

Monthly Report (00)

2020.02 Data Set

Sunday 15th March, 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.

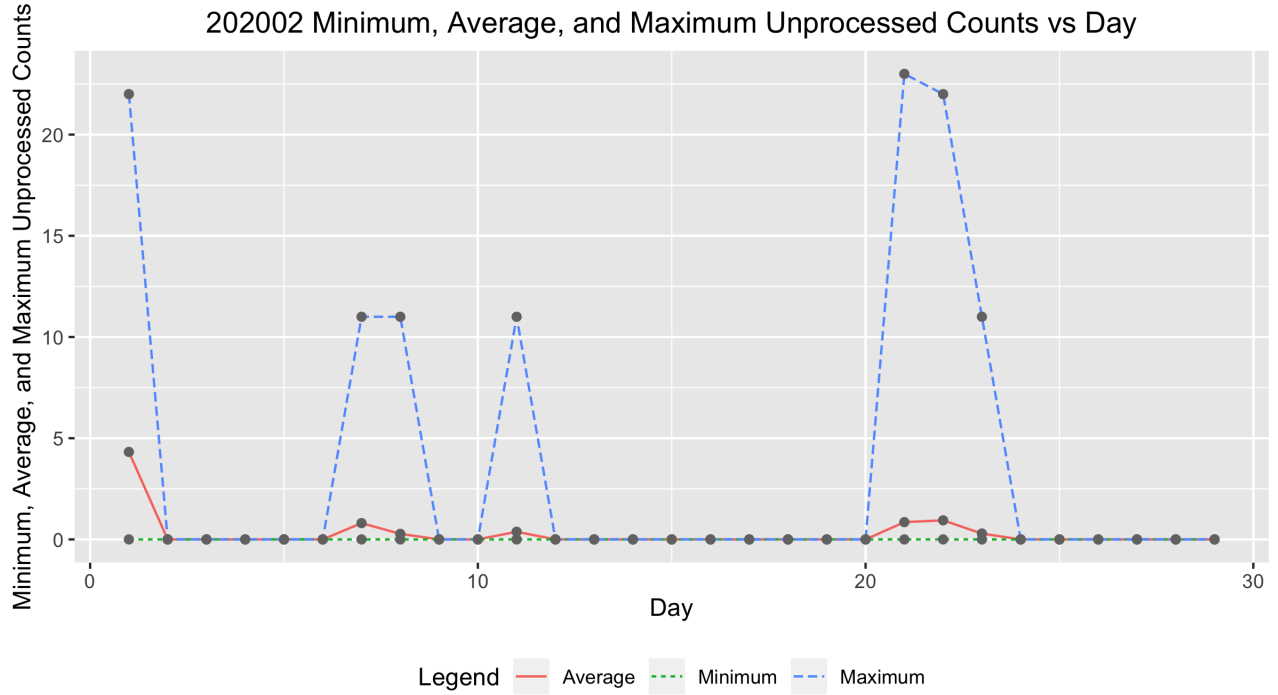


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202002 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	31.0000	0.0000	4.3226	22.0000
2.0000	37.0000	0.0000	0.0000	0.0000
3.0000	37.0000	0.0000	0.0000	0.0000
4.0000	26.0000	0.0000	0.0000	0.0000
5.0000	32.0000	0.0000	0.0000	0.0000
6.0000	27.0000	0.0000	0.0000	0.0000
7.0000	41.0000	0.0000	0.8049	11.0000
8.0000	40.0000	0.0000	0.2750	11.0000
9.0000	31.0000	0.0000	0.0000	0.0000
10.0000	27.0000	0.0000	0.0000	0.0000
11.0000	29.0000	0.0000	0.3793	11.0000
12.0000	30.0000	0.0000	0.0000	0.0000
13.0000	29.0000	0.0000	0.0000	0.0000
14.0000	40.0000	0.0000	0.0000	0.0000
15.0000	40.0000	0.0000	0.0000	0.0000
16.0000	32.0000	0.0000	0.0000	0.0000
17.0000	35.0000	0.0000	0.0000	0.0000
18.0000	27.0000	0.0000	0.0000	0.0000
19.0000	31.0000	0.0000	0.0000	0.0000
20.0000	32.0000	0.0000	0.0000	0.0000
21.0000	41.0000	0.0000	0.8537	23.0000
22.0000	35.0000	0.0000	0.9429	22.0000
23.0000	38.0000	0.0000	0.2895	11.0000
24.0000	35.0000	0.0000	0.0000	0.0000
25.0000	26.0000	0.0000	0.0000	0.0000
26.0000	28.0000	0.0000	0.0000	0.0000
27.0000	36.0000	0.0000	0.0000	0.0000
28.0000	38.0000	0.0000	0.0000	0.0000
29.0000	41.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of February 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	2.4038	3.1372	0.5000	1.0000
2009.01	5.9096	5.2622	6.5570	1.3000	1.3000
2009.02	5.0649	4.4949	5.6349	0.7000	1.2000
2009.03	6.7099	6.4433	6.9764	0.3000	0.6000
2009.04	7.5257	7.2496	7.8018	0.4000	1.2000
2009.05	7.6420	7.3322	7.9519	1.6000	2.9000
2009.06	6.6748	6.3309	7.0188	3.2000	6.3000
2009.07	6.3572	6.0969	6.6175	3.6000	5.5000
2009.08	7.0354	6.7503	7.3205	0.0000	0.0000
2009.09	7.5253	7.2520	7.7986	4.5000	7.1000
2009.10	7.0288	6.6525	7.4051	4.5000	7.7000
2009.11	6.9895	6.7958	7.1832	3.3000	6.9000
2009.12	6.5061	6.3196	6.6927	10.4000	16.3000
2010.01	21.8374	19.3232	24.3517	13.3000	19.5000
2010.02	16.9849	14.6468	19.3230	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	18.6947	16.3480	21.0415	15.4000	24.0000
2010.04	20.7097	18.2396	23.1798	7.0000	10.4000
2010.05	24.8859	24.4422	25.3295	8.4000	8.7000
2010.06	20.3939	20.0542	20.7336	11.0000	13.6000
2010.07	21.2903	20.9806	21.5999	15.2000	16.1000
2010.08	22.7820	22.4075	23.1564	18.3000	19.6000
2010.09	25.2978	24.8799	25.7156	22.8000	25.2000
2010.10	23.9073	23.4936	24.3211	21.0000	23.5000
2010.11	24.3497	23.9064	24.7930	20.9000	21.6000
2010.12	21.7378	21.2981	22.1775	13.9000	14.5000
2011.01	77.5290	75.9176	79.1405	17.7000	18.7000
2011.02	65.5895	64.1836	66.9954	29.1000	29.6000
2011.03	70.2543	68.9086	71.6000	48.0000	55.8000
2011.04	78.6818	77.2662	80.0975	47.3000	54.4000
2011.05	80.0404	78.6833	81.3975	37.3000	41.5000
2011.06	65.5589	64.4079	66.7098	35.2000	37.0000
2011.07	67.7558	66.5946	68.9170	41.5000	43.8000
2011.08	73.3552	72.1725	74.5380	42.4000	50.5000
2011.09	80.0935	78.7057	81.4813	73.8000	78.0000
2011.10	75.7086	74.4318	76.9853	78.9000	88.0000
2011.11	76.8942	75.2858	78.5026	84.6000	96.7000
2011.12	67.5568	66.1628	68.9508	65.8000	73.0000
2012.01	83.1939	81.5544	84.8335	55.8000	58.2000
2012.02	69.2065	67.7968	70.6163	29.2000	33.1000
2012.03	74.8023	73.4752	76.1294	53.1000	64.1000
2012.04	82.5322	81.0874	83.9769	51.4000	55.2000
2012.05	85.5762	84.1635	86.9888	61.8000	69.0000
2012.06	69.3820	68.2016	70.5624	59.7000	64.5000
2012.07	72.0919	70.9081	73.2758	64.2000	51.3000
2012.08	75.2846	74.0752	76.4940	57.7000	63.1000
2012.09	82.7111	81.2751	84.1471	57.7000	61.5000
2012.10	79.0436	77.5963	80.4908	48.3000	53.3000
2012.11	80.2558	78.6432	81.8685	56.7000	61.4000
2012.12	70.6935	69.1578	72.2293	37.4000	40.8000
2013.01	92.5201	90.7496	94.2906	63.8000	62.9000
2013.02	77.1070	75.5536	78.6604	37.8000	38.0000
2013.03	80.7157	79.0735	82.3578	50.6000	57.9000
2013.04	90.0026	88.4189	91.5864	70.6000	72.4000
2013.05	91.2057	89.5821	92.8294	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	75.4679	74.1330	76.8027	51.0000	52.5000
2013.07	77.4407	76.1969	78.6845	57.0000	57.0000
2013.08	82.3951	81.0693	83.7208	60.0000	66.0000
2013.09	89.2484	87.6552	90.8415	34.6000	36.9000
2013.10	84.2397	82.6764	85.8031	74.5000	85.6000
2013.11	83.9975	82.1113	85.8836	73.9000	77.6000
2013.12	76.0877	74.4610	77.7145	77.8000	90.3000
2014.01	107.7766	105.5065	110.0468	77.4000	82.0000
2014.02	91.6150	89.8079	93.4220	93.9000	102.8000
2014.03	98.1414	96.3520	99.9308	80.9000	92.2000
2014.04	109.6011	107.6852	111.5170	76.9000	84.7000
2014.05	111.7556	109.8464	113.6649	72.3000	75.2000
2014.06	92.2790	90.7179	93.8400	67.2000	71.0000
2014.07	94.3865	92.8143	95.9587	72.5000	72.5000
2014.08	100.6005	99.0274	102.1736	71.2000	74.7000
2014.09	110.1044	108.1616	112.0471	83.2000	87.6000
2014.10	103.5915	101.6818	105.5011	59.5000	60.6000
2014.11	104.3470	102.1716	106.5224	65.8000	71.1000
2014.12	92.5615	90.4124	94.7107	75.8000	78.0000
2015.01	66.6298	65.2942	67.9654	65.9000	67.0000
2015.02	55.2616	54.0434	56.4798	42.4000	44.8000
2015.03	59.9813	58.8822	61.0804	38.0000	38.4000
2015.04	66.5433	65.3490	67.7377	49.0000	54.4000
2015.05	68.1810	67.0523	69.3097	56.3000	58.8000
2015.06	56.1650	55.1500	57.1799	50.2000	68.3000
2015.07	56.9673	55.9931	57.9415	47.9000	65.8000
2015.08	61.9393	60.8966	62.9820	39.5000	57.2000
2015.09	66.9104	65.6916	68.1292	49.2000	72.1000
2015.10	63.4561	62.2282	64.6840	39.3000	48.3000
2015.11	64.6244	63.2190	66.0298	39.6000	55.9000
2015.12	57.4020	56.1390	58.6651	36.4000	44.8000
2016.01	36.4931	35.7307	37.2555	33.7000	43.3000
2016.02	30.3990	29.7644	31.0336	38.3000	46.8000
2016.03	32.4630	31.8144	33.1117	30.5000	38.9000
2016.04	35.9230	35.2374	36.6086	26.6000	30.9000
2016.05	36.8857	36.2109	37.5605	33.7000	48.4000
2016.06	30.0615	29.5481	30.5750	13.1000	19.5000
2016.07	31.0368	30.5372	31.5364	21.2000	27.5000
2016.08	33.3899	32.8017	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	36.9279	36.2530	37.6029	27.7000	37.1000
2016.10	34.6213	33.9528	35.2899	22.7000	31.7000
2016.11	34.8635	34.1337	35.5933	14.0000	22.2000
2016.12	31.3571	30.6859	32.0283	11.1000	20.0000
2017.01	19.8503	19.4321	20.2684	18.4000	26.2000
2017.02	16.6021	16.2370	16.9671	14.4000	20.6000
2017.03	17.8842	17.5431	18.2254	11.3000	15.5000
2017.04	20.0008	19.6474	20.3542	21.6000	33.2000
2017.05	20.2066	19.8573	20.5560	12.5000	18.1000
2017.06	16.4793	16.2041	16.7546	15.5000	19.3000
2017.07	17.0985	16.8263	17.3706	11.5000	16.3000
2017.08	18.3380	18.0191	18.6569	22.8000	35.7000
2017.09	20.6057	20.1771	21.0342	34.6000	42.9000
2017.10	18.8493	18.4672	19.2314	10.5000	11.0000
2017.11	18.8241	18.4298	19.2184	4.2000	5.6000
2017.12	16.8538	16.5983	17.1093	4.0000	4.6000
2018.01	5.5042	5.3864	5.6220	3.1000	6.3000
2018.02	4.5712	4.4599	4.6825	6.8000	11.8000
2018.03	4.8348	4.7393	4.9303	1.1000	1.2000
2018.04	5.3628	5.2559	5.4697	4.7000	7.5000
2018.05	5.5082	5.4040	5.6123	8.4000	14.0000
2018.06	4.4957	4.4164	4.5750	10.2000	13.6000
2018.07	4.6596	4.6075	4.7117	0.5000	1.7000
2018.08	4.9419	4.8565	5.0274	5.9000	9.5000
2018.09	5.3464	5.2468	5.4460	1.6000	2.9000
2018.10	5.1576	5.0580	5.2571	2.5000	5.6000
2018.11	5.1891	5.0833	5.2950	3.1000	4.2000
2018.12	4.7418	4.6501	4.8335	1.6000	2.3000
2019.01	3.6546	3.5864	3.7228	5.4000	2.3000
2019.02	3.1006	3.0404	3.1609	0.1000	1.2000
2019.03	3.2375	3.1823	3.2927	6.1000	12.1000
2019.04	3.6077	3.5397	3.6757	6.2000	9.3000
2019.05	3.5749	3.5113	3.6385	7.0000	11.9000
2019.06	2.9131	2.8619	2.9643	0.7000	1.5000
2019.07	3.0334	2.9862	3.0807	0.4000	2.2000
2019.08	3.2754	3.2247	3.3260	0.3000	0.8000
2019.09	3.6195	3.5604	3.6787	0.5000	1.0000
2019.10	3.3868	3.3268	3.4468	0.2000	0.5000
2019.11	3.4687	3.4010	3.5364	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	3.0694	3.0071	3.1316	0.8000	1.0000
2020.01	3.0431	2.9823	3.1039	4.0000	5.3000
2020.02	2.5505	2.4984	2.6026	0.1000	0.0000

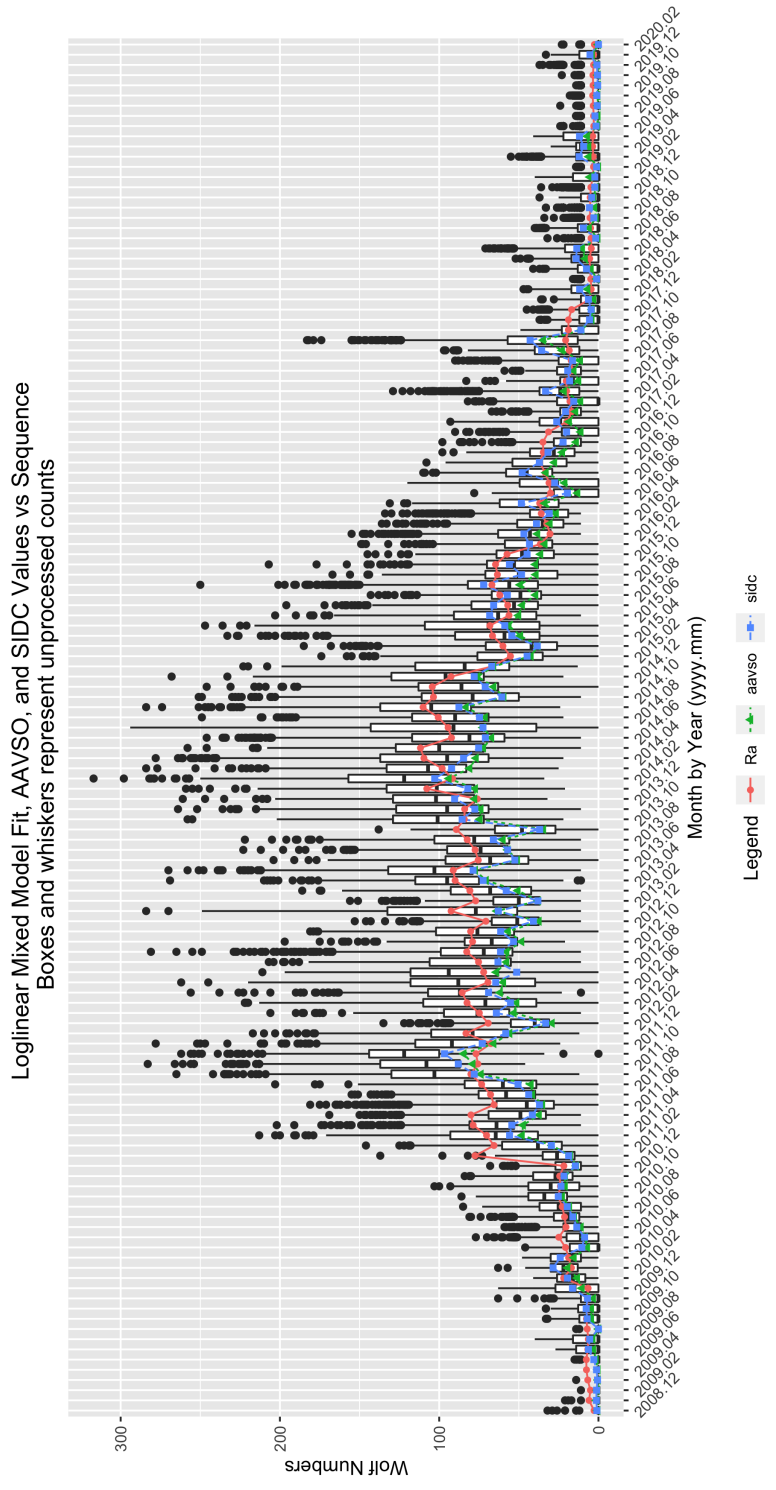


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202002 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4611	0.3087	4.7338	0.0000
seeF	-0.2188	0.0058	-37.6198	0.0000
seeG	-0.1170	0.0051	-23.0995	0.0000
seeM	-0.2025	0.0239	-8.4554	0.0000
seeP	-0.3241	0.0083	-38.9233	0.0000
sidc1	0.1355	0.0694	1.9521	0.0509
year2009	0.6372	0.3096	2.0586	0.0395
year2010	1.8474	0.3074	6.0098	0.0000
year2011	2.9648	0.3073	9.6479	0.0000
year2012	3.0015	0.3073	9.7672	0.0000
year2013	3.0974	0.3073	10.0796	0.0000
year2014	3.2943	0.3073	10.7203	0.0000
year2015	2.8094	0.3073	9.1421	0.0000
year2016	2.1928	0.3073	7.1347	0.0000
year2017	1.5875	0.3074	5.1647	0.0000
year2018	0.2898	0.3077	0.9420	0.3462
year2019	-0.1333	0.3079	-0.4330	0.6650
year2020	-0.2983	0.3121	-0.9559	0.3391
mon2	-0.1733	0.0092	-18.9388	0.0000
mon3	-0.1120	0.0086	-13.0884	0.0000
mon4	-0.0122	0.0083	-1.4816	0.1385
mon5	0.0014	0.0081	0.1671	0.8673
mon6	-0.2006	0.0085	-23.5490	0.0000
mon7	-0.1764	0.0083	-21.3032	0.0000
mon8	-0.1044	0.0081	-12.8869	0.0000
mon9	-0.0062	0.0081	-0.7615	0.4464
mon10	-0.0608	0.0084	-7.2715	0.0000
mon11	-0.0390	0.0087	-4.4629	0.0000
mon12	-0.1488	0.0089	-16.7024	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: 202002 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:123044	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 : 6.618	Mean :15.73		Mean :0.2592
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: 202002 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.0	Length:123044	Length:123044
1st Qu.: 1.000	1st Qu.: 1.0	1st Qu.: 11.0	Class :character	Class :character
Median : 2.000	Median : 9.0	Median : 35.0	Mode :character	Mode :character
Mean : 2.939	Mean : 17.5	Mean : 46.9		
3rd Qu.: 5.000	3rd Qu.: 26.0	3rd Qu.: 75.0		
Max. :19.000	Max. :204.0	Max. :317.0		

Table 6: 202002 Summary of Sunspot Numbers

inst	filter	unit
Length:123044	Length:123044	Length:123044
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202002 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0	Min. : 0.0
1st Qu.: 60.00	1st Qu.: 3.00	1st Qu.: 150	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910	Median : 57.5
Mean : 94.17	Mean : 28.13	Mean : 927	Mean : 185.6
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1200	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300	Max. :4591.0

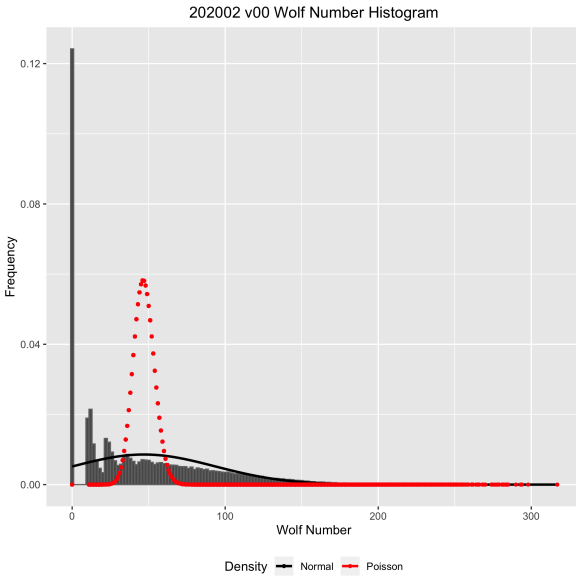


Figure 3: Box plots of raw Wolf number (w) by observer rank.

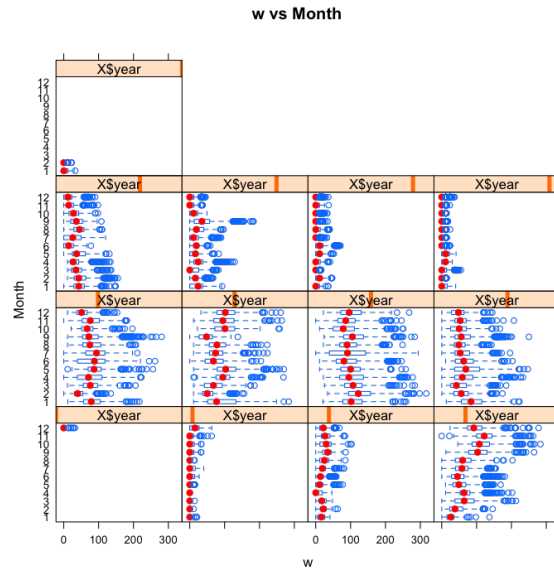


Figure 4: Box plots of raw Wolf number (w) by month and year.

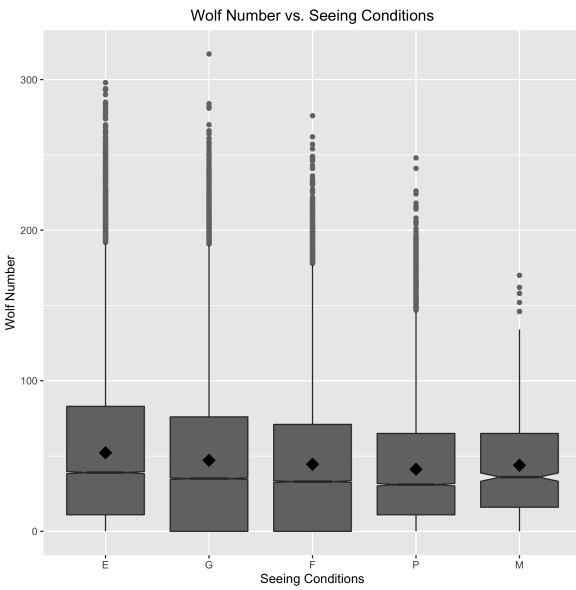


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

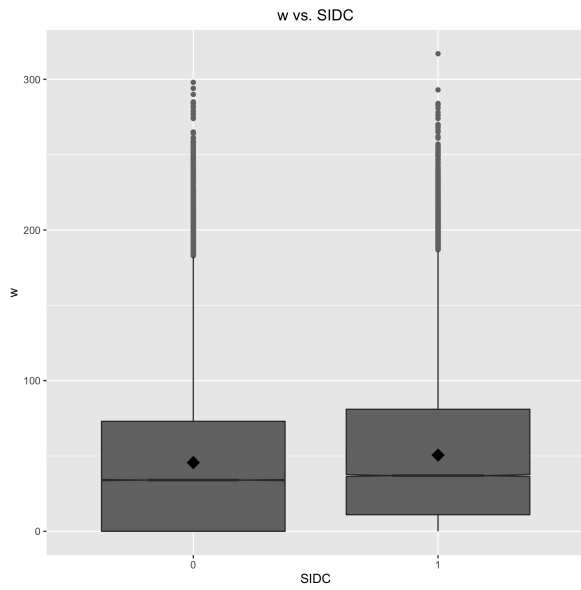


Figure 6: Box plots of raw Wolf number (w) by organization.

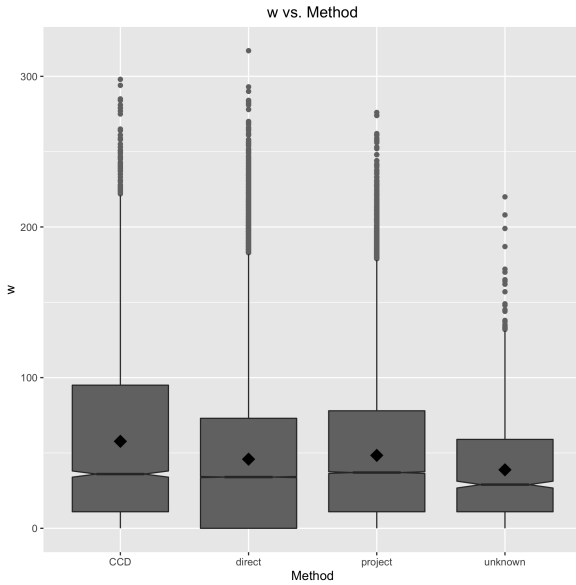


Figure 7: Box plots of raw Wolf number (w) by observer rank.

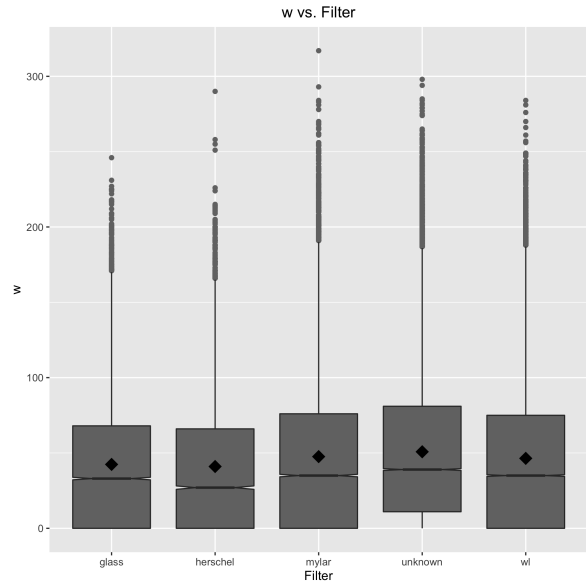


Figure 8: Box plots of raw Wolf number (w) by month and year.

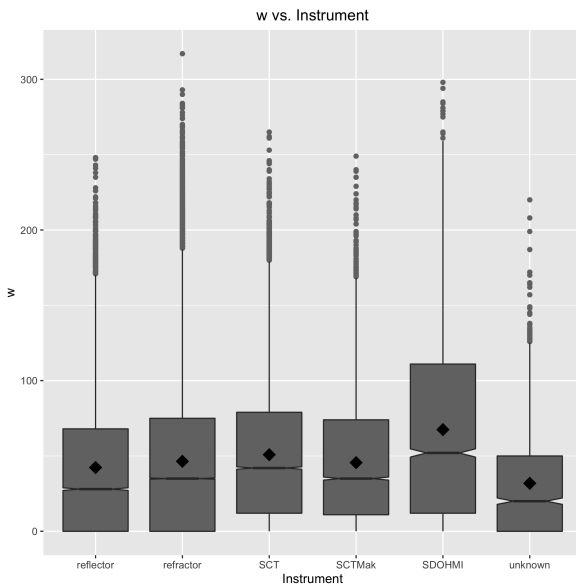


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

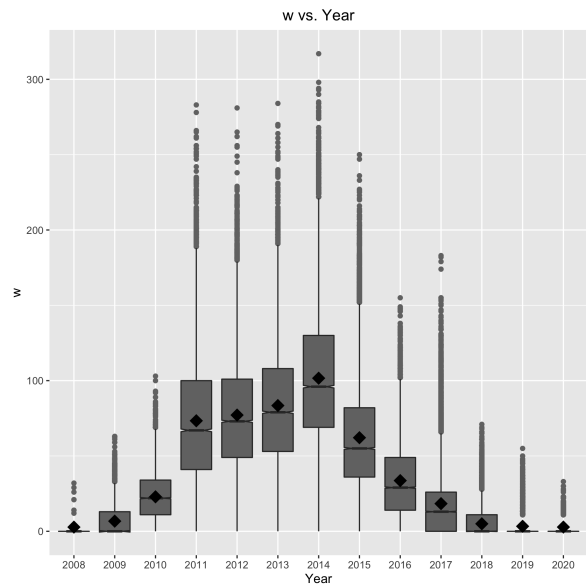


Figure 10: Box plots of raw Wolf number (w) by organization.

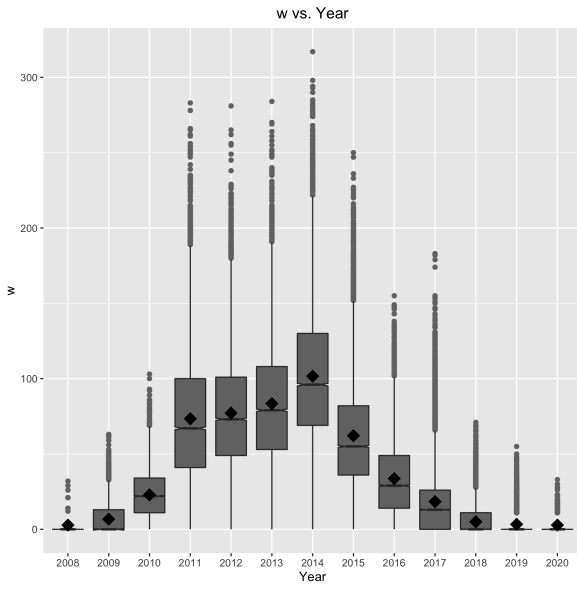


Figure 11: Box plots of raw Wolf number (w) by year.

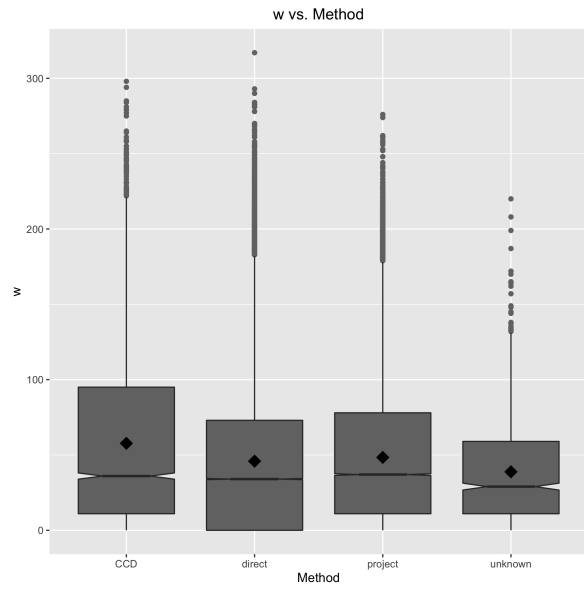


Figure 12: Box plots of raw Wolf number (w) by observing method.