

Monthly Report (00)

2021.04 Data Set

Friday 14th May, 2021

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.

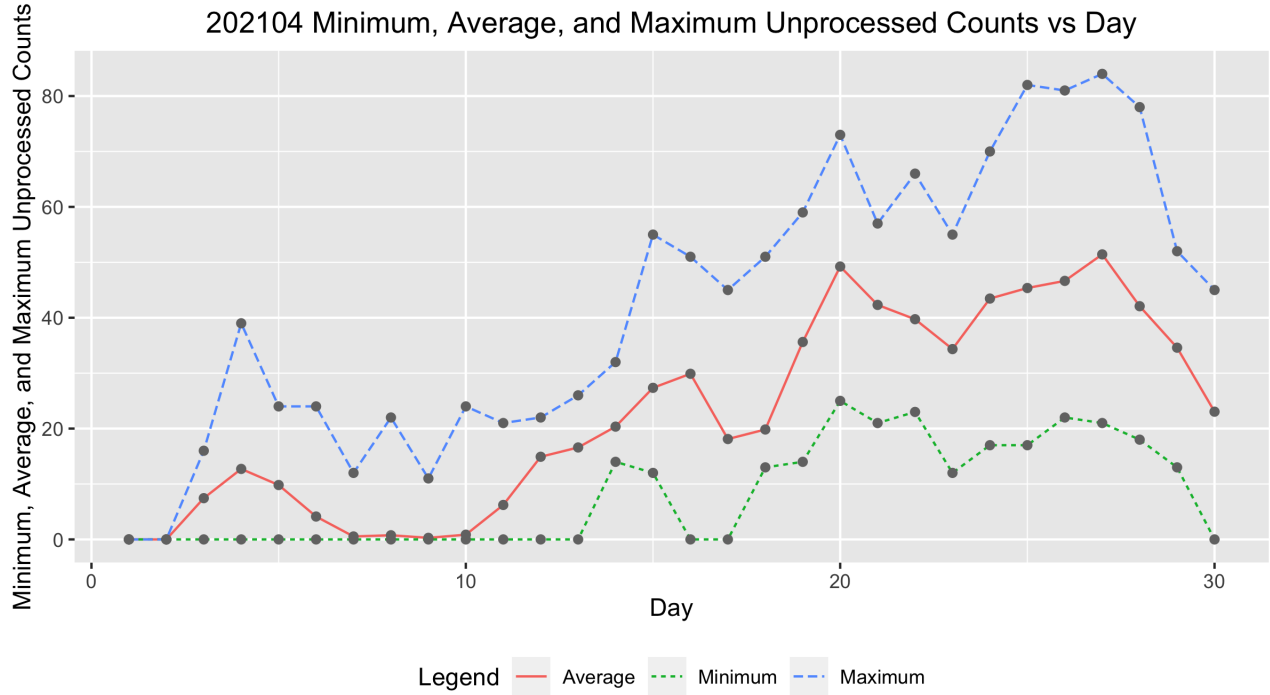


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202104 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	47.0000	0.0000	0.0000	0.0000
2.0000	50.0000	0.0000	0.0000	0.0000
3.0000	43.0000	0.0000	7.4419	16.0000
4.0000	50.0000	0.0000	12.7200	39.0000
5.0000	43.0000	0.0000	9.8140	24.0000
6.0000	46.0000	0.0000	4.1304	24.0000
7.0000	43.0000	0.0000	0.5349	12.0000
8.0000	44.0000	0.0000	0.7500	22.0000
9.0000	39.0000	0.0000	0.2821	11.0000
10.0000	41.0000	0.0000	0.8537	24.0000
11.0000	37.0000	0.0000	6.2162	21.0000
12.0000	46.0000	0.0000	14.9130	22.0000
13.0000	49.0000	0.0000	16.5918	26.0000
14.0000	40.0000	14.0000	20.3500	32.0000
15.0000	40.0000	12.0000	27.3500	55.0000
16.0000	35.0000	0.0000	29.8857	51.0000
17.0000	44.0000	0.0000	18.1136	45.0000
18.0000	48.0000	13.0000	19.8333	51.0000
19.0000	45.0000	14.0000	35.6222	59.0000
20.0000	46.0000	25.0000	49.2391	73.0000
21.0000	48.0000	21.0000	42.3125	57.0000
22.0000	52.0000	23.0000	39.7308	66.0000
23.0000	50.0000	12.0000	34.3400	55.0000
24.0000	48.0000	17.0000	43.4583	70.0000
25.0000	47.0000	17.0000	45.3617	82.0000
26.0000	51.0000	22.0000	46.6471	81.0000
27.0000	44.0000	21.0000	51.4318	84.0000
28.0000	38.0000	18.0000	42.0789	78.0000
29.0000	37.0000	13.0000	34.5946	52.0000
30.0000	44.0000	0.0000	23.0455	45.0000

3 Error Tables

Data are for the month of April 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	2.4054	3.1356	0.5000	1.0000
2009.01	5.6383	5.0233	6.2534	1.3000	1.3000
2009.02	4.8416	4.2990	5.3843	0.7000	1.2000
2009.03	6.4909	6.2355	6.7463	0.3000	0.6000
2009.04	7.4167	7.1468	7.6865	0.4000	1.2000
2009.05	7.3400	7.0460	7.6341	1.6000	2.9000
2009.06	6.5015	6.1690	6.8341	3.2000	6.3000
2009.07	6.2077	5.9555	6.4599	3.6000	5.5000
2009.08	6.8712	6.5965	7.1460	0.0000	0.0000
2009.09	7.2361	6.9755	7.4968	4.5000	7.1000
2009.10	6.9610	6.5914	7.3307	4.5000	7.7000
2009.11	7.1942	6.9962	7.3923	3.3000	6.9000
2009.12	6.5906	6.4031	6.7781	10.4000	16.3000
2010.01	21.2307	18.7958	23.6655	13.3000	19.5000
2010.02	16.5480	14.2796	18.8165	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	18.4398	16.1358	20.7437	15.4000	24.0000
2010.04	20.8159	18.3447	23.2872	7.0000	10.4000
2010.05	24.3511	23.9198	24.7824	8.4000	8.7000
2010.06	20.2402	19.9045	20.5759	11.0000	13.6000
2010.07	21.1678	20.8605	21.4750	15.2000	16.1000
2010.08	22.6712	22.3000	23.0424	18.3000	19.6000
2010.09	24.7661	24.3593	25.1728	22.8000	25.2000
2010.10	24.1063	23.6914	24.5212	21.0000	23.5000
2010.11	25.5104	25.0482	25.9726	20.9000	21.6000
2010.12	22.4475	21.9974	22.8975	13.9000	14.5000
2011.01	75.5981	74.0518	77.1443	17.7000	18.7000
2011.02	64.1299	62.7812	65.4786	29.1000	29.6000
2011.03	69.4788	68.1548	70.8027	48.0000	55.8000
2011.04	79.2914	77.8714	80.7113	47.3000	54.4000
2011.05	78.6267	77.3060	79.9473	37.3000	41.5000
2011.06	65.3170	64.1800	66.4539	35.2000	37.0000
2011.07	67.6072	66.4587	68.7556	41.5000	43.8000
2011.08	73.2508	72.0813	74.4202	42.4000	50.5000
2011.09	78.7534	77.3926	80.1141	73.8000	78.0000
2011.10	76.6418	75.3587	77.9249	78.9000	88.0000
2011.11	80.9090	79.2311	82.5869	84.6000	96.7000
2011.12	70.0113	68.5783	71.4444	65.8000	73.0000
2012.01	81.1066	79.5140	82.6992	55.8000	58.2000
2012.02	67.5972	66.2243	68.9701	29.2000	33.1000
2012.03	74.0008	72.6928	75.3088	53.1000	64.1000
2012.04	83.2011	81.7492	84.6531	51.4000	55.2000
2012.05	84.1102	82.7286	85.4918	61.8000	69.0000
2012.06	69.1526	67.9841	70.3212	59.7000	64.5000
2012.07	72.0210	70.8449	73.1971	64.2000	51.3000
2012.08	75.2470	74.0427	76.4513	57.7000	63.1000
2012.09	81.3813	79.9718	82.7907	57.7000	61.5000
2012.10	80.0751	78.6125	81.5376	48.3000	53.3000
2012.11	84.5320	82.8369	86.2271	56.7000	61.4000
2012.12	73.3296	71.7401	74.9190	37.4000	40.8000
2013.01	90.1495	88.4274	91.8716	63.8000	62.9000
2013.02	75.2926	73.7783	76.8070	37.8000	38.0000
2013.03	79.8335	78.2077	81.4594	50.6000	57.9000
2013.04	90.7166	89.1197	92.3135	70.6000	72.4000
2013.05	89.6162	88.0194	91.2129	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	75.2152	73.8869	76.5434	51.0000	52.5000
2013.07	77.3538	76.1116	78.5959	57.0000	57.0000
2013.08	82.3928	81.0669	83.7188	60.0000	66.0000
2013.09	87.7820	86.2146	89.3494	34.6000	36.9000
2013.10	85.3504	83.7662	86.9347	74.5000	85.6000
2013.11	88.4729	86.4842	90.4617	73.9000	77.6000
2013.12	78.9266	77.2374	80.6158	77.8000	90.3000
2014.01	105.0577	102.8446	107.2708	77.4000	82.0000
2014.02	89.5130	87.7466	91.2794	93.9000	102.8000
2014.03	97.1416	95.3688	98.9144	80.9000	92.2000
2014.04	110.5463	108.6118	112.4808	76.9000	84.7000
2014.05	109.8740	107.9985	111.7495	72.3000	75.2000
2014.06	92.0312	90.4752	93.5871	67.2000	71.0000
2014.07	94.3057	92.7340	95.8774	72.5000	72.5000
2014.08	100.6088	99.0361	102.1815	71.2000	74.7000
2014.09	108.3472	106.4358	110.2585	83.2000	87.6000
2014.10	104.9680	103.0340	106.9021	59.5000	60.6000
2014.11	109.9959	107.7076	112.2842	65.8000	71.1000
2014.12	96.0347	93.8092	98.2602	75.8000	78.0000
2015.01	64.9121	63.6130	66.2113	65.9000	67.0000
2015.02	53.9538	52.7653	55.1422	42.4000	44.8000
2015.03	59.3368	58.2519	60.4217	38.0000	38.4000
2015.04	67.1261	65.9273	68.3250	49.0000	54.4000
2015.05	66.9972	65.8915	68.1029	56.3000	58.8000
2015.06	56.0043	54.9976	57.0110	50.2000	68.3000
2015.07	56.9280	55.9597	57.8964	47.9000	65.8000
2015.08	61.9123	60.8744	62.9503	39.5000	57.2000
2015.09	65.8423	64.6474	67.0372	49.2000	72.1000
2015.10	64.2636	63.0238	65.5033	39.3000	48.3000
2015.11	68.0065	66.5272	69.4857	39.6000	55.9000
2015.12	59.4454	58.1327	60.7581	36.4000	44.8000
2016.01	35.5494	34.8089	36.2898	33.7000	43.3000
2016.02	29.6760	29.0577	30.2943	38.3000	46.8000
2016.03	32.0966	31.4564	32.7368	30.5000	38.9000
2016.04	36.2083	35.5193	36.8974	26.6000	30.9000
2016.05	36.2297	35.5690	36.8905	33.7000	48.4000
2016.06	29.9556	29.4446	30.4665	13.1000	19.5000
2016.07	30.9936	30.4963	31.4909	21.2000	27.5000
2016.08	33.3567	32.7709	33.9425	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	36.3108	35.6490	36.9725	27.7000	37.1000
2016.10	35.0660	34.3915	35.7405	22.7000	31.7000
2016.11	36.7167	35.9500	37.4834	14.0000	22.2000
2016.12	32.5053	31.8092	33.2014	11.1000	20.0000
2017.01	19.2994	18.8932	19.7056	18.4000	26.2000
2017.02	16.1786	15.8234	16.5338	14.4000	20.6000
2017.03	17.6546	17.3184	17.9909	11.3000	15.5000
2017.04	20.1223	19.7677	20.4769	21.6000	33.2000
2017.05	19.8190	19.4772	20.1609	12.5000	18.1000
2017.06	16.3714	16.0985	16.6442	15.5000	19.3000
2017.07	17.0207	16.7492	17.2922	11.5000	16.3000
2017.08	18.2670	17.9463	18.5877	22.8000	35.7000
2017.09	20.2628	19.8234	20.7022	34.6000	42.9000
2017.10	19.0348	18.6394	19.4302	10.5000	11.0000
2017.11	19.7610	19.3419	20.1801	4.2000	5.6000
2017.12	17.3952	17.1294	17.6610	4.0000	4.6000
2018.01	5.3714	5.2559	5.4869	3.1000	6.3000
2018.02	4.4632	4.3538	4.5725	6.8000	11.8000
2018.03	4.7856	4.6885	4.8826	1.1000	1.2000
2018.04	5.4001	5.2908	5.5093	4.7000	7.5000
2018.05	5.4075	5.3050	5.5100	8.4000	14.0000
2018.06	4.4803	4.4006	4.5600	10.2000	13.6000
2018.07	4.6560	4.6029	4.7091	0.5000	1.7000
2018.08	4.9419	4.8564	5.0274	5.9000	9.5000
2018.09	5.2678	5.1683	5.3673	1.6000	2.9000
2018.10	5.2246	5.1218	5.3275	2.5000	5.6000
2018.11	5.4522	5.3383	5.5660	3.1000	4.2000
2018.12	4.9023	4.8058	4.9988	1.6000	2.3000
2019.01	3.5401	3.4723	3.6079	5.4000	2.3000
2019.02	3.0083	2.9488	3.0678	0.1000	1.2000
2019.03	3.1855	3.1303	3.2408	6.1000	12.1000
2019.04	3.6236	3.5542	3.6930	6.2000	9.3000
2019.05	3.5093	3.4475	3.5710	7.0000	11.9000
2019.06	2.9177	2.8682	2.9672	0.7000	1.5000
2019.07	3.0402	2.9945	3.0859	0.4000	2.2000
2019.08	3.2805	3.2317	3.3294	0.3000	0.8000
2019.09	3.5744	3.5182	3.6306	0.5000	1.0000
2019.10	3.4417	3.3833	3.5001	0.2000	0.5000
2019.11	3.6555	3.5857	3.7254	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	3.1931	3.1302	3.2559	0.8000	1.0000
2020.01	7.8048	7.6523	7.9573	4.0000	5.3000
2020.02	6.5467	6.4160	6.6775	0.1000	0.0000
2020.03	7.0074	6.8764	7.1383	1.2000	1.5000
2020.04	8.0242	7.8927	8.1557	3.0000	5.1000
2020.05	7.8539	7.7310	7.9767	0.1000	0.4000
2020.06	6.5693	6.4683	6.6704	3.9000	6.4000
2020.07	6.7336	6.6343	6.8329	4.2000	7.7000
2020.08	7.1546	7.0561	7.2531	5.3000	7.8000
2020.09	7.8008	7.6764	7.9251	0.4000	0.9000
2020.10	7.6992	7.5742	7.8242	9.9000	13.6000
2020.11	8.2245	8.0906	8.3583	21.2000	33.1000
2020.12	7.3251	7.1954	7.4548	15.4000	19.8000
2021.01	15.2193	14.9461	15.4924	7.0000	15.8000
2021.02	12.9587	12.7145	13.2030	5.8000	10.7000
2021.03	14.0811	13.8339	14.3283	11.0000	17.2000
2021.04	16.0683	15.8013	16.3352	18.5000	28.8000

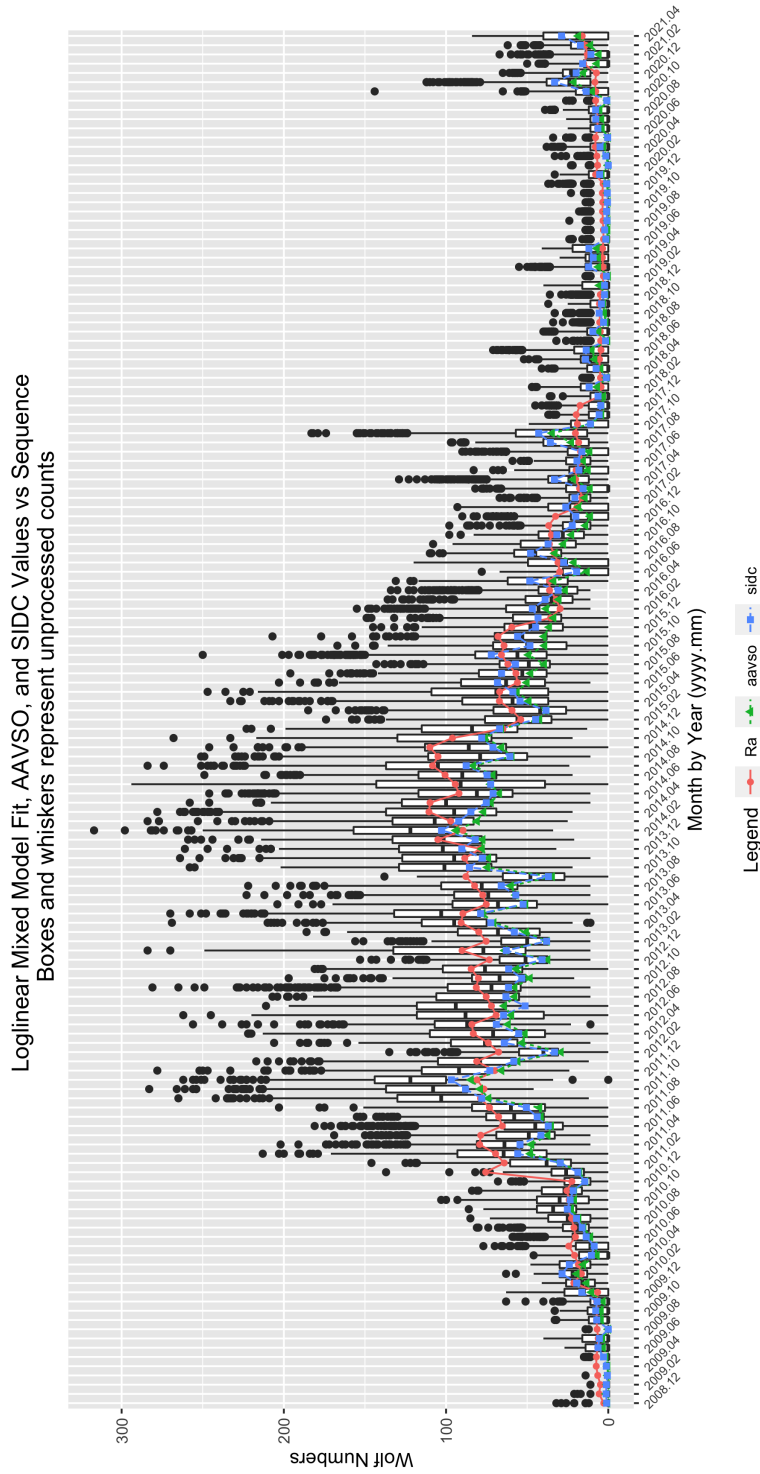


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202104 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t)$
(Intercept)	1.4328	0.3102	4.6196	0.0000
seeF	-0.2187	0.0058	-37.9321	0.0000
seeG	-0.1190	0.0050	-23.6630	0.0000
seeM	-0.2011	0.0240	-8.3689	0.0000
seeP	-0.3222	0.0082	-39.1003	0.0000
sidc1	0.0201	0.0471	0.4256	0.6704
year2009	0.6523	0.3111	2.0964	0.0360
year2010	1.8814	0.3090	6.0892	0.0000
year2011	3.0040	0.3089	9.7254	0.0000
year2012	3.0415	0.3089	9.8472	0.0000
year2013	3.1373	0.3089	10.1573	0.0000
year2014	3.3342	0.3089	10.7950	0.0000
year2015	2.8487	0.3089	9.2227	0.0000
year2016	2.2321	0.3089	7.2256	0.0000
year2017	1.6249	0.3089	5.2595	0.0000
year2018	0.3365	0.3092	1.0881	0.2765
year2019	-0.0902	0.3095	-0.2915	0.7707
year2020	0.7100	0.3091	2.2970	0.0216
year2021	1.3708	0.3093	4.4318	0.0000
mon2	-0.1713	0.0091	-18.8495	0.0000
mon3	-0.0972	0.0085	-11.4913	0.0000
mon4	0.0215	0.0081	2.6431	0.0082
mon5	0.0094	0.0081	1.1612	0.2456
mon6	-0.1780	0.0085	-20.9618	0.0000
mon7	-0.1519	0.0083	-18.3998	0.0000
mon8	-0.0792	0.0081	-9.8118	0.0000
mon9	0.0029	0.0081	0.3597	0.7191
mon10	-0.0221	0.0083	-2.6619	0.0078
mon11	0.0386	0.0086	4.4991	0.0000
mon12	-0.0865	0.0088	-9.8417	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: 202104 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:140015	Min. :0.0000
1st Qu.:2013	1st Qu.: 4.000	1st Qu.: 8.00	Class :character	1st Qu.:0.0000
Median :2016	Median : 7.000	Median :16.00	Mode :character	Median :0.0000
Mean :2015	Mean : 6.553	Mean :15.72		Mean :0.2548
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: 202104 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:140015	Length:140015
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 : 2.671	Mean : 15.7	Mean : 42.41		
3rd Qu.: 4.000	3rd Qu.: 23.0	3rd Qu.: 69.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 202104 Summary of Sunspot Numbers

inst	filter	unit
Length:140015	Length:140015	Length:140015
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202104 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 : 90.57	Mean : 32.44	Mean : 881.4	Mean : 183.1
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

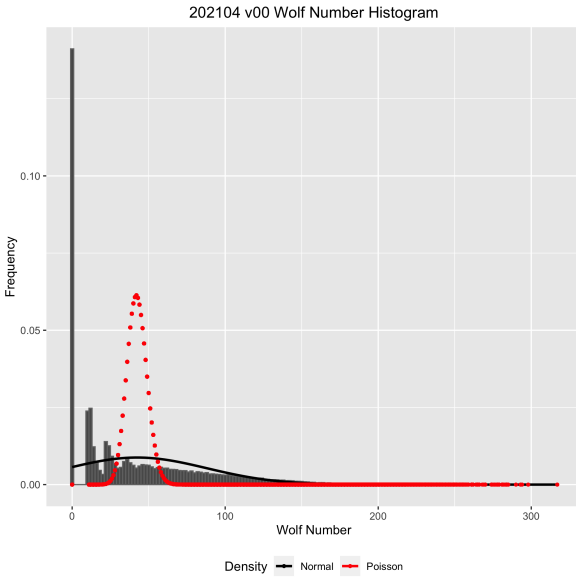


Figure 3: Box plots of raw Wolf number (w) by observer rank.

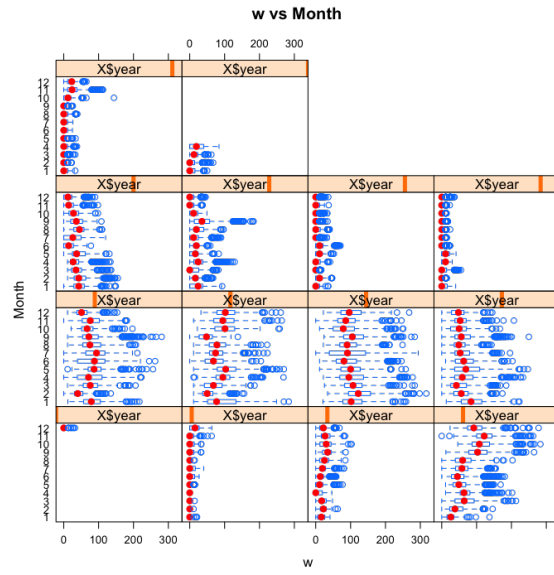


Figure 4: Box plots of raw Wolf number (w) by month and year.

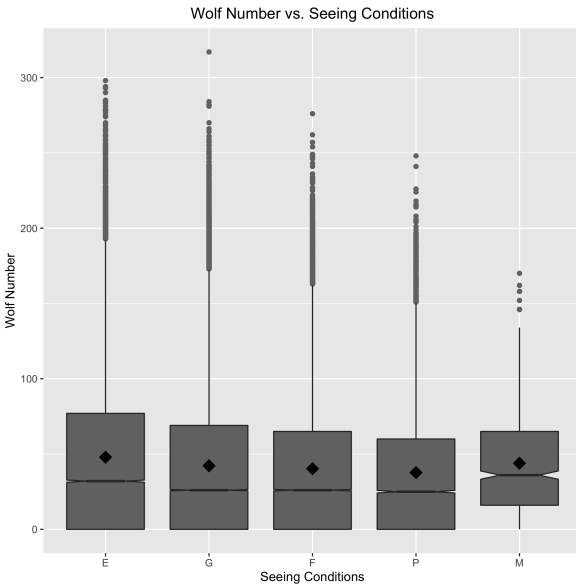


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

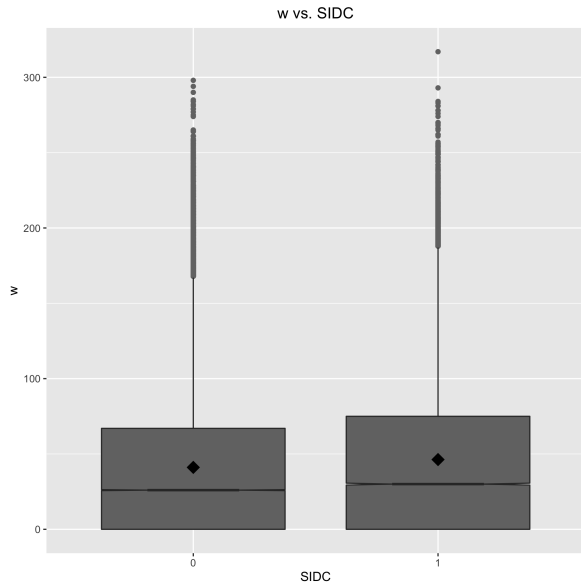


Figure 6: Box plots of raw Wolf number (w) by organization.

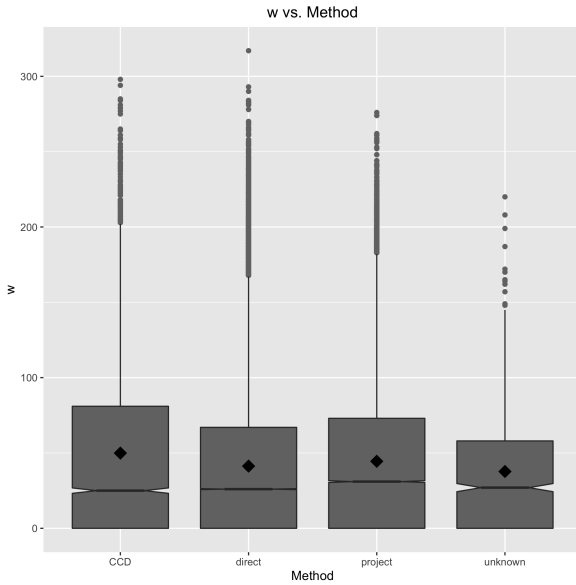


Figure 7: Box plots of raw Wolf number (w) by observer rank.

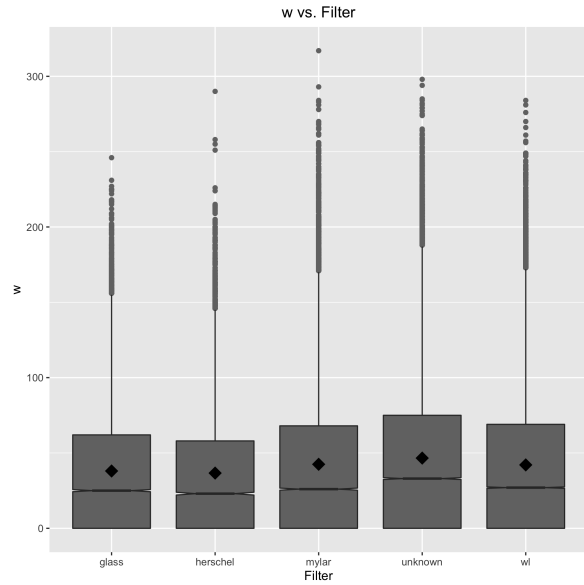


Figure 8: Box plots of raw Wolf number (w) by month and year.

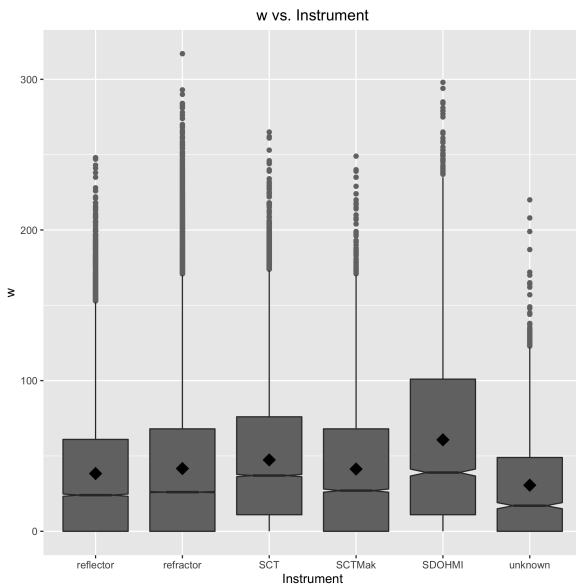


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

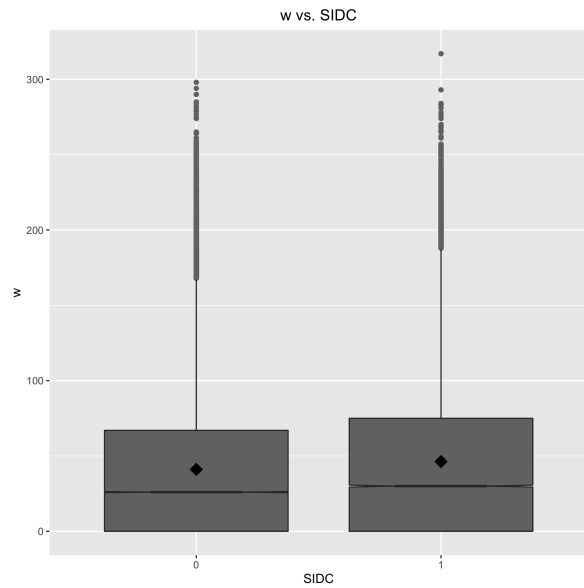


Figure 10: Box plots of raw Wolf number (w) by organization.

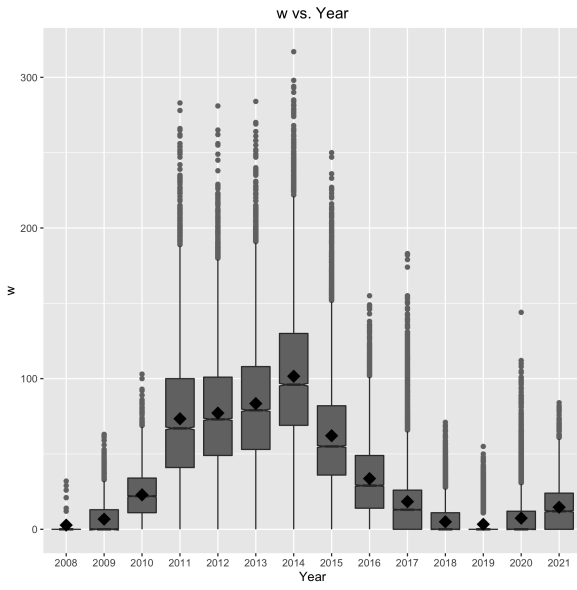


Figure 11: Box plots of raw Wolf number (w) by year.

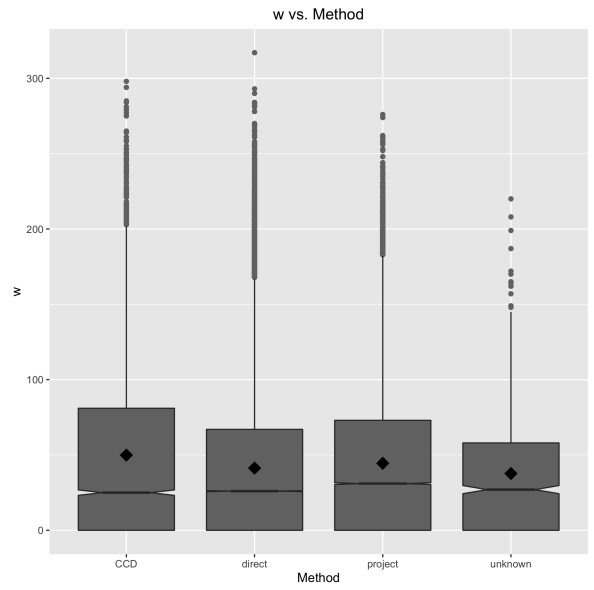


Figure 12: Box plots of raw Wolf number (w) by observing method.