

Monthly Report (00)

2021.02 Data Set

Saturday 13th March, 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.

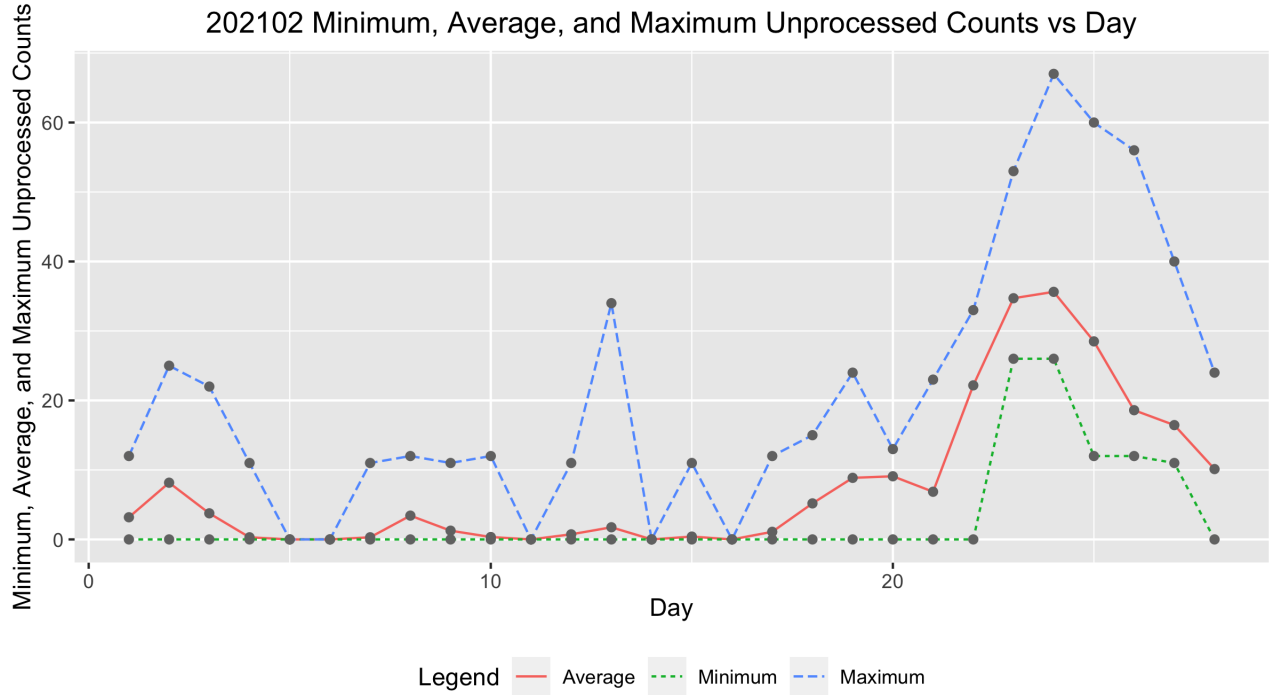


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202102 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	32.0000	0.0000	3.1875	12.0000
2.0000	37.0000	0.0000	8.1622	25.0000
3.0000	41.0000	0.0000	3.7561	22.0000
4.0000	36.0000	0.0000	0.3056	11.0000
5.0000	33.0000	0.0000	0.0000	0.0000
6.0000	35.0000	0.0000	0.0000	0.0000
7.0000	36.0000	0.0000	0.3056	11.0000
8.0000	33.0000	0.0000	3.4242	12.0000
9.0000	35.0000	0.0000	1.2571	11.0000
10.0000	35.0000	0.0000	0.3429	12.0000
11.0000	35.0000	0.0000	0.0000	0.0000
12.0000	30.0000	0.0000	0.7333	11.0000
13.0000	32.0000	0.0000	1.7500	34.0000
14.0000	35.0000	0.0000	0.0000	0.0000
15.0000	27.0000	0.0000	0.4074	11.0000
16.0000	37.0000	0.0000	0.0000	0.0000
17.0000	32.0000	0.0000	1.0938	12.0000
18.0000	27.0000	0.0000	5.1852	15.0000
19.0000	36.0000	0.0000	8.8611	24.0000
20.0000	46.0000	0.0000	9.0870	13.0000
21.0000	43.0000	0.0000	6.8605	23.0000
22.0000	35.0000	0.0000	22.1714	33.0000
23.0000	45.0000	26.0000	34.7111	53.0000
24.0000	46.0000	26.0000	35.6304	67.0000
25.0000	48.0000	12.0000	28.5000	60.0000
26.0000	47.0000	12.0000	18.5957	56.0000
27.0000	42.0000	11.0000	16.4524	40.0000
28.0000	41.0000	0.0000	10.1220	24.0000

3 Error Tables

Data are for the month of February 2021. 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	2.4025	3.1385	0.5000	1.0000
2009.01	5.7028	5.0756	6.3300	1.3000	1.3000
2009.02	4.9039	4.3498	5.4580	0.7000	1.2000
2009.03	6.4751	6.2206	6.7295	0.3000	0.6000
2009.04	7.2939	7.0287	7.5591	0.4000	1.2000
2009.05	7.3425	7.0483	7.6368	1.6000	2.9000
2009.06	6.5043	6.1720	6.8367	3.2000	6.3000
2009.07	6.2094	5.9573	6.4615	3.6000	5.5000
2009.08	6.8735	6.5983	7.1487	0.0000	0.0000
2009.09	7.2375	6.9768	7.4981	4.5000	7.1000
2009.10	6.9615	6.5914	7.3316	4.5000	7.7000
2009.11	7.1914	6.9923	7.3905	3.3000	6.9000
2009.12	6.5875	6.3991	6.7759	10.4000	16.3000
2010.01	21.4777	18.9957	23.9597	13.3000	19.5000
2010.02	16.7493	14.4342	19.0644	19.4000	28.5000

Continued on next page

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2010.03	18.3558	16.0439	20.6678	15.4000	24.0000
2010.04	20.4274	17.9828	22.8719	7.0000	10.4000
2010.05	24.3480	23.9147	24.7813	8.4000	8.7000
2010.06	20.2443	19.9080	20.5805	11.0000	13.6000
2010.07	21.1752	20.8672	21.4832	15.2000	16.1000
2010.08	22.6759	22.3041	23.0478	18.3000	19.6000
2010.09	24.7693	24.3617	25.1768	22.8000	25.2000
2010.10	24.1063	23.6905	24.5222	21.0000	23.5000
2010.11	25.5150	25.0523	25.9777	20.9000	21.6000
2010.12	22.4320	21.9804	22.8836	13.9000	14.5000
2011.01	76.5645	74.9917	78.1372	17.7000	18.7000
2011.02	65.0263	63.6521	66.4005	29.1000	29.6000
2011.03	69.3094	67.9849	70.6338	48.0000	55.8000
2011.04	77.9932	76.5966	79.3897	47.3000	54.4000
2011.05	78.6446	77.3225	79.9667	37.3000	41.5000
2011.06	65.3301	64.1917	66.4684	35.2000	37.0000
2011.07	67.6241	66.4744	68.7738	41.5000	43.8000
2011.08	73.2625	72.0918	74.4332	42.4000	50.5000
2011.09	78.7759	77.4121	80.1396	73.8000	78.0000
2011.10	76.6517	75.3681	77.9354	78.9000	88.0000
2011.11	80.9060	79.2266	82.5854	84.6000	96.7000
2011.12	69.9936	68.5598	71.4273	65.8000	73.0000
2012.01	82.1699	80.5564	83.7833	55.8000	58.2000
2012.02	68.5620	67.1697	69.9543	29.2000	33.1000
2012.03	73.7974	72.4928	75.1020	53.1000	64.1000
2012.04	81.7941	80.3672	83.2209	51.4000	55.2000
2012.05	84.1098	82.7283	85.4913	61.8000	69.0000
2012.06	69.1518	67.9833	70.3203	59.7000	64.5000
2012.07	72.0157	70.8396	73.1918	64.2000	51.3000
2012.08	75.2479	74.0439	76.4519	57.7000	63.1000
2012.09	81.3709	79.9613	82.7804	57.7000	61.5000
2012.10	80.0664	78.6037	81.5291	48.3000	53.3000
2012.11	84.5020	82.8072	86.1969	56.7000	61.4000
2012.12	73.2907	71.7021	74.8792	37.4000	40.8000
2013.01	91.3394	89.5946	93.0842	63.8000	62.9000
2013.02	76.3749	74.8386	77.9112	37.8000	38.0000
2013.03	79.6250	78.0033	81.2466	50.6000	57.9000
2013.04	89.1964	87.6262	90.7667	70.6000	72.4000
2013.05	89.6338	88.0362	91.2313	77.4000	78.7000

Continued on next page

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2013.06	75.2237	73.8953	76.5521	51.0000	52.5000
2013.07	77.3670	76.1249	78.6092	57.0000	57.0000
2013.08	82.3957	81.0696	83.7218	60.0000	66.0000
2013.09	87.7804	86.2130	89.3478	34.6000	36.9000
2013.10	85.3472	83.7628	86.9315	74.5000	85.6000
2013.11	88.4455	86.4582	90.4328	73.9000	77.6000
2013.12	78.8924	77.2039	80.5809	77.8000	90.3000
2014.01	106.4389	104.1966	108.6812	77.4000	82.0000
2014.02	90.8041	89.0119	92.5963	93.9000	102.8000
2014.03	96.8811	95.1125	98.6498	80.9000	92.2000
2014.04	108.6933	106.7916	110.5949	76.9000	84.7000
2014.05	109.8856	108.0092	111.7620	72.3000	75.2000
2014.06	92.0337	90.4768	93.5906	67.2000	71.0000
2014.07	94.3121	92.7396	95.8846	72.5000	72.5000
2014.08	100.6012	99.0273	102.1750	71.2000	74.7000
2014.09	108.3289	106.4164	110.2413	83.2000	87.6000
2014.10	104.9590	103.0249	106.8931	59.5000	60.6000
2014.11	109.9559	107.6664	112.2454	65.8000	71.1000
2014.12	95.9939	93.7685	98.2194	75.8000	78.0000
2015.01	65.7626	64.4450	67.0802	65.9000	67.0000
2015.02	54.7283	53.5222	55.9344	42.4000	44.8000
2015.03	59.1810	58.0982	60.2637	38.0000	38.4000
2015.04	65.9906	64.8108	67.1704	49.0000	54.4000
2015.05	66.9991	65.8921	68.1061	56.3000	58.8000
2015.06	56.0121	55.0045	57.0197	50.2000	68.3000
2015.07	56.9380	55.9690	57.9069	47.9000	65.8000
2015.08	61.9203	60.8815	62.9592	39.5000	57.2000
2015.09	65.8407	64.6451	67.0363	49.2000	72.1000
2015.10	64.2653	63.0250	65.5055	39.3000	48.3000
2015.11	68.0031	66.5232	69.4831	39.6000	55.9000
2015.12	59.4296	58.1160	60.7432	36.4000	44.8000
2016.01	36.0158	35.2654	36.7661	33.7000	43.3000
2016.02	30.1013	29.4739	30.7287	38.3000	46.8000
2016.03	32.0062	31.3675	32.6449	30.5000	38.9000
2016.04	35.5960	34.9182	36.2738	26.6000	30.9000
2016.05	36.2239	35.5625	36.8852	33.7000	48.4000
2016.06	29.9581	29.4469	30.4692	13.1000	19.5000
2016.07	30.9801	30.4820	31.4782	21.2000	27.5000
2016.08	33.3519	32.7656	33.9383	33.0000	47.9000

Continued on next page

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2016.09	36.3094	35.6472	36.9715	27.7000	37.1000
2016.10	35.0588	34.3839	35.7338	22.7000	31.7000
2016.11	36.7123	35.9457	37.4789	14.0000	22.2000
2016.12	32.4927	31.7972	33.1881	11.1000	20.0000
2017.01	19.5505	19.1393	19.9618	18.4000	26.2000
2017.02	16.4084	16.0483	16.7685	14.4000	20.6000
2017.03	17.6016	17.2661	17.9370	11.3000	15.5000
2017.04	19.7780	19.4291	20.1268	21.6000	33.2000
2017.05	19.8180	19.4764	20.1597	12.5000	18.1000
2017.06	16.3694	16.0969	16.6418	15.5000	19.3000
2017.07	17.0222	16.7513	17.2931	11.5000	16.3000
2017.08	18.2719	17.9508	18.5930	22.8000	35.7000
2017.09	20.2824	19.8345	20.7303	34.6000	42.9000
2017.10	19.0416	18.6449	19.4383	10.5000	11.0000
2017.11	19.7592	19.3408	20.1776	4.2000	5.6000
2017.12	17.3849	17.1194	17.6503	4.0000	4.6000
2018.01	5.4375	5.3199	5.5551	3.1000	6.3000
2018.02	4.5267	4.4150	4.6384	6.8000	11.8000
2018.03	4.7724	4.6756	4.8691	1.1000	1.2000
2018.04	5.3112	5.2031	5.4193	4.7000	7.5000
2018.05	5.4102	5.3068	5.5135	8.4000	14.0000
2018.06	4.4793	4.3991	4.5594	10.2000	13.6000
2018.07	4.6554	4.6021	4.7087	0.5000	1.7000
2018.08	4.9399	4.8539	5.0260	5.9000	9.5000
2018.09	5.2668	5.1670	5.3667	1.6000	2.9000
2018.10	5.2222	5.1194	5.3250	2.5000	5.6000
2018.11	5.4511	5.3373	5.5648	3.1000	4.2000
2018.12	4.9013	4.8047	4.9980	1.6000	2.3000
2019.01	3.5914	3.5224	3.6604	5.4000	2.3000
2019.02	3.0545	2.9937	3.1153	0.1000	1.2000
2019.03	3.1789	3.1232	3.2346	6.1000	12.1000
2019.04	3.5641	3.4952	3.6330	6.2000	9.3000
2019.05	3.5100	3.4476	3.5724	7.0000	11.9000
2019.06	2.9160	2.8660	2.9660	0.7000	1.5000
2019.07	3.0394	2.9933	3.0856	0.4000	2.2000
2019.08	3.2794	3.2299	3.3288	0.3000	0.8000
2019.09	3.5725	3.5157	3.6293	0.5000	1.0000
2019.10	3.4391	3.3799	3.4983	0.2000	0.5000
2019.11	3.6539	3.5835	3.7244	0.3000	0.6000

Continued on next page

Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2019.12	3.1885	3.1253	3.2518	0.8000	1.0000
2020.01	7.8768	7.7213	8.0324	4.0000	5.3000
2020.02	6.6118	6.4785	6.7451	0.1000	0.0000
2020.03	6.9564	6.8248	7.0881	1.2000	1.5000
2020.04	7.8517	7.7219	7.9814	3.0000	5.1000
2020.05	7.8191	7.6959	7.9423	0.1000	0.4000
2020.06	6.5427	6.4406	6.6448	3.9000	6.4000
2020.07	6.7054	6.6048	6.8059	4.2000	7.7000
2020.08	7.1417	7.0425	7.2409	5.3000	7.8000
2020.09	7.7956	7.6683	7.9228	0.4000	0.9000
2020.10	7.7131	7.5857	7.8404	9.9000	13.6000
2020.11	8.3093	8.1562	8.4624	21.2000	33.1000
2020.12	7.4918	7.3381	7.6455	15.4000	19.8000
2021.01	9.8190	9.6162	10.0219	7.0000	15.8000
2021.02	8.3138	8.1378	8.4898	5.8000	10.7000

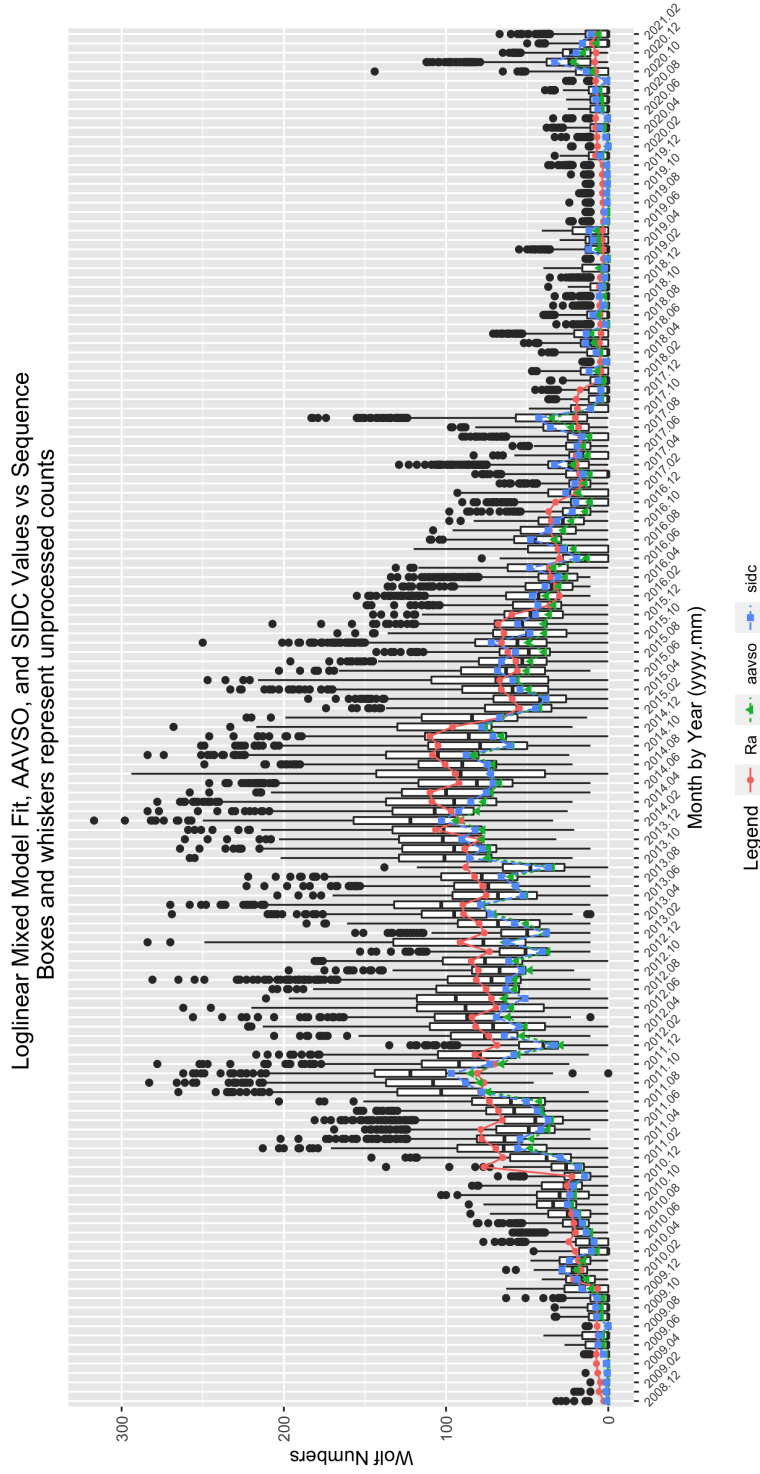


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202102 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t)$
(Intercept)	1.4662	0.3103	4.7249	0.0000
seeF	-0.2187	0.0058	-37.7800	0.0000
seeG	-0.1183	0.0050	-23.4387	0.0000
seeM	-0.2022	0.0240	-8.4118	0.0000
seeP	-0.3233	0.0083	-39.0671	0.0000
sidc1	0.0197	0.0671	0.2930	0.7695
year2009	0.6502	0.3110	2.0904	0.0366
year2010	1.8791	0.3089	6.0842	0.0000
year2011	3.0016	0.3088	9.7214	0.0000
year2012	3.0388	0.3088	9.8423	0.0000
year2013	3.1347	0.3088	10.1529	0.0000
year2014	3.3317	0.3087	10.7910	0.0000
year2015	2.8463	0.3088	9.2184	0.0000
year2016	2.2295	0.3088	7.2200	0.0000
year2017	1.6221	0.3088	5.2524	0.0000
year2018	0.3328	0.3091	1.0767	0.2816
year2019	-0.0940	0.3093	-0.3040	0.7611
year2020	0.7026	0.3090	2.2737	0.0230
year2021	0.8855	0.3103	2.8539	0.0043
mon2	-0.1701	0.0091	-18.7297	0.0000
mon3	-0.1130	0.0086	-13.1973	0.0000
mon4	-0.0087	0.0083	-1.0553	0.2913
mon5	-0.0037	0.0081	-0.4605	0.6451
mon6	-0.1913	0.0085	-22.5024	0.0000
mon7	-0.1651	0.0083	-19.9854	0.0000
mon8	-0.0925	0.0081	-11.4434	0.0000
mon9	-0.0104	0.0081	-1.2785	0.2011
mon10	-0.0354	0.0083	-4.2563	0.0000
mon11	0.0253	0.0086	2.9441	0.0032
mon12	-0.1000	0.0088	-11.3692	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: 202102 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:137382	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 : 6.612	Mean :15.72		Mean :0.2558
3rd Qu.:2018	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2021	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202102 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:137382	Length:137382
1st Qu.: 0.000	1st Qu.: 0.0	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 7.0	Median : 27.00	Mode :character	Mode :character
Mean : 2.696	Mean : 15.9	Mean : 42.86		
3rd Qu.: 4.000	3rd Qu.: 24.0	3rd Qu.: 70.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 202102 Summary of Sunspot Numbers

inst	filter	unit
Length:137382	Length:137382	Length:137382
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202102 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 51.00	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 : 90.33	Mean : 31.89	Mean : 878.9	Mean : 183.6
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

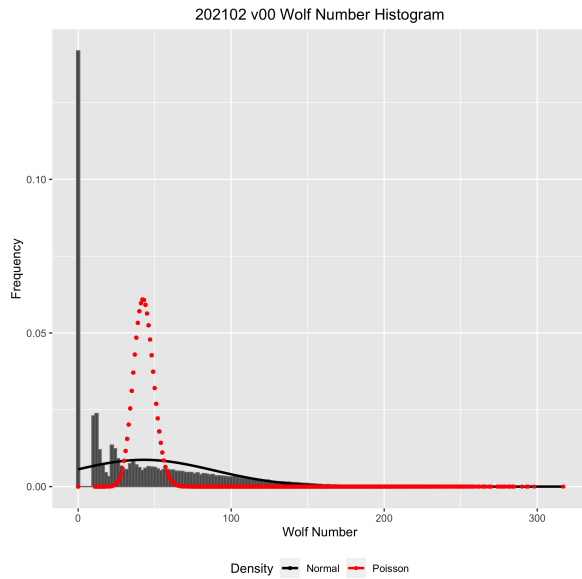


Figure 3: Box plots of raw Wolf number (w) by observer rank.

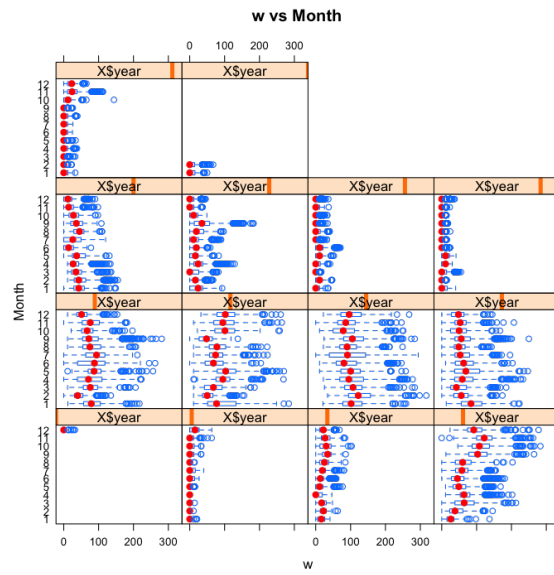


Figure 4: Box plots of raw Wolf number (w) by month and year.

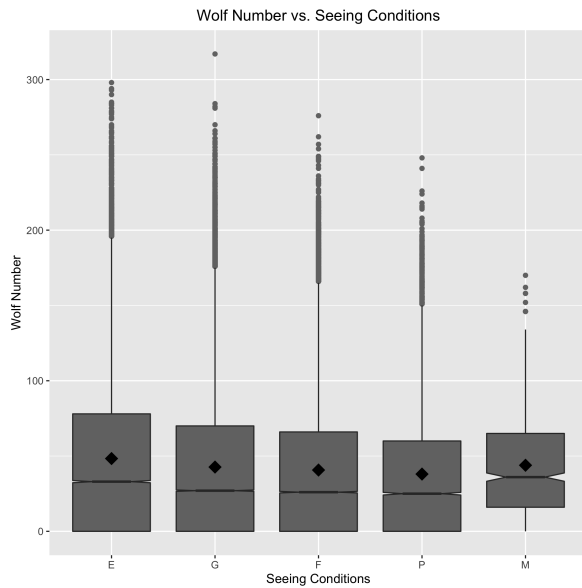


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

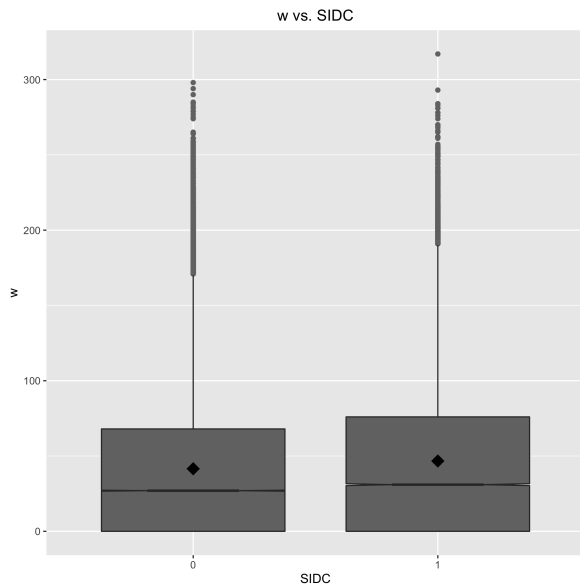


Figure 6: Box plots of raw Wolf number (w) by organization.

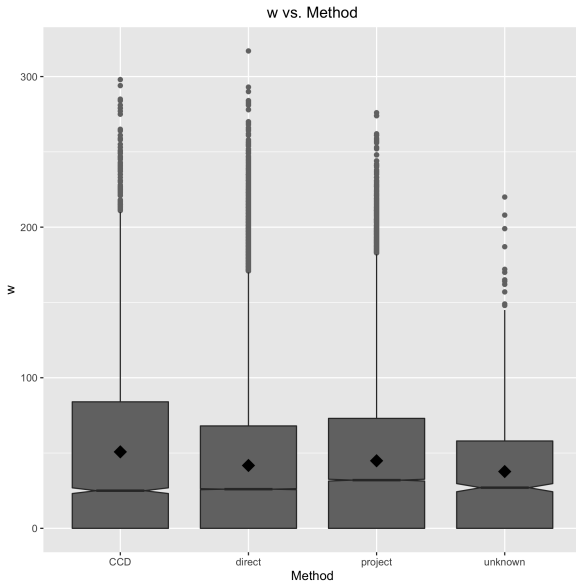


Figure 7: Box plots of raw Wolf number (w) by observer rank.

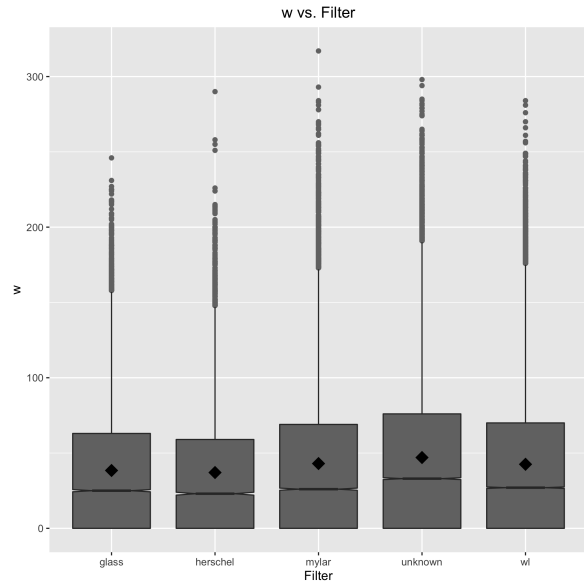


Figure 8: Box plots of raw Wolf number (w) by month and year.

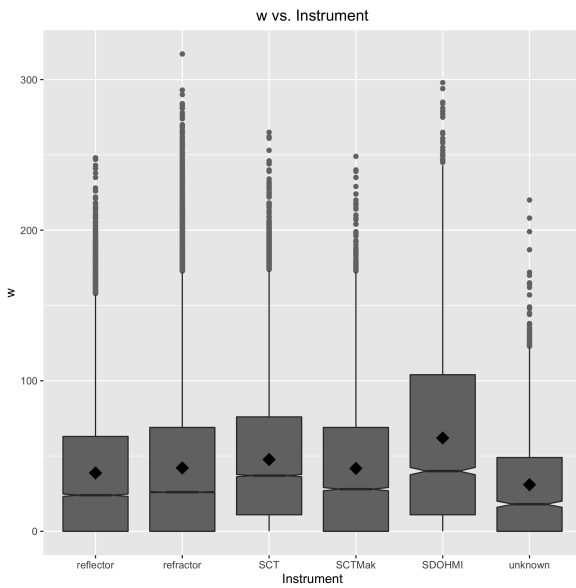


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

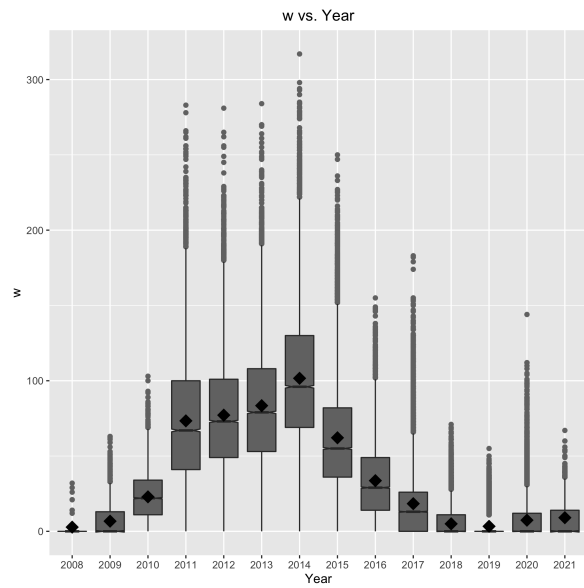


Figure 10: Box plots of raw Wolf number (w) by organization.

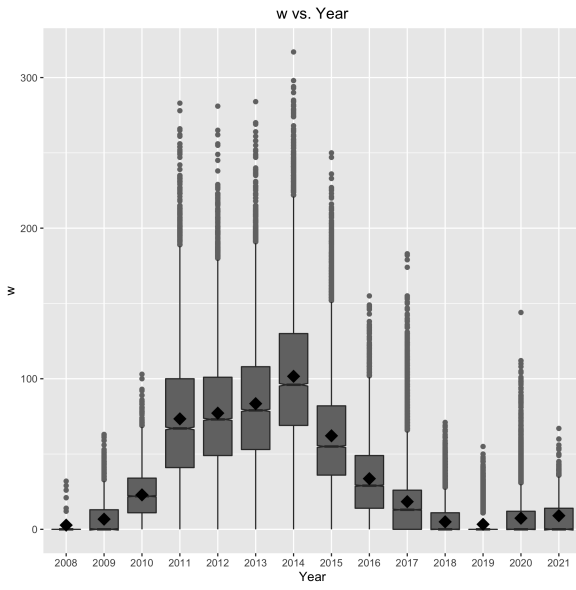


Figure 11: Box plots of raw Wolf number (w) by year.

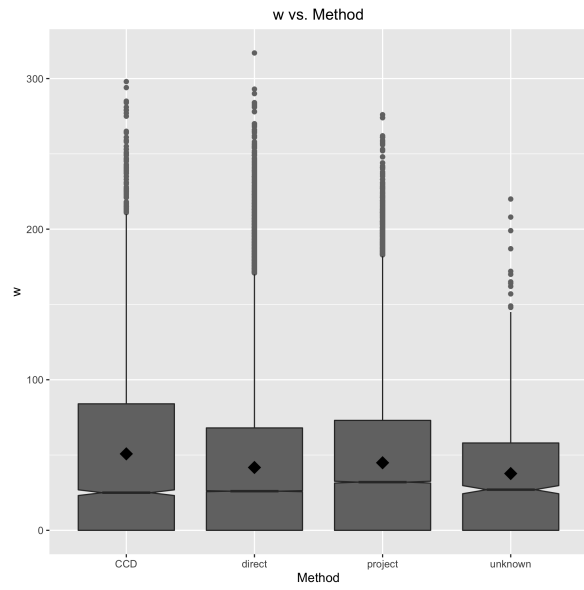


Figure 12: Box plots of raw Wolf number (w) by observing method.