

**Monthly Report (00)**  
**202011 Data Set**

Saturday 12<sup>th</sup> December, 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.

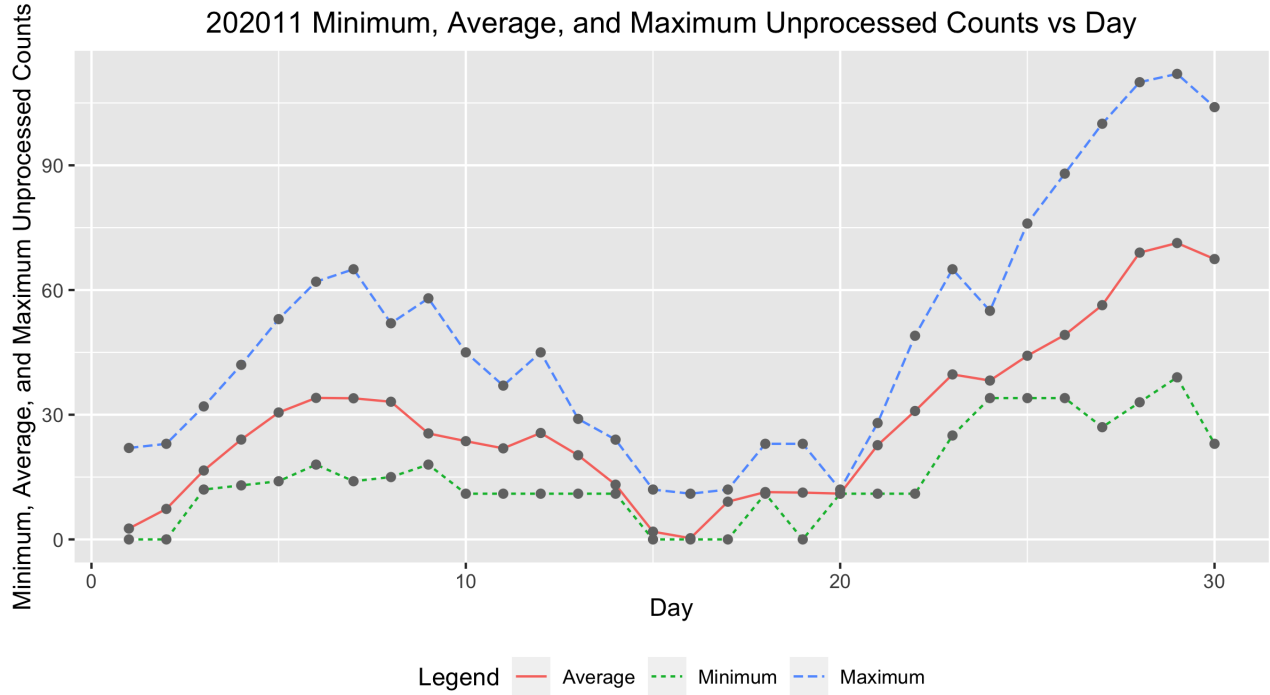


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202011 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	34.0000	0.0000	2.6176	22.0000
2.0000	36.0000	0.0000	7.3333	23.0000
3.0000	38.0000	12.0000	16.5789	32.0000
4.0000	44.0000	13.0000	24.0227	42.0000
5.0000	41.0000	14.0000	30.5366	53.0000
6.0000	44.0000	18.0000	34.0455	62.0000
7.0000	43.0000	14.0000	33.9535	65.0000
8.0000	42.0000	15.0000	33.1190	52.0000
9.0000	34.0000	18.0000	25.5000	58.0000
10.0000	39.0000	11.0000	23.6410	45.0000
11.0000	33.0000	11.0000	21.9091	37.0000
12.0000	33.0000	11.0000	25.6061	45.0000
13.0000	32.0000	11.0000	20.2500	29.0000
14.0000	42.0000	11.0000	13.1667	24.0000
15.0000	30.0000	0.0000	1.8667	12.0000
16.0000	38.0000	0.0000	0.2895	11.0000
17.0000	39.0000	0.0000	9.0769	12.0000
18.0000	41.0000	11.0000	11.3902	23.0000
19.0000	38.0000	0.0000	11.2632	23.0000
20.0000	41.0000	11.0000	11.0244	12.0000
21.0000	42.0000	11.0000	22.6667	28.0000
22.0000	29.0000	11.0000	30.8966	49.0000
23.0000	39.0000	25.0000	39.6923	65.0000
24.0000	41.0000	34.0000	38.2195	55.0000
25.0000	37.0000	34.0000	44.1892	76.0000
26.0000	31.0000	34.0000	49.1935	88.0000
27.0000	31.0000	27.0000	56.3548	100.0000
28.0000	39.0000	33.0000	69.0000	110.0000
29.0000	33.0000	39.0000	71.3030	112.0000
30.0000	29.0000	23.0000	67.4483	104.0000

### 3 Error Tables

Data are for the month of November 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	2.3995	3.1415	0.5000	1.0000
2009.01	5.7598	5.1209	6.3986	1.3000	1.3000
2009.02	4.9355	4.3731	5.4979	0.7000	1.2000
2009.03	6.5382	6.2800	6.7965	0.3000	0.6000
2009.04	7.3683	7.0994	7.6372	0.4000	1.2000
2009.05	7.4178	7.1191	7.7165	1.6000	2.9000
2009.06	6.5702	6.2334	6.9070	3.2000	6.3000
2009.07	6.2714	6.0158	6.5271	3.6000	5.5000
2009.08	6.9437	6.6646	7.2228	0.0000	0.0000
2009.09	7.3092	7.0450	7.5733	4.5000	7.1000
2009.10	7.0319	6.6570	7.4068	4.5000	7.7000
2009.11	7.2619	7.0601	7.4637	3.3000	6.9000
2009.12	6.4056	6.2217	6.5896	10.4000	16.3000
2010.01	21.5693	19.0572	24.0814	13.3000	19.5000
2010.02	16.7472	14.4124	19.0819	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	18.3931	16.0574	20.7287	15.4000	24.0000
2010.04	20.4761	18.0057	22.9465	7.0000	10.4000
2010.05	24.4260	23.9895	24.8625	8.4000	8.7000
2010.06	20.3105	19.9729	20.6481	11.0000	13.6000
2010.07	21.2453	20.9360	21.5546	15.2000	16.1000
2010.08	22.7496	22.3762	23.1231	18.3000	19.6000
2010.09	24.8528	24.4432	25.2624	22.8000	25.2000
2010.10	24.1859	23.7681	24.6037	21.0000	23.5000
2010.11	25.6072	25.1421	26.0722	20.9000	21.6000
2010.12	21.6749	21.2383	22.1115	13.9000	14.5000
2011.01	76.8895	75.3050	78.4741	17.7000	18.7000
2011.02	65.0455	63.6653	66.4257	29.1000	29.6000
2011.03	69.4870	68.1560	70.8179	48.0000	55.8000
2011.04	78.1980	76.7962	79.5998	47.3000	54.4000
2011.05	78.8425	77.5138	80.1712	37.3000	41.5000
2011.06	65.4879	64.3447	66.6312	35.2000	37.0000
2011.07	67.7937	66.6387	68.9488	41.5000	43.8000
2011.08	73.4366	72.2607	74.6125	42.4000	50.5000
2011.09	78.9651	77.5962	80.3341	73.8000	78.0000
2011.10	76.8382	75.5500	78.1265	78.9000	88.0000
2011.11	81.1263	79.4394	82.8132	84.6000	96.7000
2011.12	67.5587	66.1729	68.9445	65.8000	73.0000
2012.01	82.5141	80.8930	84.1352	55.8000	58.2000
2012.02	68.5961	67.2021	69.9900	29.2000	33.1000
2012.03	73.9708	72.6623	75.2793	53.1000	64.1000
2012.04	82.0029	80.5718	83.4339	51.4000	55.2000
2012.05	84.3124	82.9266	85.6983	61.8000	69.0000
2012.06	69.3163	68.1436	70.4890	59.7000	64.5000
2012.07	72.1750	70.9949	73.3550	64.2000	51.3000
2012.08	75.4163	74.2085	76.6242	57.7000	63.1000
2012.09	81.5569	80.1436	82.9701	57.7000	61.5000
2012.10	80.2520	78.7853	81.7186	48.3000	53.3000
2012.11	84.7165	83.0165	86.4166	56.7000	61.4000
2012.12	70.7349	69.2019	72.2679	37.4000	40.8000
2013.01	91.7433	89.9911	93.4956	63.8000	62.9000
2013.02	76.4178	74.8803	77.9553	37.8000	38.0000
2013.03	79.8190	78.1941	81.4438	50.6000	57.9000
2013.04	89.4316	87.8564	91.0067	70.6000	72.4000
2013.05	89.8773	88.2751	91.4796	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	75.4194	74.0873	76.7516	51.0000	52.5000
2013.07	77.5564	76.3116	78.8013	57.0000	57.0000
2013.08	82.5799	81.2508	83.9090	60.0000	66.0000
2013.09	88.0001	86.4288	89.5713	34.6000	36.9000
2013.10	85.5505	83.9625	87.1385	74.5000	85.6000
2013.11	88.6813	86.6890	90.6735	73.9000	77.6000
2013.12	76.1468	74.5178	77.7759	77.8000	90.3000
2014.01	106.8720	104.6206	109.1234	77.4000	82.0000
2014.02	90.8202	89.0276	92.6128	93.9000	102.8000
2014.03	97.0871	95.3151	98.8591	80.9000	92.2000
2014.04	108.9441	107.0377	110.8504	76.9000	84.7000
2014.05	110.1389	108.2577	112.0202	72.3000	75.2000
2014.06	92.2372	90.6764	93.7979	67.2000	71.0000
2014.07	94.5057	92.9305	96.0810	72.5000	72.5000
2014.08	100.7979	99.2210	102.3748	71.2000	74.7000
2014.09	108.5499	106.6335	110.4662	83.2000	87.6000
2014.10	105.1840	103.2458	107.1221	59.5000	60.6000
2014.11	110.1994	107.9029	112.4959	65.8000	71.1000
2014.12	92.6235	90.4752	94.7717	75.8000	78.0000
2015.01	66.0562	64.7321	67.3803	65.9000	67.0000
2015.02	54.7690	53.5615	55.9764	42.4000	44.8000
2015.03	59.3260	58.2402	60.4119	38.0000	38.4000
2015.04	66.1643	64.9802	67.3483	49.0000	54.4000
2015.05	67.1726	66.0618	68.2834	56.3000	58.8000
2015.06	56.1488	55.1375	57.1601	50.2000	68.3000
2015.07	57.0697	56.0973	58.0421	47.9000	65.8000
2015.08	62.0614	61.0193	63.1035	39.5000	57.2000
2015.09	65.9948	64.7955	67.1941	49.2000	72.1000
2015.10	64.4267	63.1824	65.6710	39.3000	48.3000
2015.11	68.2045	66.7210	69.6879	39.6000	55.9000
2015.12	57.3893	56.1237	58.6550	36.4000	44.8000
2016.01	36.1781	35.4241	36.9321	33.7000	43.3000
2016.02	30.1237	29.4958	30.7517	38.3000	46.8000
2016.03	32.0910	31.4504	32.7317	30.5000	38.9000
2016.04	35.6948	35.0147	36.3748	26.6000	30.9000
2016.05	36.3226	35.6591	36.9860	33.7000	48.4000
2016.06	30.0365	29.5238	30.5491	13.1000	19.5000
2016.07	31.0553	30.5554	31.5551	21.2000	27.5000
2016.08	33.4343	32.8461	34.0225	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	36.4033	35.7391	37.0674	27.7000	37.1000
2016.10	35.1502	34.4731	35.8273	22.7000	31.7000
2016.11	36.8127	36.0438	37.5816	14.0000	22.2000
2016.12	31.3655	30.6943	32.0368	11.1000	20.0000
2017.01	19.6788	19.2648	20.0928	18.4000	26.2000
2017.02	16.4530	16.0919	16.8141	14.4000	20.6000
2017.03	17.6805	17.3433	18.0176	11.3000	15.5000
2017.04	19.8694	19.5185	20.2202	21.6000	33.2000
2017.05	19.9074	19.5638	20.2510	12.5000	18.1000
2017.06	16.4489	16.1748	16.7230	15.5000	19.3000
2017.07	17.1049	16.8327	17.3771	11.5000	16.3000
2017.08	18.3578	18.0352	18.6804	22.8000	35.7000
2017.09	20.3783	19.9281	20.8285	34.6000	42.9000
2017.10	19.1338	18.7358	19.5319	10.5000	11.0000
2017.11	19.8576	19.4375	20.2776	4.2000	5.6000
2017.12	16.8242	16.5675	17.0809	4.0000	4.6000
2018.01	5.4584	5.3390	5.5777	3.1000	6.3000
2018.02	4.5331	4.4189	4.6472	6.8000	11.8000
2018.03	4.7839	4.6868	4.8810	1.1000	1.2000
2018.04	5.3323	5.2216	5.4431	4.7000	7.5000
2018.05	5.4290	5.3229	5.5350	8.4000	14.0000
2018.06	4.4901	4.4091	4.5711	10.2000	13.6000
2018.07	4.6636	4.6098	4.7173	0.5000	1.7000
2018.08	4.9478	4.8606	5.0349	5.9000	9.5000
2018.09	5.2769	5.1762	5.3776	1.6000	2.9000
2018.10	5.2314	5.1282	5.3346	2.5000	5.6000
2018.11	5.4668	5.3526	5.5810	3.1000	4.2000
2018.12	4.7343	4.6410	4.8276	1.6000	2.3000
2019.01	3.6068	3.5373	3.6763	5.4000	2.3000
2019.02	3.0576	2.9967	3.1186	0.1000	1.2000
2019.03	3.1853	3.1291	3.2415	6.1000	12.1000
2019.04	3.5733	3.5041	3.6425	6.2000	9.3000
2019.05	3.5204	3.4576	3.5831	7.0000	11.9000
2019.06	2.9247	2.8743	2.9750	0.7000	1.5000
2019.07	3.0494	3.0027	3.0960	0.4000	2.2000
2019.08	3.2878	3.2378	3.3378	0.3000	0.8000
2019.09	3.5806	3.5229	3.6382	0.5000	1.0000
2019.10	3.4419	3.3818	3.5021	0.2000	0.5000
2019.11	3.6577	3.5864	3.7290	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	3.0766	3.0151	3.1381	0.8000	1.0000
2020.01	6.7535	6.6190	6.8880	4.0000	5.3000
2020.02	5.6469	5.5319	5.7619	0.1000	0.0000
2020.03	5.9623	5.8485	6.0761	1.2000	1.5000
2020.04	6.7348	6.6231	6.8465	3.0000	5.1000
2020.05	6.7034	6.5965	6.8103	0.1000	0.4000
2020.06	5.6067	5.5178	5.6957	3.9000	6.4000
2020.07	5.7618	5.6743	5.8493	4.2000	7.7000
2020.08	6.1440	6.0568	6.2311	5.3000	7.8000
2020.09	6.7242	6.6118	6.8366	0.4000	0.9000
2020.10	6.6596	6.5459	6.7732	9.9000	13.6000
2020.11	7.2258	7.0773	7.3742	21.2000	33.1000

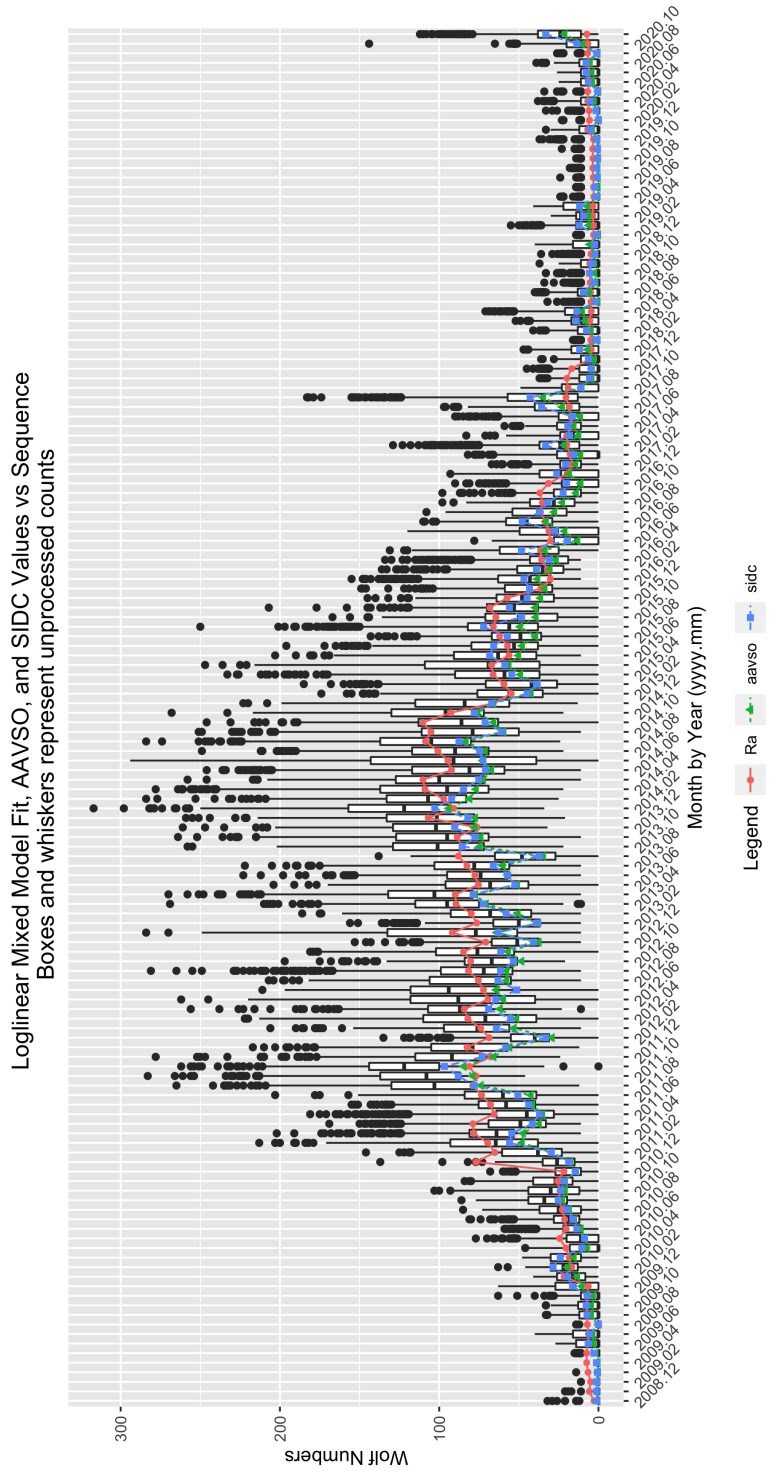


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202011 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4969	0.3096	4.8347	0.0000
seeF	-0.2184	0.0058	-37.7104	0.0000
seeG	-0.1174	0.0050	-23.2695	0.0000
seeM	-0.2009	0.0240	-8.3796	0.0000
seeP	-0.3224	0.0083	-38.9256	0.0000
sidc1	0.0891	0.0731	1.2187	0.2230
year2009	0.6205	0.3101	2.0010	0.0454
year2010	1.8430	0.3080	5.9846	0.0000
year2011	2.9642	0.3079	9.6285	0.0000
year2012	3.0014	0.3079	9.7494	0.0000
year2013	3.0974	0.3079	10.0612	0.0000
year2014	3.2941	0.3078	10.7005	0.0000
year2015	2.8091	0.3079	9.1244	0.0000
year2016	2.1923	0.3079	7.1202	0.0000
year2017	1.5869	0.3079	5.1533	0.0000
year2018	0.2939	0.3082	0.9535	0.3403
year2019	-0.1341	0.3084	-0.4348	0.6637
year2020	0.5047	0.3082	1.6376	0.1015
mon2	-0.1739	0.0092	-18.9643	0.0000
mon3	-0.1149	0.0086	-13.4192	0.0000
mon4	-0.0102	0.0083	-1.2394	0.2152
mon5	-0.0053	0.0081	-0.6566	0.5114
mon6	-0.1929	0.0085	-22.7080	0.0000
mon7	-0.1668	0.0083	-20.2043	0.0000
mon8	-0.0944	0.0081	-11.6765	0.0000
mon9	-0.0122	0.0081	-1.4947	0.1350
mon10	-0.0372	0.0083	-4.4701	0.0000
mon11	0.0237	0.0086	2.7579	0.0058
mon12	-0.1398	0.0089	-15.6810	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: 202011 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:134316	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 : 6.649	Mean :15.72		Mean :0.2569
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: 202011 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:134316	Length:134316
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 : 2.735	Mean : 16.19	Mean : 43.54		
3rd Qu.: 5.000	3rd Qu.: 24.00	3rd Qu.: 71.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202011 Summary of Sunspot Numbers

inst	filter	unit
Length:134316	Length:134316	Length:134316
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202011 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.: 33.0	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 910.0	Median : 57.5
Mean : 89.99	Mean : 31.06	Mean : 876.9	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

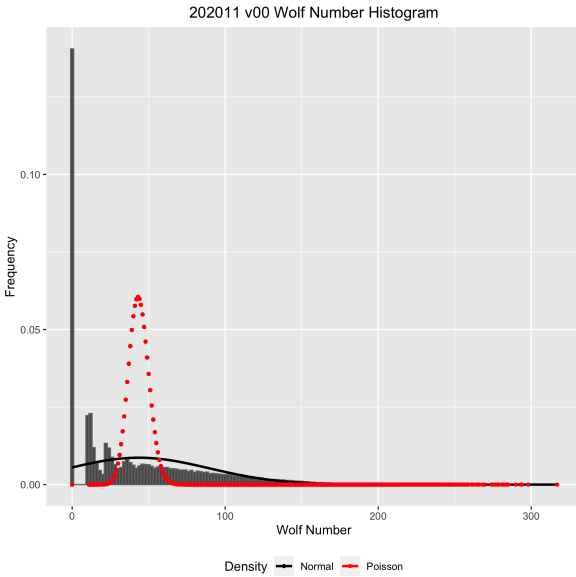


Figure 3: Box plots of raw Wolf number (w) by observer rank.

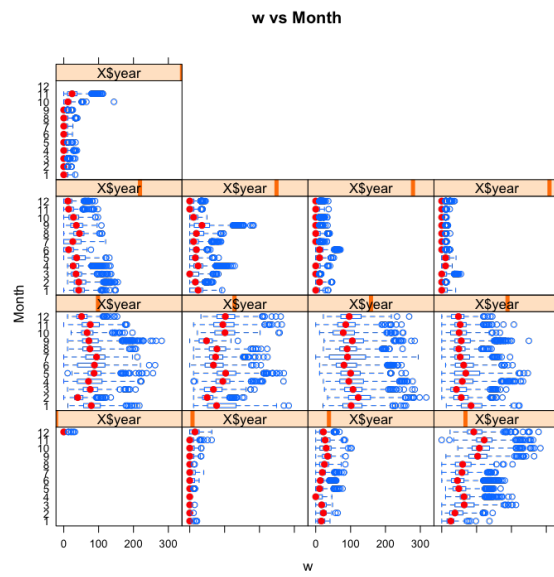


Figure 4: Box plots of raw Wolf number (w) by month and year.

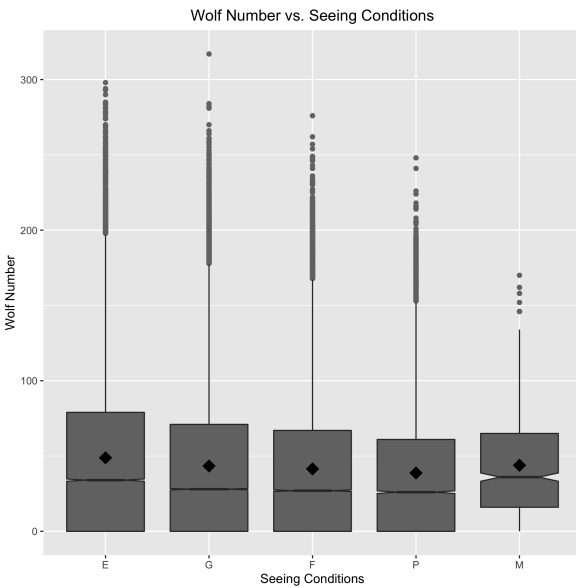


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

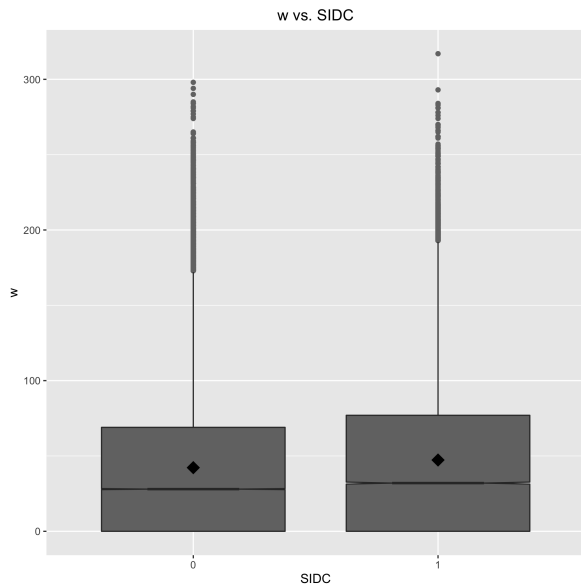


Figure 6: Box plots of raw Wolf number (w) by organization.

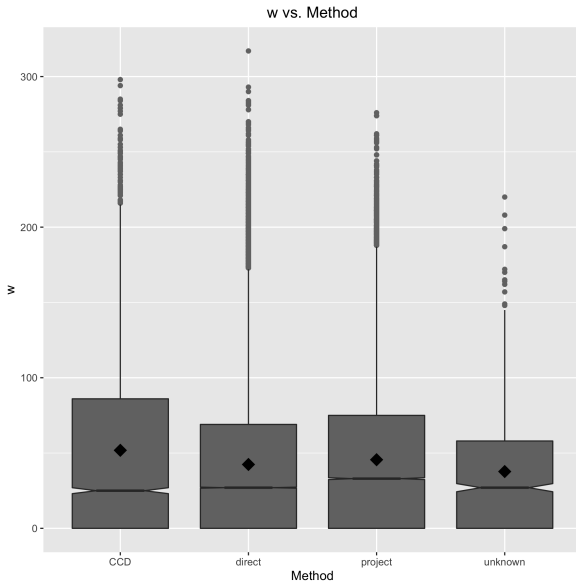


Figure 7: Box plots of raw Wolf number ( $w$ ) by observer rank.

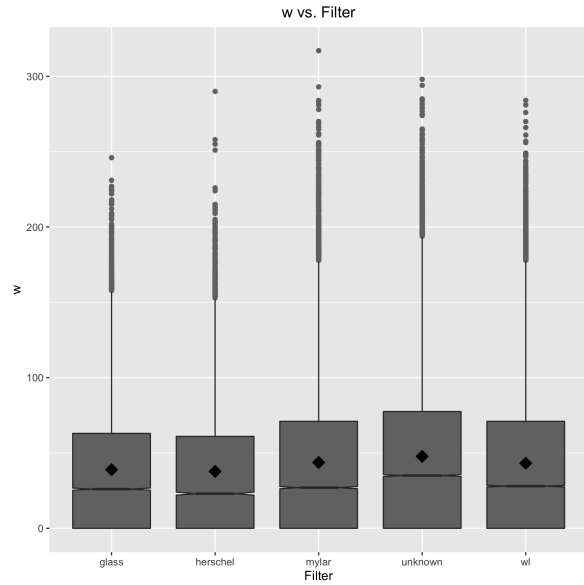


Figure 8: Box plots of raw Wolf number ( $w$ ) by month and year.

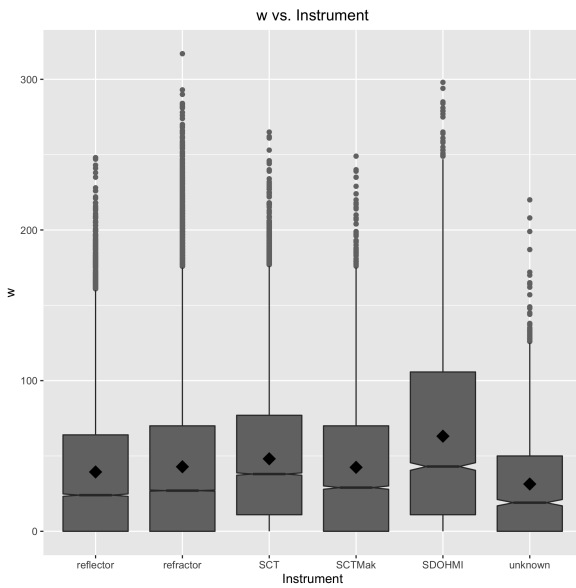


Figure 9: Box plots of raw Wolf number ( $w$ ) by seeing condition.

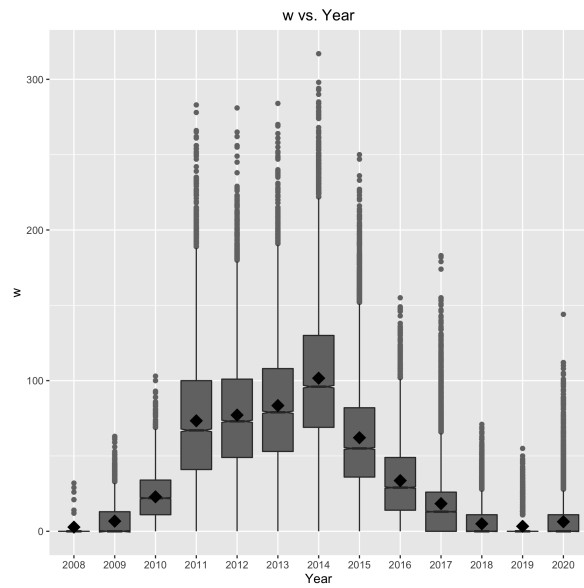


Figure 10: Box plots of raw Wolf number ( $w$ ) by organization.



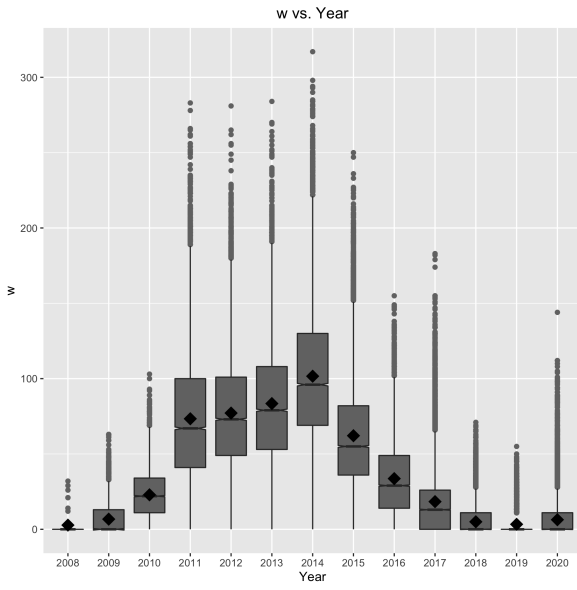


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

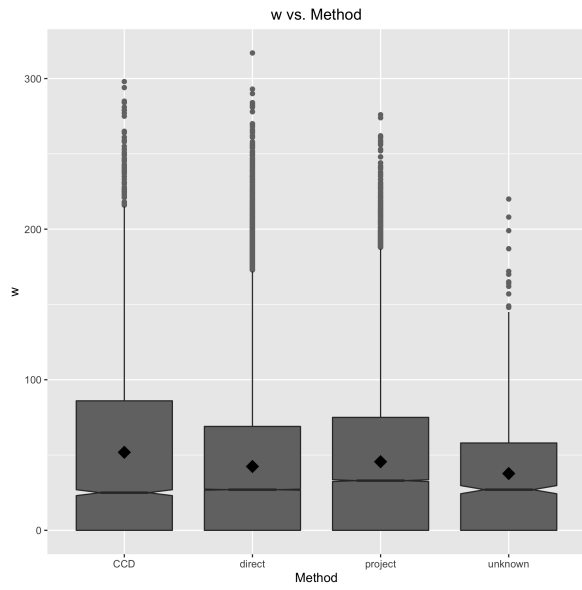


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.