

**Monthly Report (00)**  
**2020.01 Data Set**

**Thursday 13<sup>th</sup> February, 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.

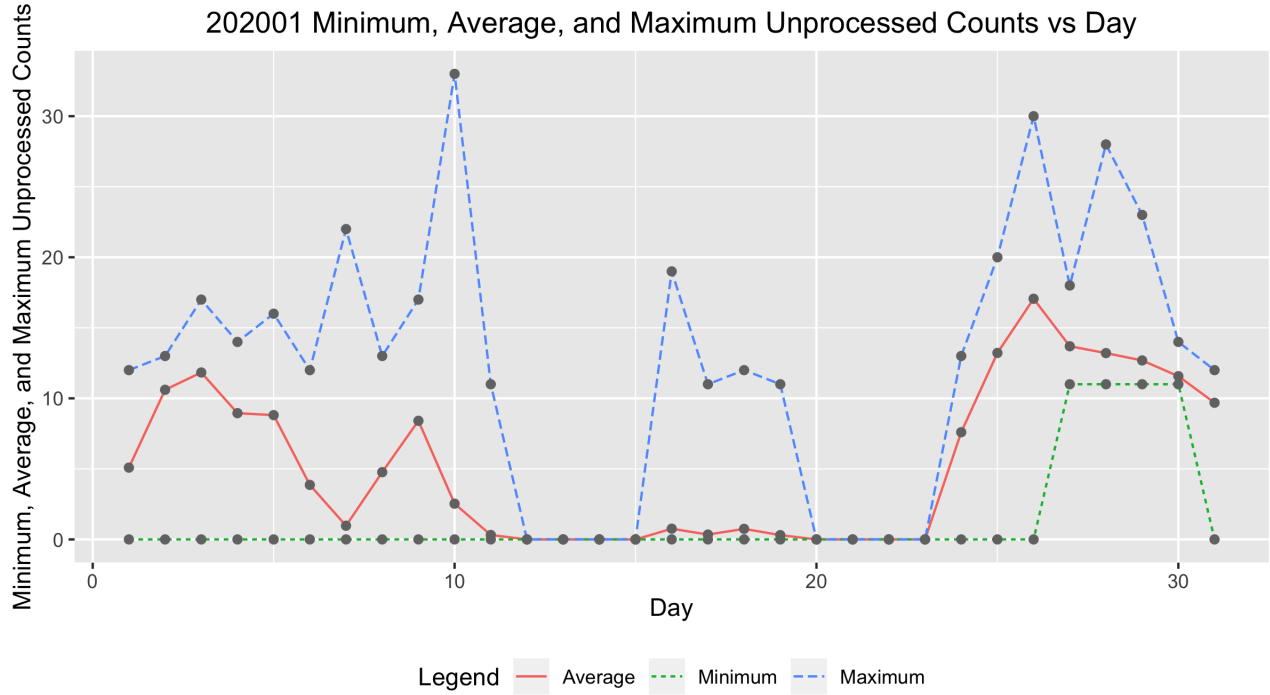


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202001 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	34.0000	0.0000	5.0882	12.0000
2.0000	28.0000	0.0000	10.6071	13.0000
3.0000	24.0000	0.0000	11.8333	17.0000
4.0000	39.0000	0.0000	8.9487	14.0000
5.0000	37.0000	0.0000	8.8108	16.0000
6.0000	44.0000	0.0000	3.8636	12.0000
7.0000	34.0000	0.0000	0.9706	22.0000
8.0000	30.0000	0.0000	4.7667	13.0000
9.0000	27.0000	0.0000	8.4074	17.0000
10.0000	32.0000	0.0000	2.5312	33.0000
11.0000	35.0000	0.0000	0.3143	11.0000
12.0000	39.0000	0.0000	0.0000	0.0000
13.0000	28.0000	0.0000	0.0000	0.0000
14.0000	26.0000	0.0000	0.0000	0.0000
15.0000	33.0000	0.0000	0.0000	0.0000
16.0000	25.0000	0.0000	0.7600	19.0000
17.0000	32.0000	0.0000	0.3438	11.0000
18.0000	32.0000	0.0000	0.7500	12.0000
19.0000	36.0000	0.0000	0.3056	11.0000
20.0000	35.0000	0.0000	0.0000	0.0000
21.0000	31.0000	0.0000	0.0000	0.0000
22.0000	24.0000	0.0000	0.0000	0.0000
23.0000	24.0000	0.0000	0.0000	0.0000
24.0000	30.0000	0.0000	7.6000	13.0000
25.0000	32.0000	0.0000	13.2188	20.0000
26.0000	34.0000	0.0000	17.0588	30.0000
27.0000	26.0000	11.0000	13.6923	18.0000
28.0000	29.0000	11.0000	13.2069	28.0000
29.0000	32.0000	11.0000	12.6875	23.0000
30.0000	28.0000	11.0000	11.5714	14.0000
31.0000	32.0000	0.0000	9.6875	12.0000

### 3 Error Tables

Data are for the month of January 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	2.4040	3.1370	0.5000	1.0000
2009.01	5.8799	5.2361	6.5236	1.3000	1.3000
2009.02	5.0988	4.5254	5.6723	0.7000	1.2000
2009.03	6.7099	6.4434	6.9765	0.3000	0.6000
2009.04	7.5259	7.2498	7.8019	0.4000	1.2000
2009.05	7.6423	7.3325	7.9522	1.6000	2.9000
2009.06	6.6748	6.3309	7.0186	3.2000	6.3000
2009.07	6.3573	6.0970	6.6176	3.6000	5.5000
2009.08	7.0359	6.7509	7.3209	0.0000	0.0000
2009.09	7.5255	7.2522	7.7988	4.5000	7.1000
2009.10	7.0291	6.6528	7.4054	4.5000	7.7000
2009.11	6.9894	6.7957	7.1832	3.3000	6.9000
2009.12	6.5063	6.3197	6.6930	10.4000	16.3000
2010.01	21.7254	19.2257	24.2252	13.3000	19.5000
2010.02	17.0977	14.7457	19.4498	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	18.6974	16.3518	21.0430	15.4000	24.0000
2010.04	20.7126	18.2437	23.1815	7.0000	10.4000
2010.05	24.8863	24.4429	25.3298	8.4000	8.7000
2010.06	20.3937	20.0541	20.7333	11.0000	13.6000
2010.07	21.2899	20.9803	21.5994	15.2000	16.1000
2010.08	22.7819	22.4075	23.1562	18.3000	19.6000
2010.09	25.2974	24.8797	25.7151	22.8000	25.2000
2010.10	23.9071	23.4935	24.3208	21.0000	23.5000
2010.11	24.3493	23.9061	24.7924	20.9000	21.6000
2010.12	21.7384	21.2990	22.1779	13.9000	14.5000
2011.01	77.1308	75.5284	78.7332	17.7000	18.7000
2011.02	66.0136	64.5983	67.4289	29.1000	29.6000
2011.03	70.2558	68.9104	71.6013	48.0000	55.8000
2011.04	78.6816	77.2661	80.0970	47.3000	54.4000
2011.05	80.0388	78.6819	81.3957	37.3000	41.5000
2011.06	65.5580	64.4073	66.7088	35.2000	37.0000
2011.07	67.7558	66.5948	68.9167	41.5000	43.8000
2011.08	73.3546	72.1720	74.5371	42.4000	50.5000
2011.09	80.0916	78.7040	81.4791	73.8000	78.0000
2011.10	75.7079	74.4313	76.9844	78.9000	88.0000
2011.11	76.8933	75.2851	78.5016	84.6000	96.7000
2011.12	67.5569	66.1630	68.9508	65.8000	73.0000
2012.01	82.7612	81.1307	84.3917	55.8000	58.2000
2012.02	69.6572	68.2386	71.0757	29.2000	33.1000
2012.03	74.8023	73.4755	76.1290	53.1000	64.1000
2012.04	82.5314	81.0871	83.9757	51.4000	55.2000
2012.05	85.5747	84.1625	86.9869	61.8000	69.0000
2012.06	69.3811	68.2011	70.5611	59.7000	64.5000
2012.07	72.0915	70.9080	73.2749	64.2000	51.3000
2012.08	75.2843	74.0752	76.4934	57.7000	63.1000
2012.09	82.7112	81.2756	84.1468	57.7000	61.5000
2012.10	79.0430	77.5961	80.4899	48.3000	53.3000
2012.11	80.2544	78.6422	81.8665	56.7000	61.4000
2012.12	70.6934	69.1580	72.2287	37.4000	40.8000
2013.01	92.0422	90.2814	93.8030	63.8000	62.9000
2013.02	77.6111	76.0480	79.1741	37.8000	38.0000
2013.03	80.7175	79.0758	82.3592	50.6000	57.9000
2013.04	90.0050	88.4216	91.5884	70.6000	72.4000
2013.05	91.2073	89.5840	92.8307	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	75.4685	74.1339	76.8031	51.0000	52.5000
2013.07	77.4421	76.1985	78.6857	57.0000	57.0000
2013.08	82.3970	81.0715	83.7225	60.0000	66.0000
2013.09	89.2506	87.6578	90.8435	34.6000	36.9000
2013.10	84.2408	82.6778	85.8039	74.5000	85.6000
2013.11	83.9995	82.1137	85.8852	73.9000	77.6000
2013.12	76.0896	74.4631	77.7161	77.8000	90.3000
2014.01	107.2161	104.9582	109.4741	77.4000	82.0000
2014.02	92.2083	90.3898	94.0268	93.9000	102.8000
2014.03	98.1388	96.3498	99.9278	80.9000	92.2000
2014.04	109.5988	107.6833	111.5142	76.9000	84.7000
2014.05	111.7531	109.8442	113.6619	72.3000	75.2000
2014.06	92.2763	90.7156	93.8370	67.2000	71.0000
2014.07	94.3836	92.8118	95.9555	72.5000	72.5000
2014.08	100.5965	99.0238	102.1693	71.2000	74.7000
2014.09	110.1005	108.1582	112.0427	83.2000	87.6000
2014.10	103.5888	101.6796	105.4981	59.5000	60.6000
2014.11	104.3446	102.1698	106.5195	65.8000	71.1000
2014.12	92.5581	90.4094	94.7068	75.8000	78.0000
2015.01	66.2841	64.9558	67.6125	65.9000	67.0000
2015.02	55.6209	54.3949	56.8468	42.4000	44.8000
2015.03	59.9829	58.8839	61.0819	38.0000	38.4000
2015.04	66.5457	65.3514	67.7399	49.0000	54.4000
2015.05	68.1829	67.0542	69.3115	56.3000	58.8000
2015.06	56.1669	55.1520	57.1818	50.2000	68.3000
2015.07	56.9697	55.9957	57.9438	47.9000	65.8000
2015.08	61.9413	60.8987	62.9839	39.5000	57.2000
2015.09	66.9137	65.6950	68.1324	49.2000	72.1000
2015.10	63.4594	62.2316	64.6872	39.3000	48.3000
2015.11	64.6270	63.2218	66.0322	39.6000	55.9000
2015.12	57.4042	56.1413	58.6670	36.4000	44.8000
2016.01	36.3023	35.5440	37.0606	33.7000	43.3000
2016.02	30.5966	29.9580	31.2353	38.3000	46.8000
2016.03	32.4615	31.8130	33.1101	30.5000	38.9000
2016.04	35.9213	35.2358	36.6068	26.6000	30.9000
2016.05	36.8846	36.2099	37.5593	33.7000	48.4000
2016.06	30.0609	29.5474	30.5743	13.1000	19.5000
2016.07	31.0380	30.5385	31.5376	21.2000	27.5000
2016.08	33.3900	32.8020	33.9780	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	36.9269	36.2521	37.6017	27.7000	37.1000
2016.10	34.6200	33.9516	35.2885	22.7000	31.7000
2016.11	34.8635	34.1338	35.5932	14.0000	22.2000
2016.12	31.3563	30.6852	32.0274	11.1000	20.0000
2017.01	19.7468	19.3309	20.1627	18.4000	26.2000
2017.02	16.7105	16.3431	17.0779	14.4000	20.6000
2017.03	17.8847	17.5436	18.2258	11.3000	15.5000
2017.04	20.0017	19.6483	20.3550	21.6000	33.2000
2017.05	20.2074	19.8581	20.5566	12.5000	18.1000
2017.06	16.4805	16.2053	16.7557	15.5000	19.3000
2017.07	17.0990	16.8269	17.3711	11.5000	16.3000
2017.08	18.3381	18.0194	18.6568	22.8000	35.7000
2017.09	20.6056	20.1775	21.0337	34.6000	42.9000
2017.10	18.8493	18.4674	19.2312	10.5000	11.0000
2017.11	18.8250	18.4309	19.2192	4.2000	5.6000
2017.12	16.8532	16.5979	17.1086	4.0000	4.6000
2018.01	5.4758	5.3587	5.5928	3.1000	6.3000
2018.02	4.6005	4.4887	4.7123	6.8000	11.8000
2018.03	4.8341	4.7388	4.9295	1.1000	1.2000
2018.04	5.3620	5.2552	5.4687	4.7000	7.5000
2018.05	5.5106	5.4065	5.6148	8.4000	14.0000
2018.06	4.4959	4.4166	4.5752	10.2000	13.6000
2018.07	4.6588	4.6068	4.7107	0.5000	1.7000
2018.08	4.9423	4.8570	5.0276	5.9000	9.5000
2018.09	5.3460	5.2467	5.4454	1.6000	2.9000
2018.10	5.1565	5.0572	5.2559	2.5000	5.6000
2018.11	5.1888	5.0830	5.2947	3.1000	4.2000
2018.12	4.7423	4.6505	4.8341	1.6000	2.3000
2019.01	3.6333	3.5655	3.7012	5.4000	2.3000
2019.02	3.1205	3.0598	3.1813	0.1000	1.2000
2019.03	3.2369	3.1818	3.2921	6.1000	12.1000
2019.04	3.6074	3.5395	3.6753	6.2000	9.3000
2019.05	3.5742	3.5107	3.6376	7.0000	11.9000
2019.06	2.9142	2.8631	2.9653	0.7000	1.5000
2019.07	3.0333	2.9861	3.0804	0.4000	2.2000
2019.08	3.2759	3.2254	3.3265	0.3000	0.8000
2019.09	3.6209	3.5618	3.6800	0.5000	1.0000
2019.10	3.3885	3.3286	3.4485	0.2000	0.5000
2019.11	3.4684	3.4008	3.5360	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	3.0693	3.0070	3.1316	0.8000	1.0000
2020.01	5.3179	5.2120	5.4238	4.0000	5.3000

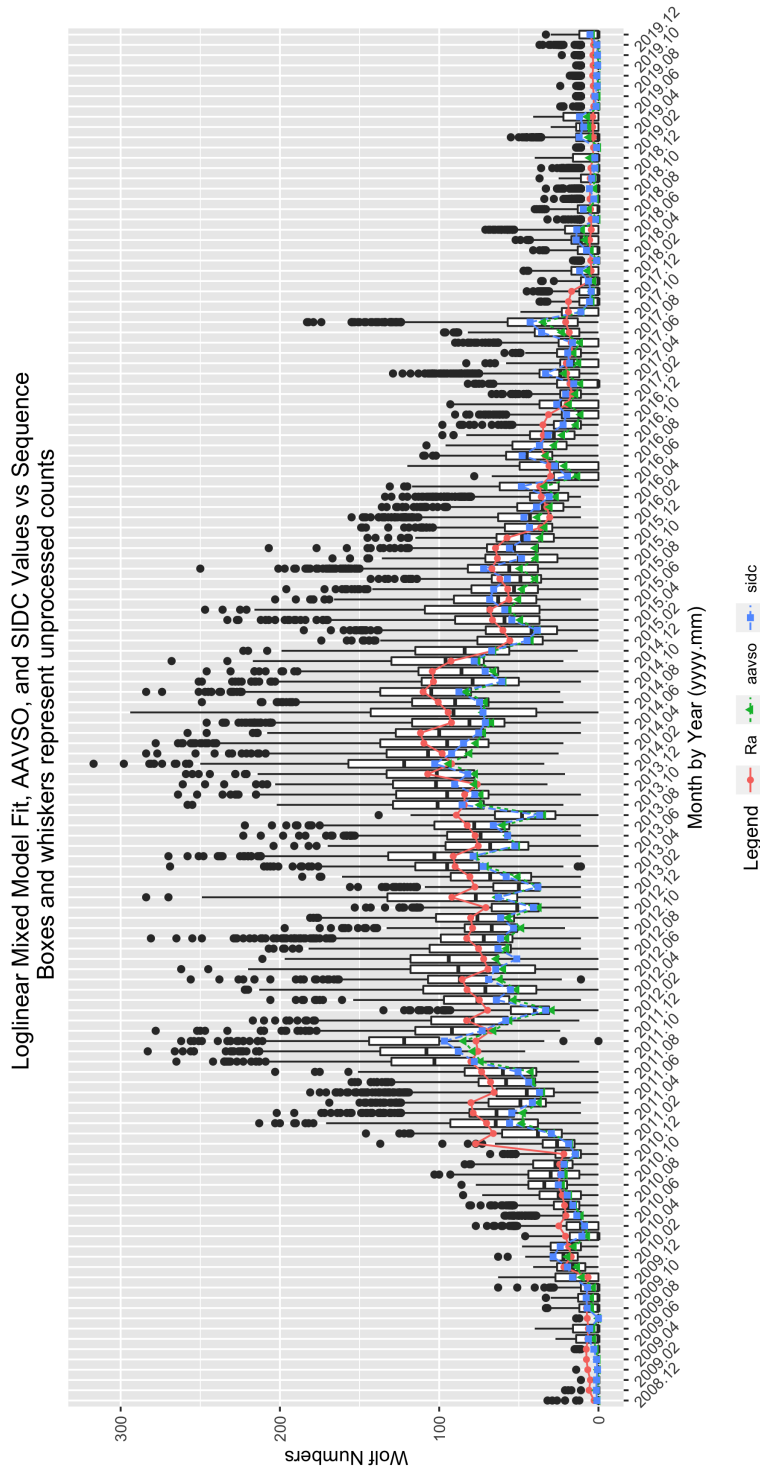


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202001 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4564	0.3094	4.7077	0.0000
seeF	-0.2187	0.0058	-37.5101	0.0000
seeG	-0.1168	0.0051	-23.0112	0.0000
seeM	-0.2022	0.0240	-8.4245	0.0000
seeP	-0.3240	0.0083	-38.8177	0.0000
sidc1	0.1343	0.0692	1.9408	0.0523
year2009	0.6374	0.3103	2.0544	0.0399
year2010	1.8475	0.3081	5.9963	0.0000
year2011	2.9650	0.3080	9.6261	0.0000
year2012	3.0016	0.3080	9.7452	0.0000
year2013	3.0976	0.3080	10.0570	0.0000
year2014	3.2944	0.3080	10.6962	0.0000
year2015	2.8097	0.3080	9.1219	0.0000
year2016	2.1929	0.3080	7.1188	0.0000
year2017	1.5877	0.3081	5.1534	0.0000
year2018	0.2900	0.3084	0.9403	0.3471
year2019	-0.1336	0.3086	-0.4330	0.6650
year2020	0.2651	0.3131	0.8468	0.3971
mon2	-0.1616	0.0092	-17.5663	0.0000
mon3	-0.1068	0.0086	-12.4226	0.0000
mon4	-0.0070	0.0083	-0.8452	0.3980
mon5	0.0066	0.0081	0.8075	0.4194
mon6	-0.1954	0.0086	-22.8338	0.0000
mon7	-0.1712	0.0083	-20.5780	0.0000
mon8	-0.0992	0.0081	-12.1853	0.0000
mon9	-0.0010	0.0082	-0.1186	0.9056
mon10	-0.0556	0.0084	-6.6167	0.0000
mon11	-0.0338	0.0088	-3.8486	0.0001
mon12	-0.1436	0.0089	-16.0480	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: 202001 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:122072	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 : 6.655	Mean :15.73		Mean :0.2593
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: 202001 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:122072	Length:122072
1st Qu.: 1.000	1st Qu.: 1.00	1st Qu.: 11.00	Class :character	Class :character
Median : 2.000	Median : 10.00	Median : 36.00	Mode :character	Mode :character
Mean : 2.962	Mean : 17.64	Mean : 47.27		
3rd Qu.: 5.000	3rd Qu.: 26.00	3rd Qu.: 76.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202001 Summary of Sunspot Numbers

inst	filter	unit
Length:122072	Length:122072	Length:122072
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202001 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.: 350.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 94.81	Mean : 27.78	Mean : 934.2	Mean : 185.5
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1203.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

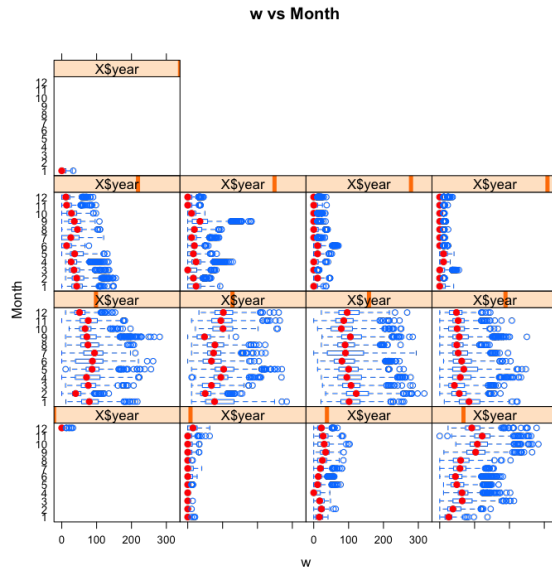
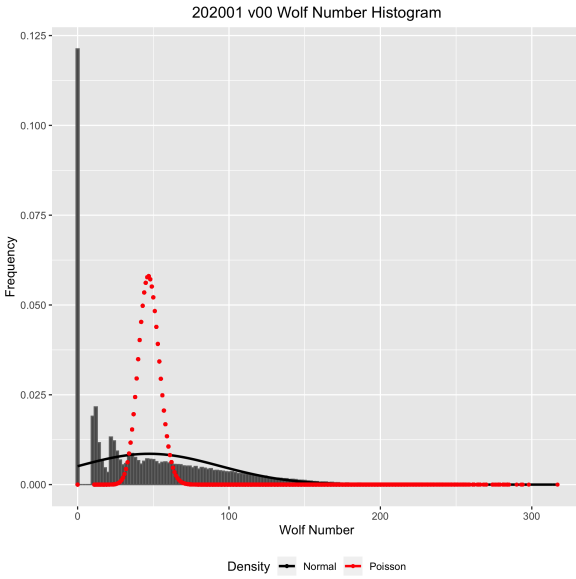


Figure 3: Box plots of raw Wolf number (w) by observer rank.

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

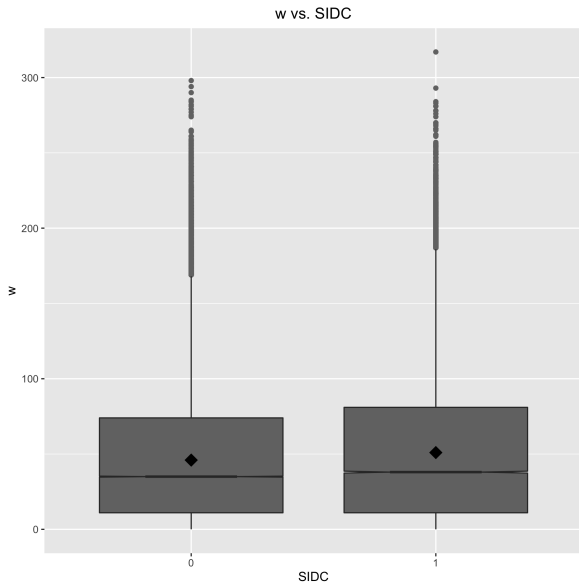
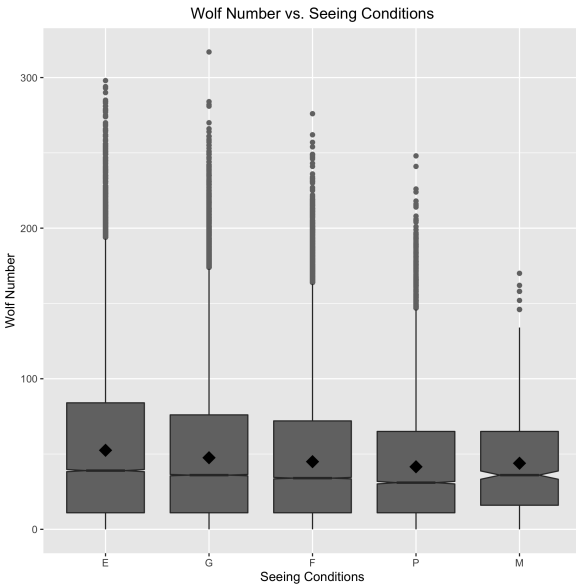


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

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

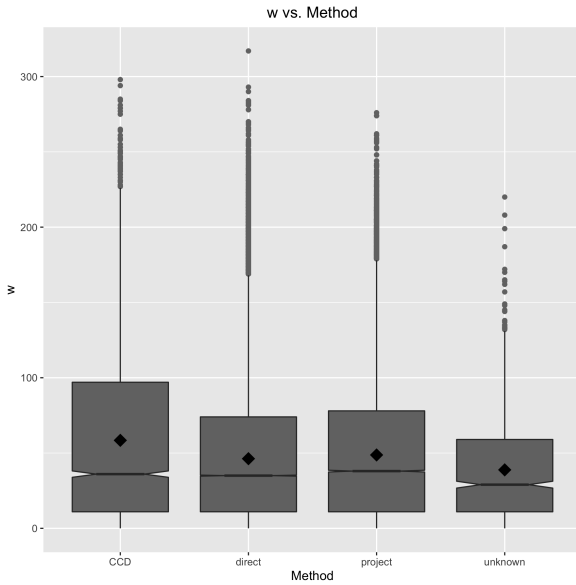


Figure 7: Box plots of raw Wolf number (w) by observer rank.

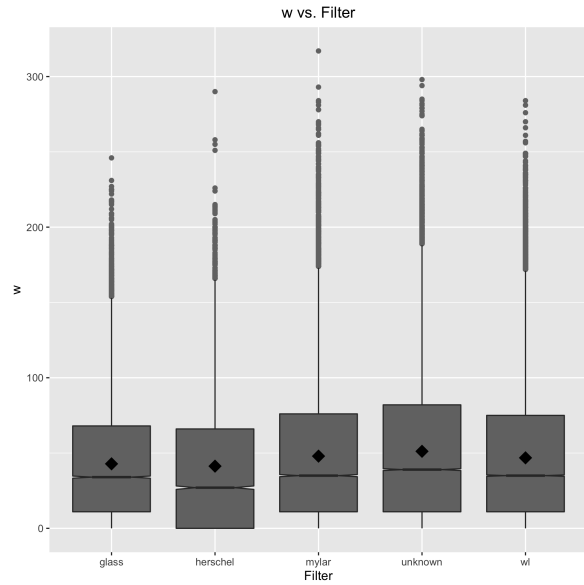


Figure 8: Box plots of raw Wolf number (w) by month and year.

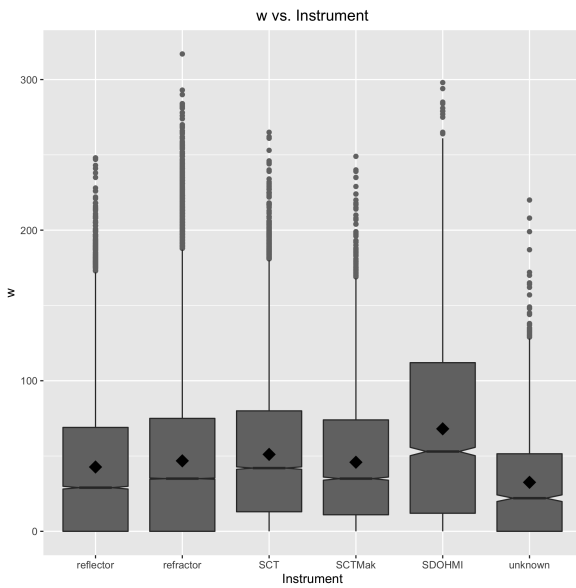


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

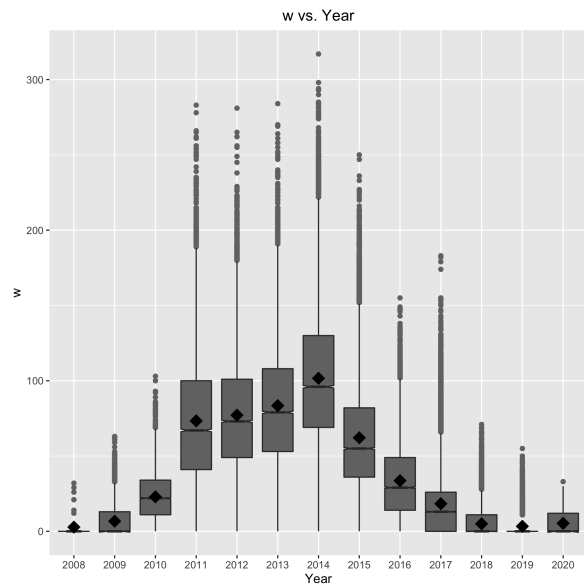


Figure 10: Box plots of raw Wolf number (w) by organization.



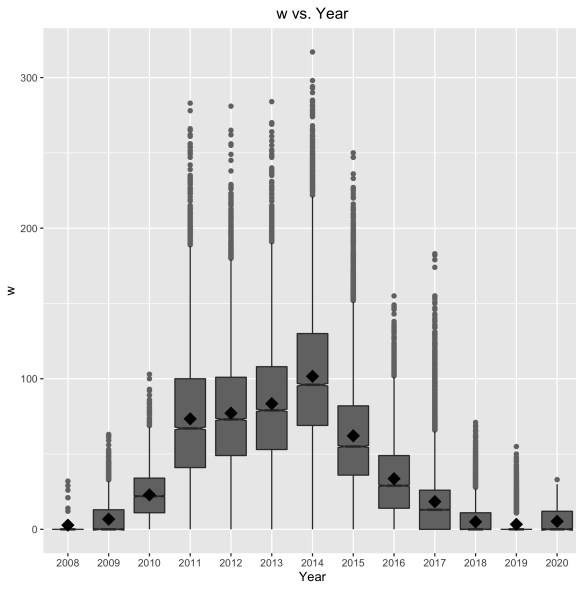


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

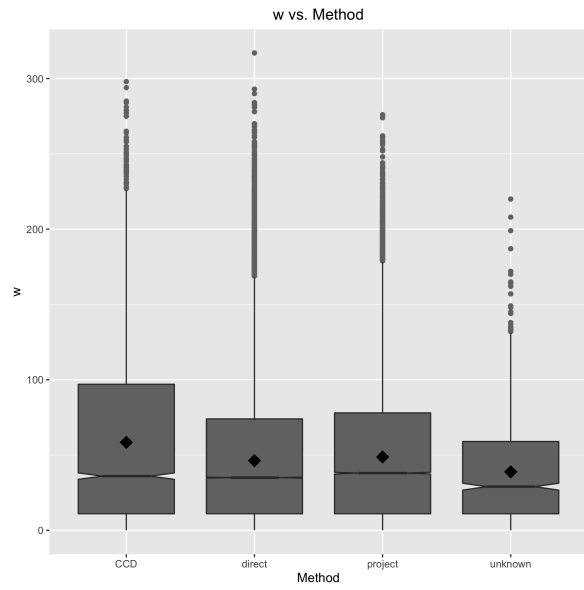


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.