000	46.0000	0.0000	0.0000	0.0000
6.0000	47.0000	0.0000	0.0000	0.0000
7.0000	51.0000	0.0000	0.0000	0.0000
8.0000	48.0000	0.0000	0.0000	0.0000
9.0000	43.0000	0.0000	0.2558	11.0000
10.0000	32.0000	0.0000	0.0000	0.0000
11.0000	39.0000	0.0000	0.0000	0.0000
12.0000	42.0000	0.0000	0.0000	0.0000
13.0000	43.0000	0.0000	0.0000	0.0000
14.0000	41.0000	0.0000	0.0000	0.0000
15.0000	39.0000	0.0000	0.0000	0.0000
16.0000	38.0000	0.0000	0.0000	0.0000
17.0000	43.0000	0.0000	0.0000	0.0000
18.0000	42.0000	0.0000	0.0000	0.0000
19.0000	45.0000	0.0000	0.0000	0.0000
20.0000	46.0000	0.0000	0.0000	0.0000
21.0000	45.0000	0.0000	0.0000	0.0000
22.0000	45.0000	0.0000	0.5111	23.0000
23.0000	41.0000	0.0000	0.8537	24.0000
24.0000	46.0000	0.0000	0.0000	0.0000
25.0000	39.0000	0.0000	0.0000	0.0000
26.0000	43.0000	0.0000	0.2558	11.0000
27.0000	44.0000	0.0000	0.2500	11.0000
28.0000	41.0000	0.0000	0.0000	0.0000
29.0000	45.0000	0.0000	0.0000	0.0000
30.0000	43.0000	0.0000	1.0233	11.0000
31.0000	39.0000	0.0000	1.1282	11.0000

### 3 Error Tables

Data are for the month of May 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	2.4031	3.1379	0.5000	1.0000
2009.01	5.9175	5.2680	6.5670	1.3000	1.3000
2009.02	5.0723	4.5003	5.6442	0.7000	1.2000
2009.03	6.7003	6.4341	6.9664	0.3000	0.6000
2009.04	7.5575	7.2802	7.8348	0.4000	1.2000
2009.05	7.6062	7.2978	7.9146	1.6000	2.9000
2009.06	6.6748	6.3310	7.0187	3.2000	6.3000
2009.07	6.3575	6.0972	6.6178	3.6000	5.5000
2009.08	7.0356	6.7506	7.3206	0.0000	0.0000
2009.09	7.5257	7.2524	7.7990	4.5000	7.1000
2009.10	7.0295	6.6532	7.4057	4.5000	7.7000
2009.11	6.9892	6.7954	7.1830	3.3000	6.9000
2009.12	6.5060	6.3193	6.6926	10.4000	16.3000
2010.01	21.8833	19.3592	24.4074	13.3000	19.5000
2010.02	17.0199	14.6723	19.3675	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	18.6715	16.3234	21.0196	15.4000	24.0000
2010.04	20.8025	18.3168	23.2882	7.0000	10.4000
2010.05	24.7827	24.3408	25.2246	8.4000	8.7000
2010.06	20.4066	20.0667	20.7464	11.0000	13.6000
2010.07	21.3030	20.9931	21.6129	15.2000	16.1000
2010.08	22.7954	22.4207	23.1701	18.3000	19.6000
2010.09	25.3123	24.8942	25.7304	22.8000	25.2000
2010.10	23.9232	23.5092	24.3372	21.0000	23.5000
2010.11	24.3674	23.9239	24.8109	20.9000	21.6000
2010.12	21.7510	21.3108	22.1911	13.9000	14.5000
2011.01	77.6534	76.0389	79.2679	17.7000	18.7000
2011.02	65.6975	64.2886	67.1064	29.1000	29.6000
2011.03	70.1523	68.8084	71.4962	48.0000	55.8000
2011.04	79.0044	77.5830	80.4258	47.3000	54.4000
2011.05	79.6686	78.3185	81.0187	37.3000	41.5000
2011.06	65.5609	64.4103	66.7115	35.2000	37.0000
2011.07	67.7559	66.5949	68.9169	41.5000	43.8000
2011.08	73.3585	72.1761	74.5409	42.4000	50.5000
2011.09	80.0953	78.7072	81.4833	73.8000	78.0000
2011.10	75.7100	74.4333	76.9866	78.9000	88.0000
2011.11	76.8938	75.2859	78.5017	84.6000	96.7000
2011.12	67.5560	66.1621	68.9498	65.8000	73.0000
2012.01	83.3337	81.6906	84.9768	55.8000	58.2000
2012.02	69.3283	67.9152	70.7414	29.2000	33.1000
2012.03	74.6893	73.3637	76.0150	53.1000	64.1000
2012.04	82.8776	81.4262	84.3289	51.4000	55.2000
2012.05	85.1723	83.7660	86.5786	61.8000	69.0000
2012.06	69.3828	68.2020	70.5636	59.7000	64.5000
2012.07	72.0935	70.9092	73.2777	64.2000	51.3000
2012.08	75.2840	74.0740	76.4939	57.7000	63.1000
2012.09	82.7097	81.2732	84.1463	57.7000	61.5000
2012.10	79.0436	77.5958	80.4915	48.3000	53.3000
2012.11	80.2548	78.6415	81.8681	56.7000	61.4000
2012.12	70.6924	69.1560	72.2289	37.4000	40.8000
2013.01	92.6679	90.8937	94.4421	63.8000	62.9000
2013.02	77.2377	75.6808	78.7946	37.8000	38.0000
2013.03	80.5872	78.9466	82.2277	50.6000	57.9000
2013.04	90.3714	88.7803	91.9626	70.6000	72.4000
2013.05	90.7713	89.1540	92.3886	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	75.4626	74.1271	76.7980	51.0000	52.5000
2013.07	77.4351	76.1907	78.6796	57.0000	57.0000
2013.08	82.3915	81.0652	83.7178	60.0000	66.0000
2013.09	89.2414	87.6475	90.8352	34.6000	36.9000
2013.10	84.2343	82.6701	85.7984	74.5000	85.6000
2013.11	83.9904	82.1032	85.8777	73.9000	77.6000
2013.12	76.0816	74.4539	77.7094	77.8000	90.3000
2014.01	107.9472	105.6719	110.2226	77.4000	82.0000
2014.02	91.7699	89.9585	93.5812	93.9000	102.8000
2014.03	97.9896	96.2018	99.7774	80.9000	92.2000
2014.04	110.0540	108.1291	111.9790	76.9000	84.7000
2014.05	111.2237	109.3229	113.1246	72.3000	75.2000
2014.06	92.2768	90.7150	93.8385	67.2000	71.0000
2014.07	94.3826	92.8097	95.9555	72.5000	72.5000
2014.08	100.5968	99.0229	102.1708	71.2000	74.7000
2014.09	110.0990	108.1553	112.0428	83.2000	87.6000
2014.10	103.5872	101.6768	105.4976	59.5000	60.6000
2014.11	104.3471	102.1707	106.5235	65.8000	71.1000
2014.12	92.5597	90.4092	94.7103	75.8000	78.0000
2015.01	66.7392	65.4007	68.0778	65.9000	67.0000
2015.02	55.3584	54.1374	56.5795	42.4000	44.8000
2015.03	59.8909	58.7927	60.9891	38.0000	38.4000
2015.04	66.8191	65.6193	68.0190	49.0000	54.4000
2015.05	67.8565	66.7326	68.9803	56.3000	58.8000
2015.06	56.1612	55.1458	57.1767	50.2000	68.3000
2015.07	56.9659	55.9913	57.9405	47.9000	65.8000
2015.08	61.9342	60.8911	62.9773	39.5000	57.2000
2015.09	66.9086	65.6894	68.1278	49.2000	72.1000
2015.10	63.4546	62.2262	64.6831	39.3000	48.3000
2015.11	64.6229	63.2165	66.0293	39.6000	55.9000
2015.12	57.3991	56.1351	58.6630	36.4000	44.8000
2016.01	36.5549	35.7908	37.3190	33.7000	43.3000
2016.02	30.4533	29.8172	31.0895	38.3000	46.8000
2016.03	32.4150	31.7669	33.0630	30.5000	38.9000
2016.04	36.0751	35.3862	36.7640	26.6000	30.9000
2016.05	36.7080	36.0361	37.3800	33.7000	48.4000
2016.06	30.0611	29.5473	30.5749	13.1000	19.5000
2016.07	31.0286	30.5286	31.5286	21.2000	27.5000
2016.08	33.3868	32.7983	33.9754	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	36.9278	36.2523	37.6033	27.7000	37.1000
2016.10	34.6193	33.9503	35.2883	22.7000	31.7000
2016.11	34.8618	34.1315	35.5921	14.0000	22.2000
2016.12	31.3541	30.6824	32.0258	11.1000	20.0000
2017.01	19.8830	19.4638	20.3022	18.4000	26.2000
2017.02	16.6309	16.2649	16.9969	14.4000	20.6000
2017.03	17.8561	17.5151	18.1970	11.3000	15.5000
2017.04	20.0822	19.7270	20.4374	21.6000	33.2000
2017.05	20.1098	19.7618	20.4578	12.5000	18.1000
2017.06	16.4770	16.2013	16.7526	15.5000	19.3000
2017.07	17.0975	16.8250	17.3701	11.5000	16.3000
2017.08	18.3381	18.0187	18.6575	22.8000	35.7000
2017.09	20.6058	20.1760	21.0357	34.6000	42.9000
2017.10	18.8470	18.4639	19.2301	10.5000	11.0000
2017.11	18.8229	18.4278	19.2179	4.2000	5.6000
2017.12	16.8557	16.5998	17.1116	4.0000	4.6000
2018.01	5.5118	5.3933	5.6303	3.1000	6.3000
2018.02	4.5783	4.4661	4.6904	6.8000	11.8000
2018.03	4.8275	4.7315	4.9234	1.1000	1.2000
2018.04	5.3869	5.2788	5.4949	4.7000	7.5000
2018.05	5.4809	5.3768	5.5850	8.4000	14.0000
2018.06	4.4960	4.4164	4.5756	10.2000	13.6000
2018.07	4.6611	4.6085	4.7137	0.5000	1.7000
2018.08	4.9415	4.8555	5.0274	5.9000	9.5000
2018.09	5.3477	5.2474	5.4480	1.6000	2.9000
2018.10	5.1574	5.0572	5.2577	2.5000	5.6000
2018.11	5.1878	5.0816	5.2940	3.1000	4.2000
2018.12	4.7411	4.6492	4.8329	1.6000	2.3000
2019.01	3.6566	3.5880	3.7252	5.4000	2.3000
2019.02	3.1001	3.0396	3.1606	0.1000	1.2000
2019.03	3.2267	3.1713	3.2820	6.1000	12.1000
2019.04	3.6178	3.5495	3.6861	6.2000	9.3000
2019.05	3.5575	3.4943	3.6207	7.0000	11.9000
2019.06	2.9143	2.8635	2.9651	0.7000	1.5000
2019.07	3.0373	2.9905	3.0842	0.4000	2.2000
2019.08	3.2790	3.2290	3.3289	0.3000	0.8000
2019.09	3.6210	3.5625	3.6796	0.5000	1.0000
2019.10	3.3894	3.3303	3.4484	0.2000	0.5000
2019.11	3.4694	3.4020	3.5367	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	3.0728	3.0116	3.1340	0.8000	1.0000
2020.01	2.3356	2.2895	2.3816	4.0000	5.3000
2020.02	1.9557	1.9162	1.9951	0.1000	0.0000
2020.03	2.0625	2.0240	2.1010	1.2000	1.5000
2020.04	2.3390	2.3006	2.3774	3.0000	5.1000
2020.05	2.3217	2.2852	2.3582	0.1000	0.4000

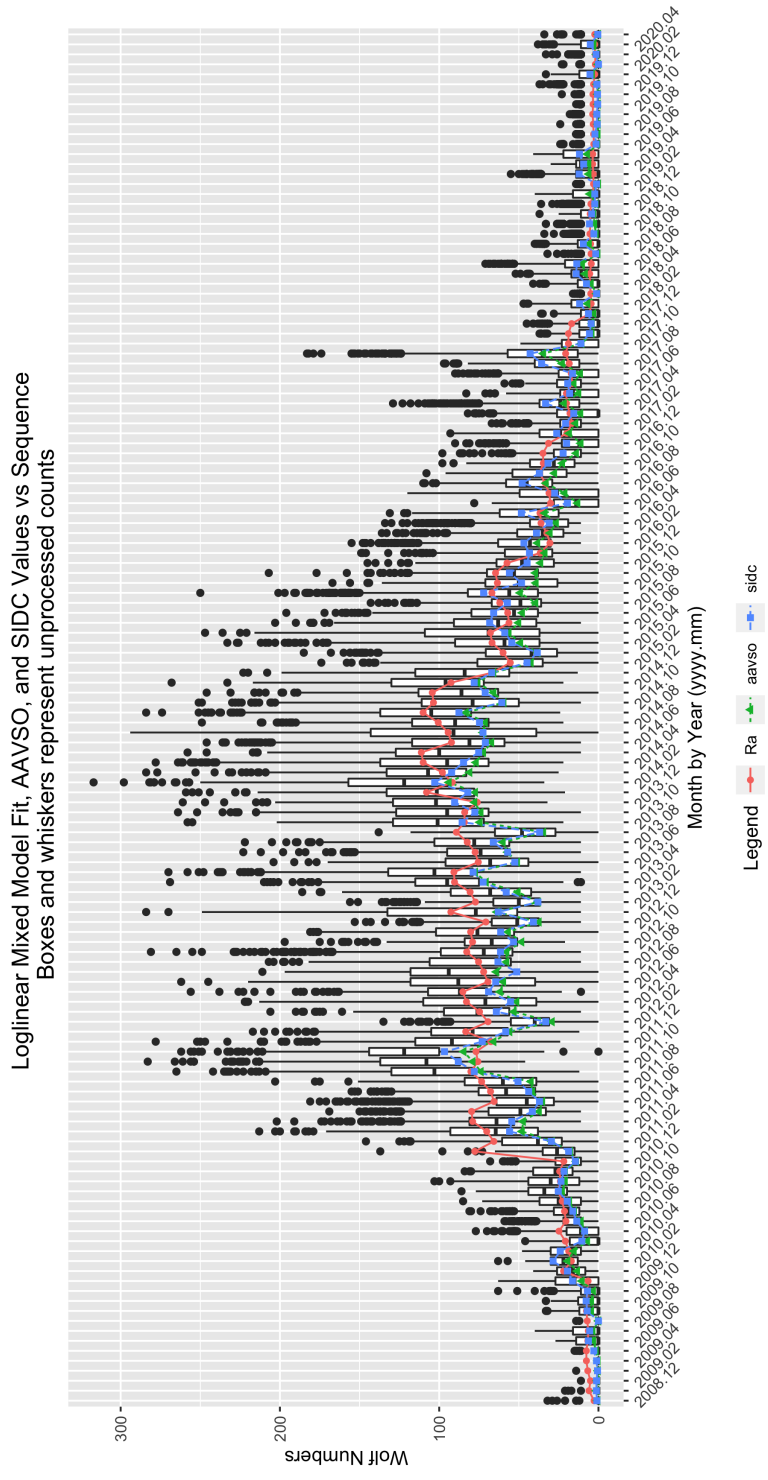


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202005 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4678	0.3065	4.7893	0.0000
seeF	-0.2185	0.0058	-37.8617	0.0000
seeG	-0.1169	0.0050	-23.2537	0.0000
seeM	-0.2021	0.0238	-8.5006	0.0000
seeP	-0.3236	0.0083	-39.1728	0.0000
sidc1	0.1382	0.0687	2.0120	0.0442
year2009	0.6370	0.3073	2.0725	0.0382
year2010	1.8478	0.3052	6.0543	0.0000
year2011	2.9646	0.3051	9.7166	0.0000
year2012	3.0011	0.3051	9.8367	0.0000
year2013	3.0971	0.3051	10.1513	0.0000
year2014	3.2940	0.3051	10.7967	0.0000
year2015	2.8092	0.3051	9.2073	0.0000
year2016	2.1925	0.3051	7.1855	0.0000
year2017	1.5873	0.3052	5.2014	0.0000
year2018	0.2905	0.3055	0.9509	0.3417
year2019	-0.1347	0.3057	-0.4407	0.6595
year2020	-0.5677	0.3072	-1.8481	0.0646
mon2	-0.1732	0.0091	-19.0651	0.0000
mon3	-0.1152	0.0085	-13.5804	0.0000
mon4	-0.0097	0.0082	-1.1889	0.2345
mon5	-0.0051	0.0080	-0.6294	0.5291
mon6	-0.2022	0.0085	-23.9303	0.0000
mon7	-0.1780	0.0082	-21.6731	0.0000
mon8	-0.1061	0.0080	-13.1933	0.0000
mon9	-0.0079	0.0081	-0.9723	0.3309
mon10	-0.0625	0.0083	-7.5270	0.0000
mon11	-0.0406	0.0087	-4.6885	0.0000
mon12	-0.1505	0.0088	-17.0224	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: 202005 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:126717	Min. :0.000
1st Qu.:2013	1st Qu.: 4.000	1st Qu.: 8.00	Class :character	1st Qu.:0.000
Median :2015	Median : 7.000	Median :16.00	Mode :character	Median :0.000
Mean :2015	Mean : 6.544	Mean :15.73		Mean :0.258
3rd Qu.:2018	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.000
Max. :2020	Max. :12.000	Max. :31.00		Max. :1.000

Table 5: 202005 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:126717	Length:126717
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 9.00	Median : 33.00	Mode :character	Mode :character
Mean : 2.858	Mean : 17.01	Mean : 45.59		
3rd Qu.: 5.000	3rd Qu.: 26.00	3rd Qu.: 74.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202005 Summary of Sunspot Numbers

inst	filter	unit
Length:126717	Length:126717	Length:126717
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202005 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.: 4.00	1st Qu.: 35.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 91.86	Mean : 29.17	Mean : 900.6	Mean : 185.1
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

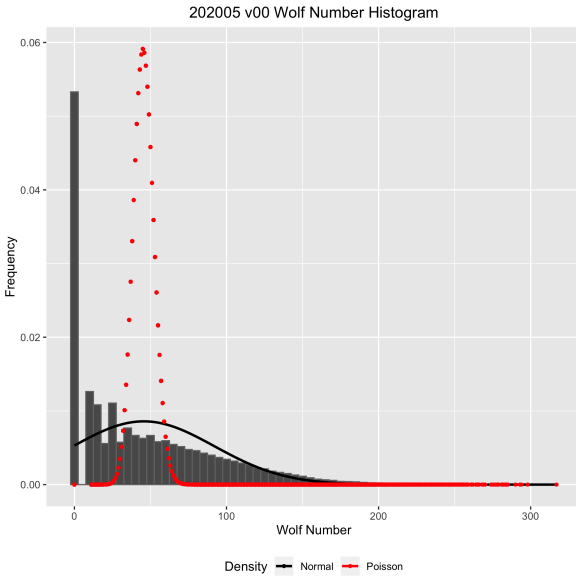


Figure 3: Box plots of raw Wolf number (w) by observer rank.

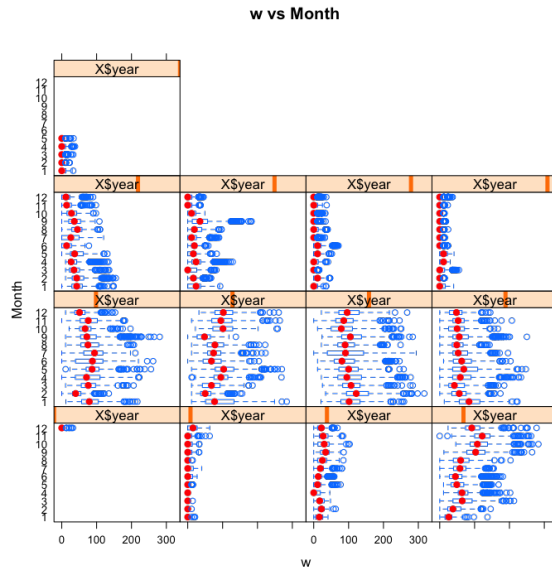


Figure 4: Box plots of raw Wolf number (w) by month and year.

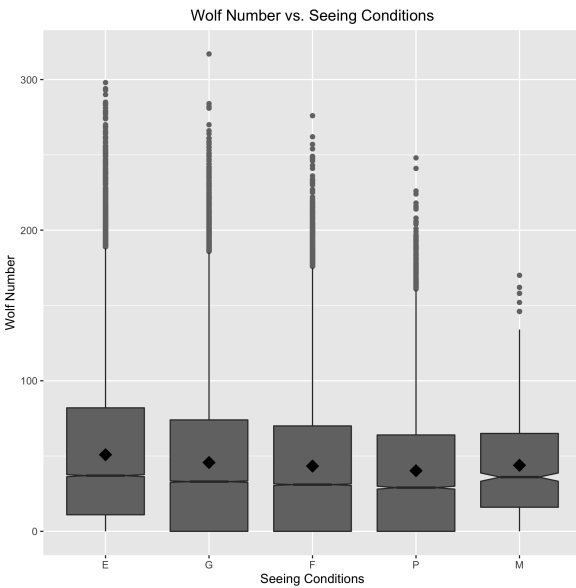


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

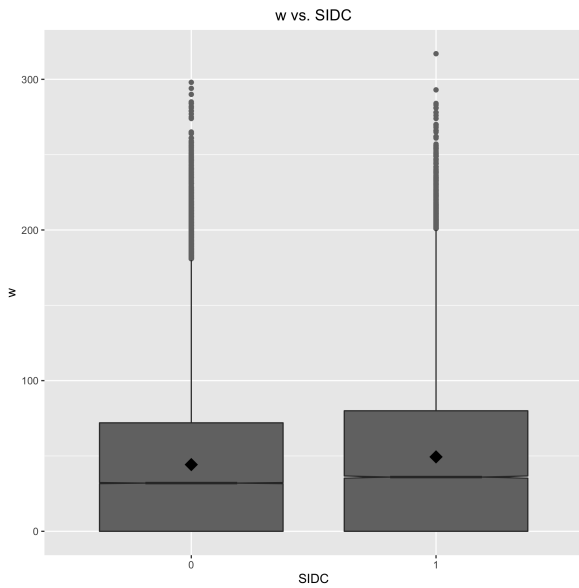


Figure 6: Box plots of raw Wolf number (w) by organization.

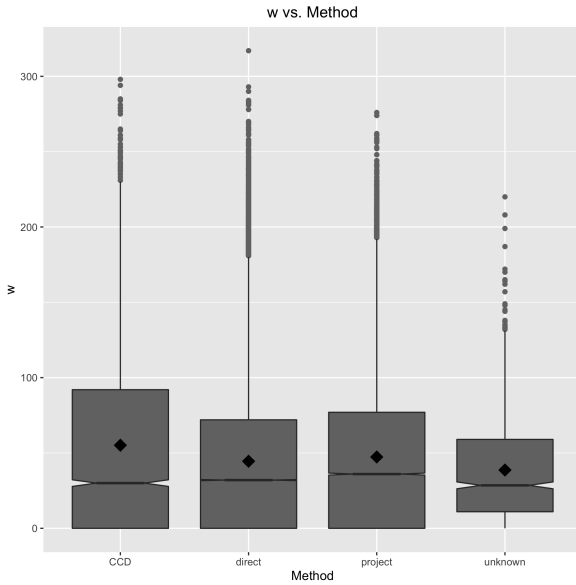


Figure 7: Box plots of raw Wolf number (w) by observer rank.

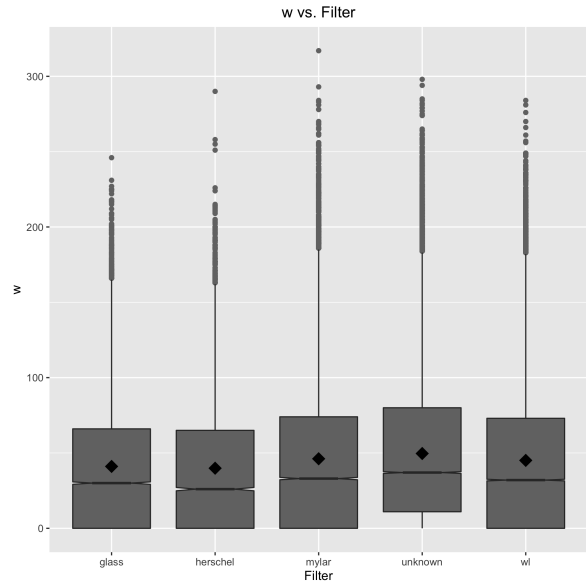


Figure 8: Box plots of raw Wolf number (w) by month and year.

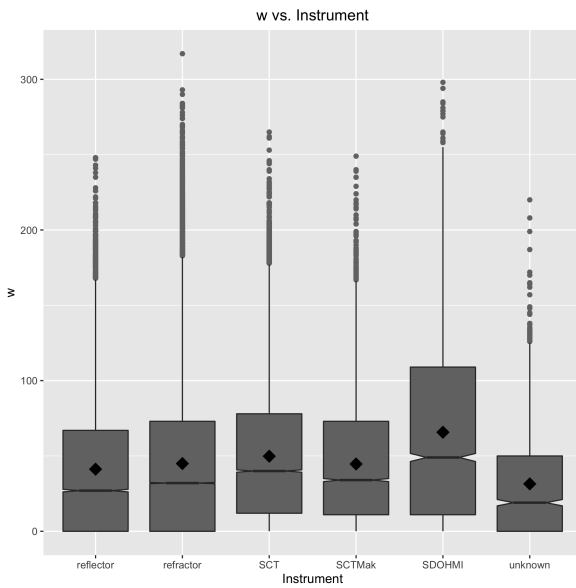


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

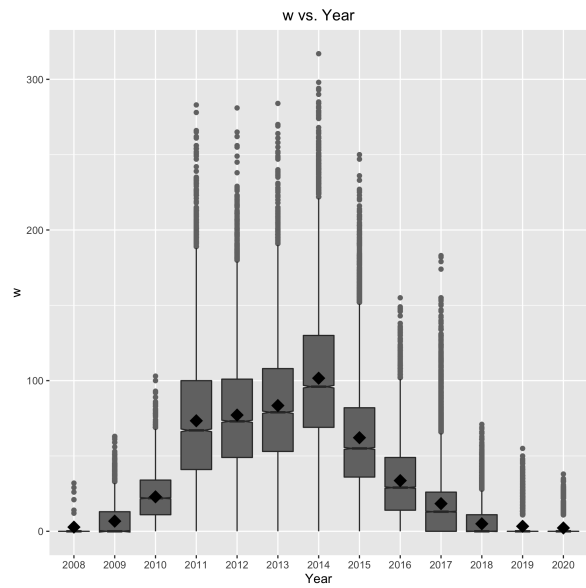


Figure 10: Box plots of raw Wolf number (w) by organization.



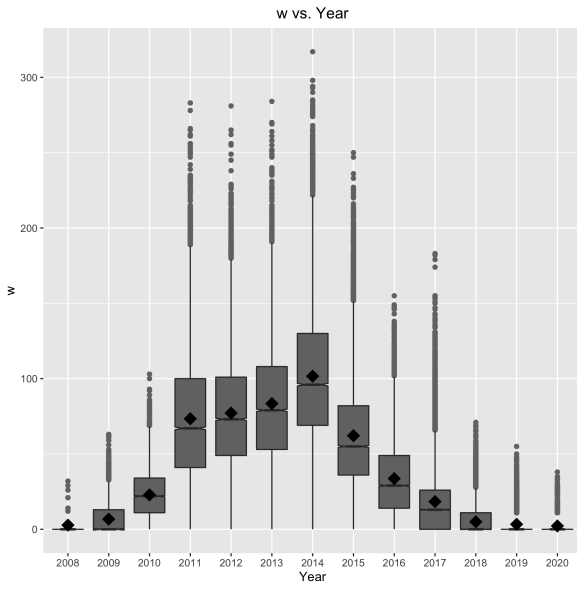


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

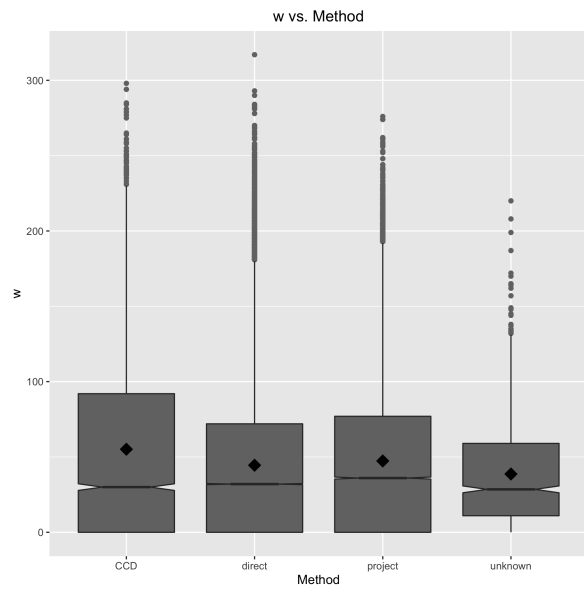


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.