

Monthly Report (00)
202012 Data Set

Monday 11th January, 2021

Prepared for

Statistics for Physical and Engineering Sciences

by

Jamie Riggs, Ph.D.

Principal Statistician
Statistics for Physical and Engineering Sciences Institute

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.

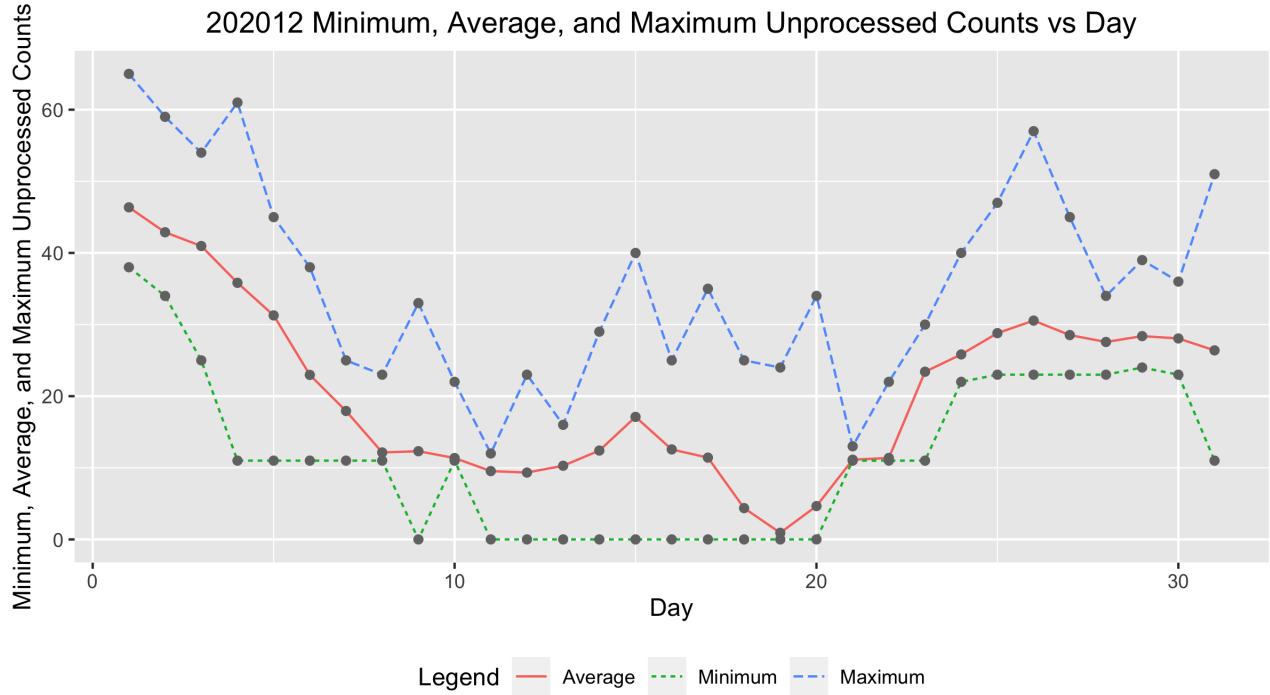


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202012 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	33.0000	38.0000	46.3636	65.0000
2.0000	34.0000	34.0000	42.8824	59.0000
3.0000	32.0000	25.0000	40.9688	54.0000
4.0000	35.0000	11.0000	35.8286	61.0000
5.0000	36.0000	11.0000	31.2778	45.0000
6.0000	34.0000	11.0000	22.9706	38.0000
7.0000	30.0000	11.0000	17.9333	25.0000
8.0000	35.0000	11.0000	12.1429	23.0000
9.0000	38.0000	0.0000	12.3158	33.0000
10.0000	33.0000	11.0000	11.3636	22.0000
11.0000	26.0000	0.0000	9.5385	12.0000
12.0000	27.0000	0.0000	9.3333	23.0000
13.0000	28.0000	0.0000	10.2857	16.0000
14.0000	32.0000	0.0000	12.4062	29.0000
15.0000	37.0000	0.0000	17.1081	40.0000
16.0000	23.0000	0.0000	12.5652	25.0000
17.0000	31.0000	0.0000	11.4194	35.0000
18.0000	35.0000	0.0000	4.3714	25.0000
19.0000	26.0000	0.0000	0.9231	24.0000
20.0000	29.0000	0.0000	4.6552	34.0000
21.0000	31.0000	11.0000	11.1290	13.0000
22.0000	40.0000	11.0000	11.3750	22.0000
23.0000	34.0000	11.0000	23.4118	30.0000
24.0000	35.0000	22.0000	25.8286	40.0000
25.0000	35.0000	23.0000	28.8000	47.0000
26.0000	38.0000	23.0000	30.5526	57.0000
27.0000	32.0000	23.0000	28.5312	45.0000
28.0000	30.0000	23.0000	27.5667	34.0000
29.0000	39.0000	24.0000	28.3846	39.0000
30.0000	34.0000	23.0000	28.0588	36.0000
31.0000	28.0000	11.0000	26.3929	51.0000

3 Error Tables

Data are for the month of December 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	2.3994	3.1416	0.5000	1.0000
2009.01	5.7054	5.0724	6.3384	1.3000	1.3000
2009.02	4.8882	4.3310	5.4455	0.7000	1.2000
2009.03	6.4791	6.2246	6.7336	0.3000	0.6000
2009.04	7.2994	7.0341	7.5646	0.4000	1.2000
2009.05	7.3482	7.0538	7.6426	1.6000	2.9000
2009.06	6.5086	6.1764	6.8408	3.2000	6.3000
2009.07	6.2139	5.9617	6.4661	3.6000	5.5000
2009.08	6.8789	6.6036	7.1542	0.0000	0.0000
2009.09	7.2414	6.9807	7.5021	4.5000	7.1000
2009.10	6.9651	6.5948	7.3354	4.5000	7.7000
2009.11	7.1900	6.9902	7.3897	3.3000	6.9000
2009.12	6.5857	6.3967	6.7746	10.4000	16.3000
2010.01	21.4930	18.9887	23.9974	13.3000	19.5000
2010.02	16.6836	14.3566	19.0106	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	18.3271	15.9991	20.6551	15.4000	24.0000
2010.04	20.3985	17.9366	22.8603	7.0000	10.4000
2010.05	24.3472	23.9123	24.7820	8.4000	8.7000
2010.06	20.2488	19.9125	20.5850	11.0000	13.6000
2010.07	21.1817	20.8734	21.4901	15.2000	16.1000
2010.08	22.6810	22.3091	23.0530	18.3000	19.6000
2010.09	24.7709	24.3632	25.1786	22.8000	25.2000
2010.10	24.1081	23.6923	24.5239	21.0000	23.5000
2010.11	25.5125	25.0498	25.9752	20.9000	21.6000
2010.12	22.4179	21.9662	22.8695	13.9000	14.5000
2011.01	76.7027	75.1250	78.2804	17.7000	18.7000
2011.02	64.8803	63.5064	66.2542	29.1000	29.6000
2011.03	69.3312	68.0038	70.6585	48.0000	55.8000
2011.04	78.0075	76.6106	79.4044	47.3000	54.4000
2011.05	78.6553	77.3328	79.9778	37.3000	41.5000
2011.06	65.3355	64.1967	66.4743	35.2000	37.0000
2011.07	67.6283	66.4782	68.7785	41.5000	43.8000
2011.08	73.2638	72.0932	74.4345	42.4000	50.5000
2011.09	78.7843	77.4185	80.1501	73.8000	78.0000
2011.10	76.6448	75.3615	77.9282	78.9000	88.0000
2011.11	80.8822	79.2031	82.5613	84.6000	96.7000
2011.12	69.9445	68.5117	71.3773	65.8000	73.0000
2012.01	82.3262	80.7104	83.9419	55.8000	58.2000
2012.02	68.4243	67.0353	69.8133	29.2000	33.1000
2012.03	73.8043	72.5002	75.1083	53.1000	64.1000
2012.04	81.8071	80.3806	83.2335	51.4000	55.2000
2012.05	84.1170	82.7358	85.4982	61.8000	69.0000
2012.06	69.1603	67.9920	70.3286	59.7000	64.5000
2012.07	72.0206	70.8449	73.1963	64.2000	51.3000
2012.08	75.2530	74.0492	76.4569	57.7000	63.1000
2012.09	81.3663	79.9571	82.7754	57.7000	61.5000
2012.10	80.0655	78.6032	81.5279	48.3000	53.3000
2012.11	84.4751	82.7812	86.1690	56.7000	61.4000
2012.12	73.2427	71.6558	74.8295	37.4000	40.8000
2013.01	91.5120	89.7647	93.2594	63.8000	62.9000
2013.02	76.2195	74.6868	77.7522	37.8000	38.0000
2013.03	79.6322	78.0109	81.2535	50.6000	57.9000
2013.04	89.2035	87.6326	90.7744	70.6000	72.4000
2013.05	89.6524	88.0538	91.2511	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	75.2328	73.9045	76.5611	51.0000	52.5000
2013.07	77.3764	76.1344	78.6183	57.0000	57.0000
2013.08	82.3976	81.0717	83.7236	60.0000	66.0000
2013.09	87.7776	86.2103	89.3449	34.6000	36.9000
2013.10	85.3388	83.7549	86.9228	74.5000	85.6000
2013.11	88.4146	86.4282	90.4009	73.9000	77.6000
2013.12	78.8360	77.1492	80.5229	77.8000	90.3000
2014.01	106.6403	104.3942	108.8865	77.4000	82.0000
2014.02	90.6218	88.8335	92.4102	93.9000	102.8000
2014.03	96.8937	95.1252	98.6623	80.9000	92.2000
2014.04	108.7129	106.8113	110.6146	76.9000	84.7000
2014.05	109.9045	108.0279	111.7811	72.3000	75.2000
2014.06	92.0479	90.4909	93.6049	67.2000	71.0000
2014.07	94.3232	92.7510	95.8954	72.5000	72.5000
2014.08	100.6053	99.0316	102.1790	71.2000	74.7000
2014.09	108.3173	106.4052	110.2295	83.2000	87.6000
2014.10	104.9501	103.0166	106.8836	59.5000	60.6000
2014.11	109.9157	107.6267	112.2046	65.8000	71.1000
2014.12	95.9258	93.7019	98.1498	75.8000	78.0000
2015.01	65.8847	64.5644	67.2051	65.9000	67.0000
2015.02	54.6181	53.4142	55.8220	42.4000	44.8000
2015.03	59.1863	58.1034	60.2692	38.0000	38.4000
2015.04	65.9986	64.8182	67.1790	49.0000	54.4000
2015.05	67.0071	65.8996	68.1147	56.3000	58.8000
2015.06	56.0187	55.0107	57.0267	50.2000	68.3000
2015.07	56.9433	55.9740	57.9126	47.9000	65.8000
2015.08	61.9246	60.8856	62.9637	39.5000	57.2000
2015.09	65.8368	64.6411	67.0325	49.2000	72.1000
2015.10	64.2623	63.0220	65.5026	39.3000	48.3000
2015.11	67.9827	66.5027	69.4626	39.6000	55.9000
2015.12	59.3845	58.0710	60.6981	36.4000	44.8000
2016.01	36.0860	35.3342	36.8377	33.7000	43.3000
2016.02	30.0416	29.4154	30.6677	38.3000	46.8000
2016.03	32.0108	31.3720	32.6496	30.5000	38.9000
2016.04	35.6016	34.9236	36.2796	26.6000	30.9000
2016.05	36.2278	35.5663	36.8894	33.7000	48.4000
2016.06	29.9643	29.4530	30.4756	13.1000	19.5000
2016.07	30.9794	30.4808	31.4779	21.2000	27.5000
2016.08	33.3519	32.7652	33.9385	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	36.3083	35.6461	36.9706	27.7000	37.1000
2016.10	35.0576	34.3825	35.7327	22.7000	31.7000
2016.11	36.7008	35.9344	37.4672	14.0000	22.2000
2016.12	32.4732	31.7783	33.1681	11.1000	20.0000
2017.01	19.5865	19.1745	19.9985	18.4000	26.2000
2017.02	16.3736	16.0143	16.7329	14.4000	20.6000
2017.03	17.6005	17.2650	17.9360	11.3000	15.5000
2017.04	19.7763	19.4273	20.1253	21.6000	33.2000
2017.05	19.8161	19.4744	20.1577	12.5000	18.1000
2017.06	16.3696	16.0972	16.6420	15.5000	19.3000
2017.07	17.0251	16.7545	17.2956	11.5000	16.3000
2017.08	18.2751	17.9534	18.5967	22.8000	35.7000
2017.09	20.2990	19.8439	20.7541	34.6000	42.9000
2017.10	19.0469	18.6487	19.4450	10.5000	11.0000
2017.11	19.7529	19.3346	20.1713	4.2000	5.6000
2017.12	17.3713	17.1060	17.6366	4.0000	4.6000
2018.01	5.4441	5.3257	5.5624	3.1000	6.3000
2018.02	4.5175	4.4051	4.6298	6.8000	11.8000
2018.03	4.7721	4.6752	4.8690	1.1000	1.2000
2018.04	5.3137	5.2047	5.4228	4.7000	7.5000
2018.05	5.4136	5.3092	5.5181	8.4000	14.0000
2018.06	4.4800	4.3994	4.5606	10.2000	13.6000
2018.07	4.6553	4.6017	4.7088	0.5000	1.7000
2018.08	4.9389	4.8522	5.0256	5.9000	9.5000
2018.09	5.2649	5.1645	5.3653	1.6000	2.9000
2018.10	5.2206	5.1177	5.3236	2.5000	5.6000
2018.11	5.4514	5.3375	5.5653	3.1000	4.2000
2018.12	4.9013	4.8044	4.9981	1.6000	2.3000
2019.01	3.6003	3.5308	3.6699	5.4000	2.3000
2019.02	3.0500	2.9889	3.1112	0.1000	1.2000
2019.03	3.1796	3.1233	3.2359	6.1000	12.1000
2019.04	3.5653	3.4957	3.6348	6.2000	9.3000
2019.05	3.5098	3.4469	3.5727	7.0000	11.9000
2019.06	2.9156	2.8652	2.9660	0.7000	1.5000
2019.07	3.0398	2.9933	3.0864	0.4000	2.2000
2019.08	3.2796	3.2297	3.3295	0.3000	0.8000
2019.09	3.5717	3.5145	3.6290	0.5000	1.0000
2019.10	3.4382	3.3784	3.4979	0.2000	0.5000
2019.11	3.6517	3.5809	3.7226	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	3.1850	3.1216	3.2485	0.8000	1.0000
2020.01	7.8368	7.6813	7.9923	4.0000	5.3000
2020.02	6.5515	6.4187	6.6843	0.1000	0.0000
2020.03	6.9073	6.7754	7.0392	1.2000	1.5000
2020.04	7.7939	7.6644	7.9234	3.0000	5.1000
2020.05	7.7622	7.6390	7.8853	0.1000	0.4000
2020.06	6.4961	6.3935	6.5987	3.9000	6.4000
2020.07	6.6677	6.5665	6.7690	4.2000	7.7000
2020.08	7.1206	7.0200	7.2213	5.3000	7.8000
2020.09	7.7964	7.6637	7.9290	0.4000	0.9000
2020.10	7.7348	7.6017	7.8678	9.9000	13.6000
2020.11	8.4326	8.2422	8.6231	21.2000	33.1000
2020.12	7.7642	7.5503	7.9781	15.4000	19.8000

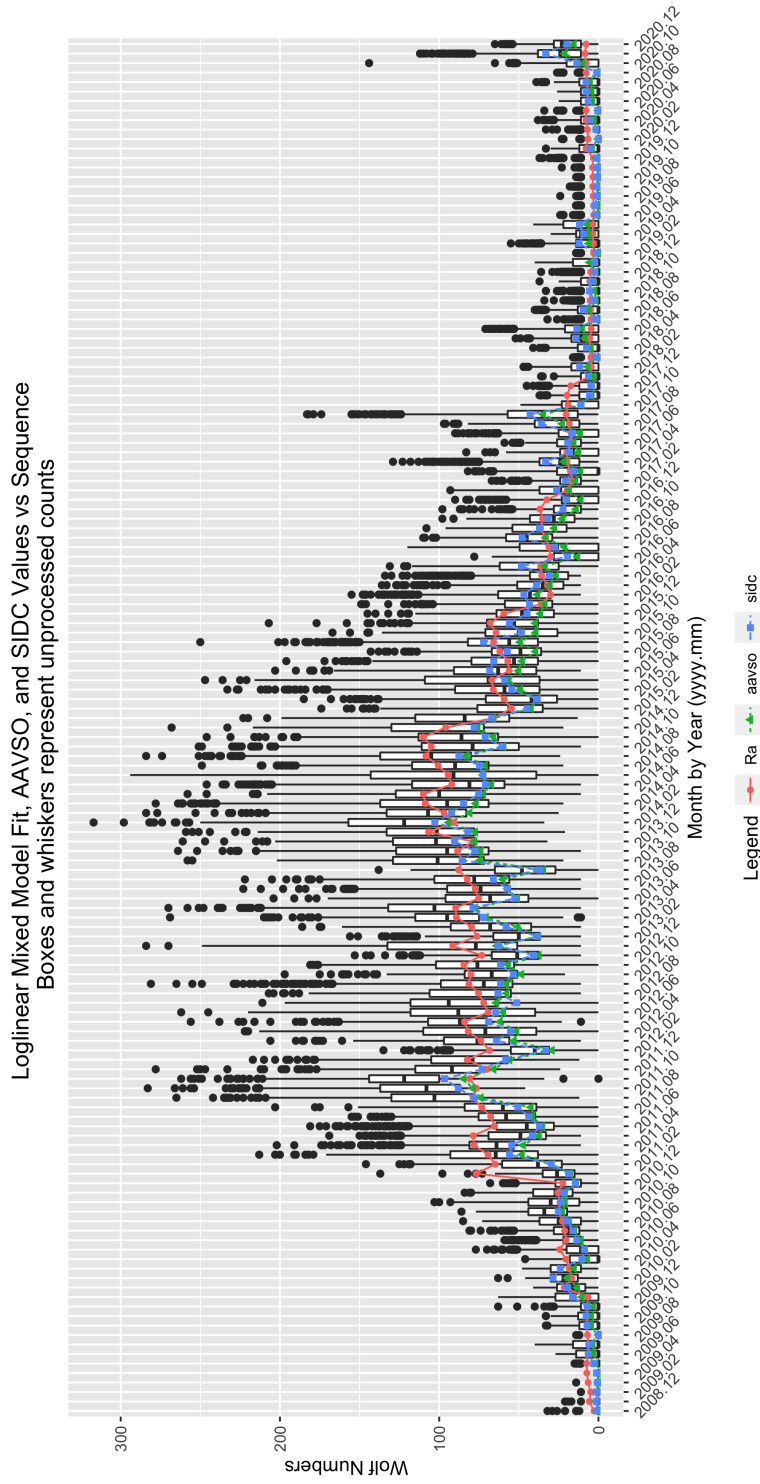


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202012 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4856	0.3106	4.7829	0.0000
seeF	-0.2182	0.0058	-37.6278	0.0000
seeG	-0.1176	0.0051	-23.2709	0.0000
seeM	-0.2009	0.0240	-8.3588	0.0000
seeP	-0.3227	0.0083	-38.9247	0.0000
sidc1	0.0220	0.0735	0.2989	0.7650
year2009	0.6482	0.3110	2.0841	0.0372
year2010	1.8768	0.3089	6.0765	0.0000
year2011	2.9991	0.3088	9.7132	0.0000
year2012	3.0364	0.3088	9.8344	0.0000
year2013	3.1323	0.3088	10.1449	0.0000
year2014	3.3293	0.3088	10.7832	0.0000
year2015	2.8440	0.3088	9.2108	0.0000
year2016	2.2272	0.3088	7.2125	0.0000
year2017	1.6197	0.3088	5.2444	0.0000
year2018	0.3297	0.3091	1.0666	0.2862
year2019	-0.0981	0.3093	-0.3171	0.7512
year2020	0.6912	0.3090	2.2368	0.0253
mon2	-0.1740	0.0092	-18.9292	0.0000
mon3	-0.1148	0.0086	-13.3742	0.0000
mon4	-0.0104	0.0083	-1.2563	0.2090
mon5	-0.0054	0.0081	-0.6684	0.5039
mon6	-0.1930	0.0085	-22.6481	0.0000
mon7	-0.1668	0.0083	-20.1419	0.0000
mon8	-0.0943	0.0081	-11.6311	0.0000
mon9	-0.0123	0.0082	-1.5049	0.1323
mon10	-0.0373	0.0083	-4.4748	0.0000
mon11	0.0232	0.0086	2.6875	0.0072
mon12	-0.1026	0.0088	-11.6308	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: 202012 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:135326	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 : 6.689	Mean :15.72		Mean :0.2565
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: 202012 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:135326	Length:135326
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 8.00	Median : 28.00	Mode :character	Mode :character
Mean : 2.727	Mean : 16.11	Mean : 43.38		
3rd Qu.: 4.000	3rd Qu.: 24.00	3rd Qu.: 70.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202012 Summary of Sunspot Numbers

inst	filter	unit
Length:135326	Length:135326	Length:135326
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202012 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 : 90.11	Mean : 31.35	Mean : 877.5	Mean : 183.8
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

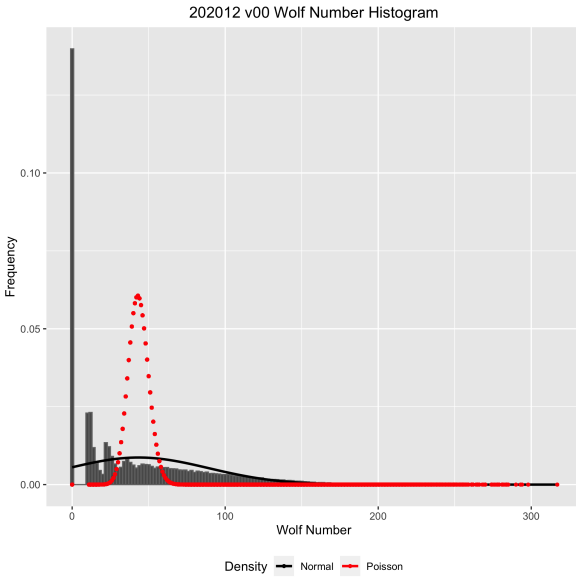


Figure 3: Box plots of raw Wolf number (w) by observer rank.

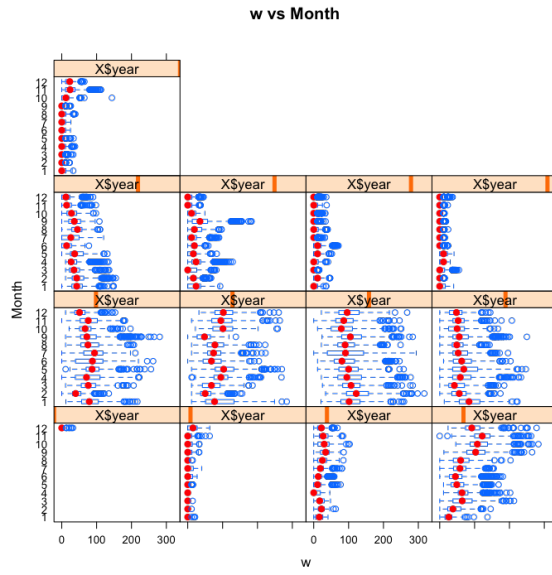


Figure 4: Box plots of raw Wolf number (w) by month and year.

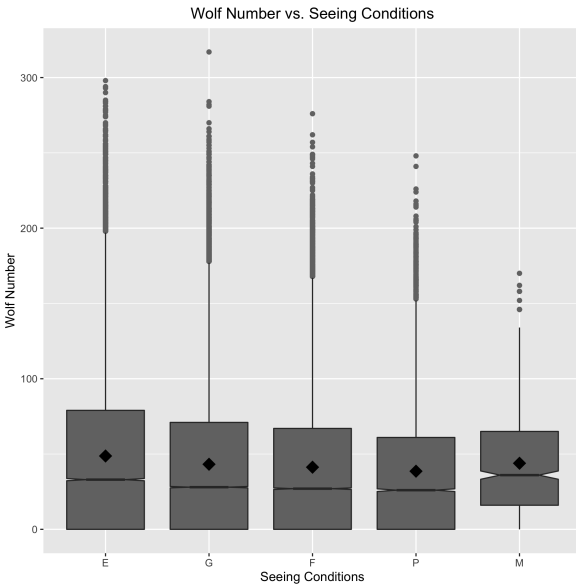


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

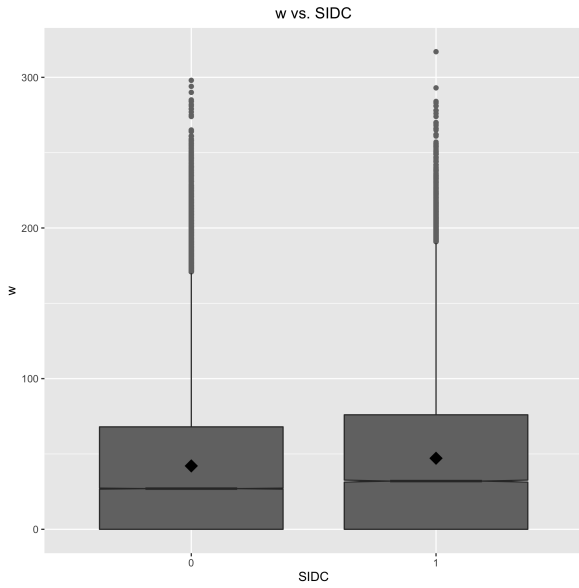


Figure 6: Box plots of raw Wolf number (w) by organization.

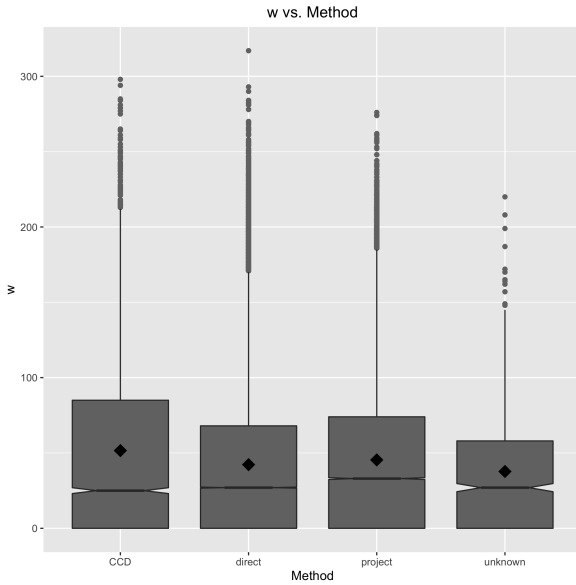


Figure 7: Box plots of raw Wolf number (w) by observer rank.

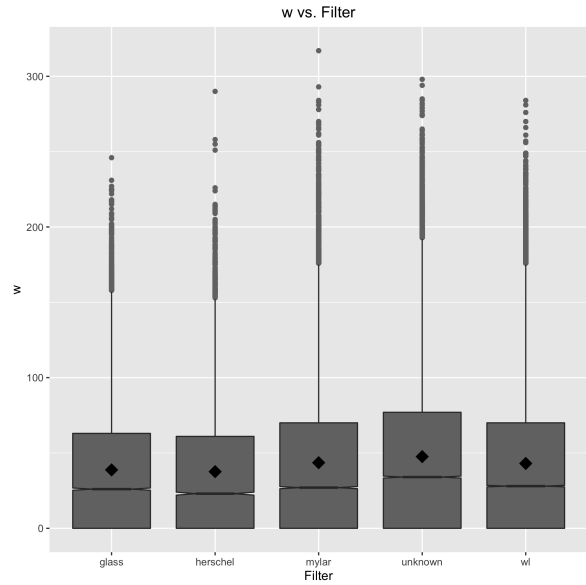


Figure 8: Box plots of raw Wolf number (w) by month and year.

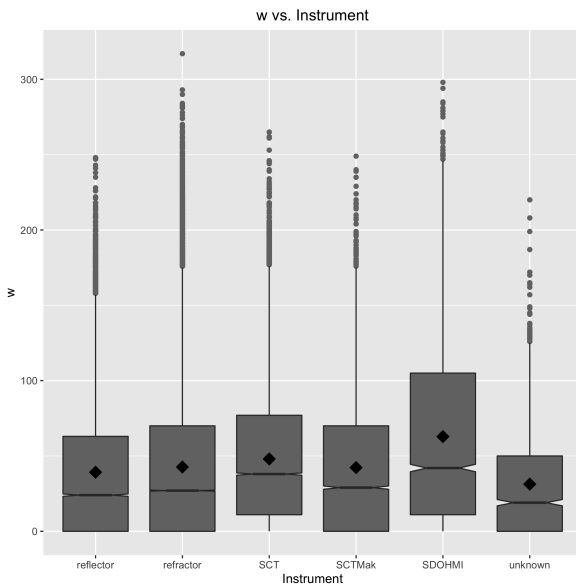


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

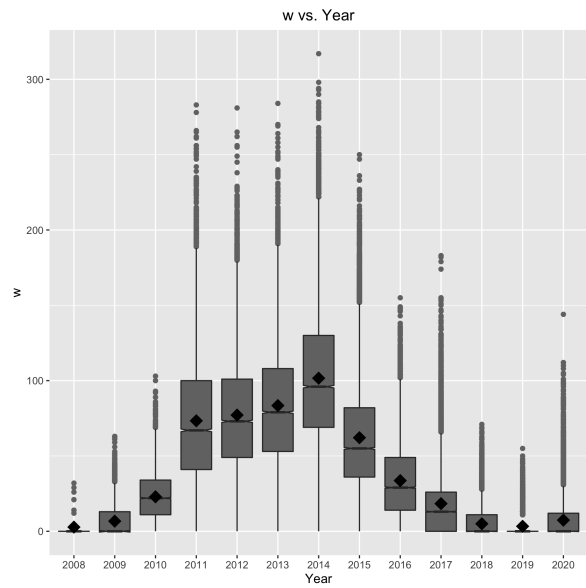


Figure 10: Box plots of raw Wolf number (w) by organization.

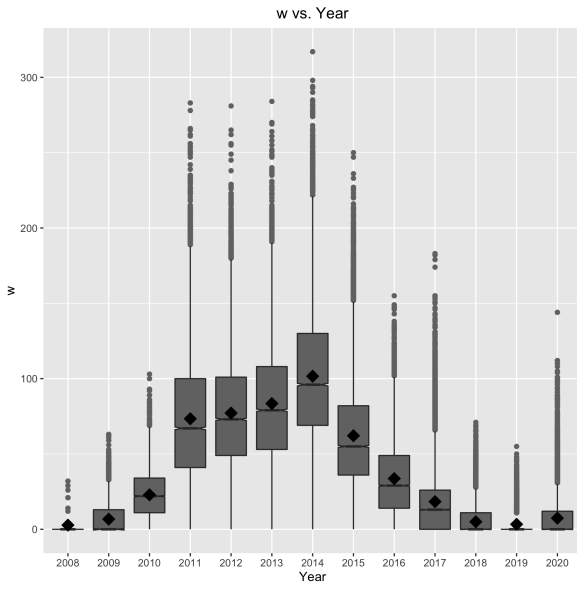


Figure 11: Box plots of raw Wolf number (w) by year.

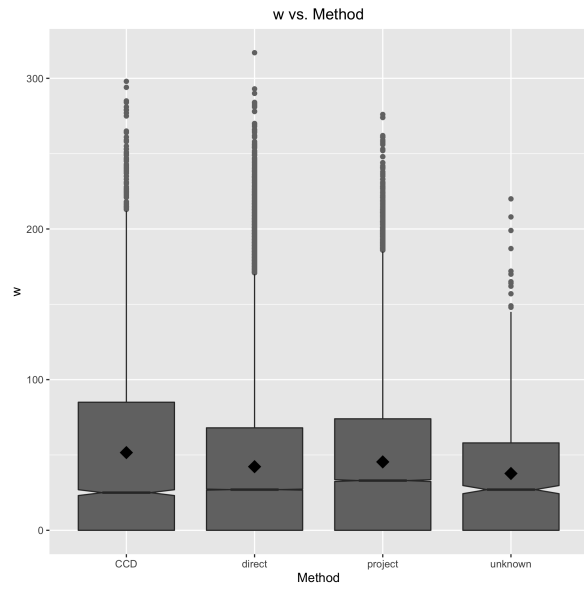


Figure 12: Box plots of raw Wolf number (w) by observing method.