

Monthly Report (00)

2021.03 Data Set

Wednesday 14th April, 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.

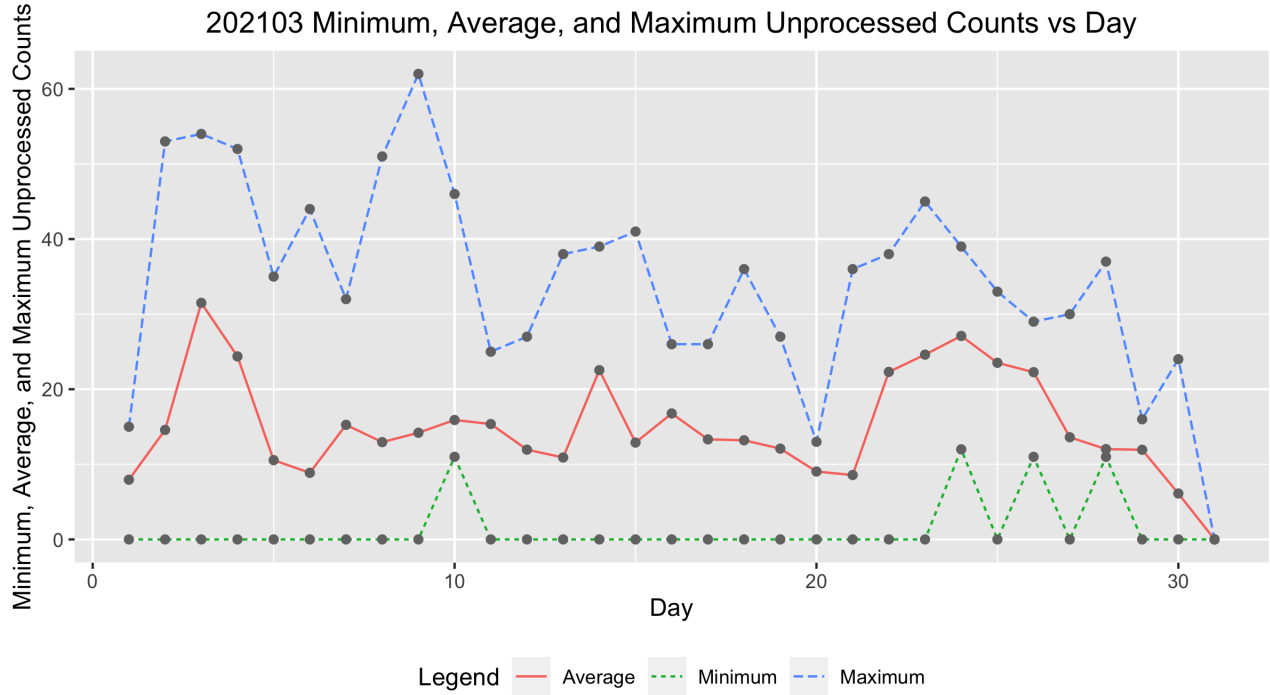


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202103 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	38.0000	0.0000	7.9474	15.0000
2.0000	43.0000	0.0000	14.5814	53.0000
3.0000	48.0000	0.0000	31.5000	54.0000
4.0000	48.0000	0.0000	24.3750	52.0000
5.0000	38.0000	0.0000	10.5526	35.0000
6.0000	46.0000	0.0000	8.8696	44.0000
7.0000	50.0000	0.0000	15.2600	32.0000
8.0000	46.0000	0.0000	12.9565	51.0000
9.0000	44.0000	0.0000	14.2045	62.0000
10.0000	41.0000	11.0000	15.9024	46.0000
11.0000	38.0000	0.0000	15.3684	25.0000
12.0000	44.0000	0.0000	11.9545	27.0000
13.0000	45.0000	0.0000	10.9111	38.0000
14.0000	33.0000	0.0000	22.5455	39.0000
15.0000	38.0000	0.0000	12.8947	41.0000
16.0000	36.0000	0.0000	16.7778	26.0000
17.0000	37.0000	0.0000	13.3243	26.0000
18.0000	35.0000	0.0000	13.2000	36.0000
19.0000	45.0000	0.0000	12.0889	27.0000
20.0000	49.0000	0.0000	9.0408	13.0000
21.0000	40.0000	0.0000	8.5750	36.0000
22.0000	39.0000	0.0000	22.3077	38.0000
23.0000	41.0000	0.0000	24.6098	45.0000
24.0000	41.0000	12.0000	27.0976	39.0000
25.0000	44.0000	0.0000	23.5227	33.0000
26.0000	40.0000	11.0000	22.2750	29.0000
27.0000	41.0000	0.0000	13.6098	30.0000
28.0000	35.0000	11.0000	12.0286	37.0000
29.0000	48.0000	0.0000	11.9375	16.0000
30.0000	43.0000	0.0000	6.1163	24.0000
31.0000	44.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of March 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	2.4037	3.1372	0.5000	1.0000
2009.01	5.6730	5.0513	6.2946	1.3000	1.3000
2009.02	4.8749	4.3260	5.4238	0.7000	1.2000
2009.03	6.5424	6.2852	6.7996	0.3000	0.6000
2009.04	7.2931	7.0278	7.5583	0.4000	1.2000
2009.05	7.3418	7.0476	7.6361	1.6000	2.9000
2009.06	6.5033	6.1709	6.8357	3.2000	6.3000
2009.07	6.2088	5.9567	6.4610	3.6000	5.5000
2009.08	6.8731	6.5980	7.1483	0.0000	0.0000
2009.09	7.2369	6.9763	7.4976	4.5000	7.1000
2009.10	6.9612	6.5912	7.3311	4.5000	7.7000
2009.11	7.1925	6.9938	7.3911	3.3000	6.9000
2009.12	6.5888	6.4008	6.7768	10.4000	16.3000
2010.01	21.3652	18.9046	23.8258	13.3000	19.5000
2010.02	16.6563	14.3625	18.9502	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	18.5661	16.2359	20.8964	15.4000	24.0000
2010.04	20.4457	18.0074	22.8840	7.0000	10.4000
2010.05	24.3490	23.9165	24.7816	8.4000	8.7000
2010.06	20.2426	19.9065	20.5787	11.0000	13.6000
2010.07	21.1725	20.8647	21.4803	15.2000	16.1000
2010.08	22.6739	22.3022	23.0456	18.3000	19.6000
2010.09	24.7685	24.3611	25.1759	22.8000	25.2000
2010.10	24.1063	23.6908	24.5219	21.0000	23.5000
2010.11	25.5112	25.0485	25.9740	20.9000	21.6000
2010.12	22.4387	21.9875	22.8900	13.9000	14.5000
2011.01	76.1227	74.5610	77.6845	17.7000	18.7000
2011.02	64.6134	63.2503	65.9765	29.1000	29.6000
2011.03	70.0247	68.6875	71.3619	48.0000	55.8000
2011.04	77.9869	76.5903	79.3835	47.3000	54.4000
2011.05	78.6329	77.3104	79.9553	37.3000	41.5000
2011.06	65.3248	64.1867	66.4630	35.2000	37.0000
2011.07	67.6194	66.4698	68.7691	41.5000	43.8000
2011.08	73.2612	72.0906	74.4318	42.4000	50.5000
2011.09	78.7670	77.4042	80.1298	73.8000	78.0000
2011.10	76.6495	75.3657	77.9333	78.9000	88.0000
2011.11	80.9110	79.2316	82.5904	84.6000	96.7000
2011.12	70.0066	68.5723	71.4410	65.8000	73.0000
2012.01	81.6764	80.0719	83.2809	55.8000	58.2000
2012.02	68.1097	66.7259	69.4934	29.2000	33.1000
2012.03	74.5672	73.2486	75.8858	53.1000	64.1000
2012.04	81.7891	80.3620	83.2163	51.4000	55.2000
2012.05	84.1045	82.7230	85.4861	61.8000	69.0000
2012.06	69.1448	67.9760	70.3136	59.7000	64.5000
2012.07	72.0104	70.8341	73.1868	64.2000	51.3000
2012.08	75.2437	74.0394	76.4479	57.7000	63.1000
2012.09	81.3705	79.9609	82.7802	57.7000	61.5000
2012.10	80.0629	78.6000	81.5258	48.3000	53.3000
2012.11	84.5098	82.8146	86.2051	56.7000	61.4000
2012.12	73.3074	71.7182	74.8965	37.4000	40.8000
2013.01	90.8047	89.0699	92.5394	63.8000	62.9000
2013.02	75.8791	74.3524	77.4058	37.8000	38.0000
2013.03	80.4648	78.8256	82.1041	50.6000	57.9000
2013.04	89.2010	87.6306	90.7713	70.6000	72.4000
2013.05	89.6355	88.0380	91.2329	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	75.2236	73.8949	76.5522	51.0000	52.5000
2013.07	77.3688	76.1264	78.6113	57.0000	57.0000
2013.08	82.3984	81.0719	83.7249	60.0000	66.0000
2013.09	87.7882	86.2203	89.3561	34.6000	36.9000
2013.10	85.3535	83.7687	86.9383	74.5000	85.6000
2013.11	88.4613	86.4727	90.4500	73.9000	77.6000
2013.12	78.9173	77.2278	80.6067	77.8000	90.3000
2014.01	105.8142	103.5847	108.0436	77.4000	82.0000
2014.02	90.2114	88.4308	91.9921	93.9000	102.8000
2014.03	97.8916	96.1040	99.6792	80.9000	92.2000
2014.04	108.6810	106.7794	110.5827	76.9000	84.7000
2014.05	109.8818	108.0056	111.7580	72.3000	75.2000
2014.06	92.0351	90.4782	93.5919	67.2000	71.0000
2014.07	94.3122	92.7397	95.8847	72.5000	72.5000
2014.08	100.6009	99.0269	102.1748	71.2000	74.7000
2014.09	108.3303	106.4177	110.2428	83.2000	87.6000
2014.10	104.9604	103.0259	106.8948	59.5000	60.6000
2014.11	109.9763	107.6865	112.2660	65.8000	71.1000
2014.12	96.0214	93.7948	98.2480	75.8000	78.0000
2015.01	65.3727	64.0629	66.6825	65.9000	67.0000
2015.02	54.3673	53.1689	55.5657	42.4000	44.8000
2015.03	59.8002	58.7059	60.8945	38.0000	38.4000
2015.04	65.9866	64.8068	67.1663	49.0000	54.4000
2015.05	66.9938	65.8867	68.1010	56.3000	58.8000
2015.06	56.0073	54.9997	57.0149	50.2000	68.3000
2015.07	56.9339	55.9648	57.9030	47.9000	65.8000
2015.08	61.9174	60.8786	62.9562	39.5000	57.2000
2015.09	65.8398	64.6441	67.0354	49.2000	72.1000
2015.10	64.2645	63.0242	65.5049	39.3000	48.3000
2015.11	68.0089	66.5288	69.4891	39.6000	55.9000
2015.12	59.4413	58.1275	60.7551	36.4000	44.8000
2016.01	35.8040	35.0579	36.5501	33.7000	43.3000
2016.02	29.9066	29.2832	30.5300	38.3000	46.8000
2016.03	32.3449	31.6993	32.9904	30.5000	38.9000
2016.04	35.5969	34.9191	36.2748	26.6000	30.9000
2016.05	36.2229	35.5614	36.8843	33.7000	48.4000
2016.06	29.9571	29.4458	30.4684	13.1000	19.5000
2016.07	30.9796	30.4812	31.4779	21.2000	27.5000
2016.08	33.3529	32.7664	33.9393	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	36.3106	35.6482	36.9729	27.7000	37.1000
2016.10	35.0615	34.3864	35.7366	22.7000	31.7000
2016.11	36.7203	35.9533	37.4872	14.0000	22.2000
2016.12	32.5002	31.8043	33.1962	11.1000	20.0000
2017.01	19.4369	19.0278	19.8460	18.4000	26.2000
2017.02	16.3036	15.9456	16.6616	14.4000	20.6000
2017.03	17.7893	17.4501	18.1284	11.3000	15.5000
2017.04	19.7805	19.4316	20.1295	21.6000	33.2000
2017.05	19.8216	19.4796	20.1635	12.5000	18.1000
2017.06	16.3697	16.0968	16.6427	15.5000	19.3000
2017.07	17.0215	16.7499	17.2931	11.5000	16.3000
2017.08	18.2693	17.9479	18.5908	22.8000	35.7000
2017.09	20.2736	19.8289	20.7183	34.6000	42.9000
2017.10	19.0357	18.6387	19.4327	10.5000	11.0000
2017.11	19.7595	19.3400	20.1789	4.2000	5.6000
2017.12	17.3895	17.1236	17.6554	4.0000	4.6000
2018.01	5.4081	5.2914	5.5248	3.1000	6.3000
2018.02	4.4972	4.3866	4.6078	6.8000	11.8000
2018.03	4.8233	4.7254	4.9213	1.1000	1.2000
2018.04	5.3105	5.2027	5.4184	4.7000	7.5000
2018.05	5.4099	5.3068	5.5130	8.4000	14.0000
2018.06	4.4802	4.4002	4.5602	10.2000	13.6000
2018.07	4.6547	4.6014	4.7081	0.5000	1.7000
2018.08	4.9403	4.8543	5.0262	5.9000	9.5000
2018.09	5.2671	5.1672	5.3671	1.6000	2.9000
2018.10	5.2219	5.1188	5.3250	2.5000	5.6000
2018.11	5.4515	5.3375	5.5655	3.1000	4.2000
2018.12	4.9024	4.8056	4.9991	1.6000	2.3000
2019.01	3.5687	3.5000	3.6374	5.4000	2.3000
2019.02	3.0331	2.9728	3.0935	0.1000	1.2000
2019.03	3.2113	3.1551	3.2674	6.1000	12.1000
2019.04	3.5626	3.4938	3.6314	6.2000	9.3000
2019.05	3.5093	3.4470	3.5717	7.0000	11.9000
2019.06	2.9158	2.8657	2.9658	0.7000	1.5000
2019.07	3.0387	2.9926	3.0848	0.4000	2.2000
2019.08	3.2798	3.2306	3.3291	0.3000	0.8000
2019.09	3.5728	3.5162	3.6295	0.5000	1.0000
2019.10	3.4417	3.3830	3.5005	0.2000	0.5000
2019.11	3.6557	3.5854	3.7259	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	3.1911	3.1281	3.2541	0.8000	1.0000
2020.01	7.8517	7.6976	8.0058	4.0000	5.3000
2020.02	6.5889	6.4568	6.7211	0.1000	0.0000
2020.03	7.0484	6.9157	7.1811	1.2000	1.5000
2020.04	7.8686	7.7386	7.9987	3.0000	5.1000
2020.05	7.8364	7.7130	7.9598	0.1000	0.4000
2020.06	6.5568	6.4549	6.6588	3.9000	6.4000
2020.07	6.7203	6.6201	6.8206	4.2000	7.7000
2020.08	7.1491	7.0499	7.2483	5.3000	7.8000
2020.09	7.8021	7.6759	7.9283	0.4000	0.9000
2020.10	7.7123	7.5857	7.8388	9.9000	13.6000
2020.11	8.2616	8.1211	8.4022	21.2000	33.1000
2020.12	7.3916	7.2552	7.5281	15.4000	19.8000
2021.01	12.2698	12.0413	12.4984	7.0000	15.8000
2021.02	10.4511	10.2383	10.6639	5.8000	10.7000
2021.03	11.4001	11.1758	11.6243	11.0000	17.2000

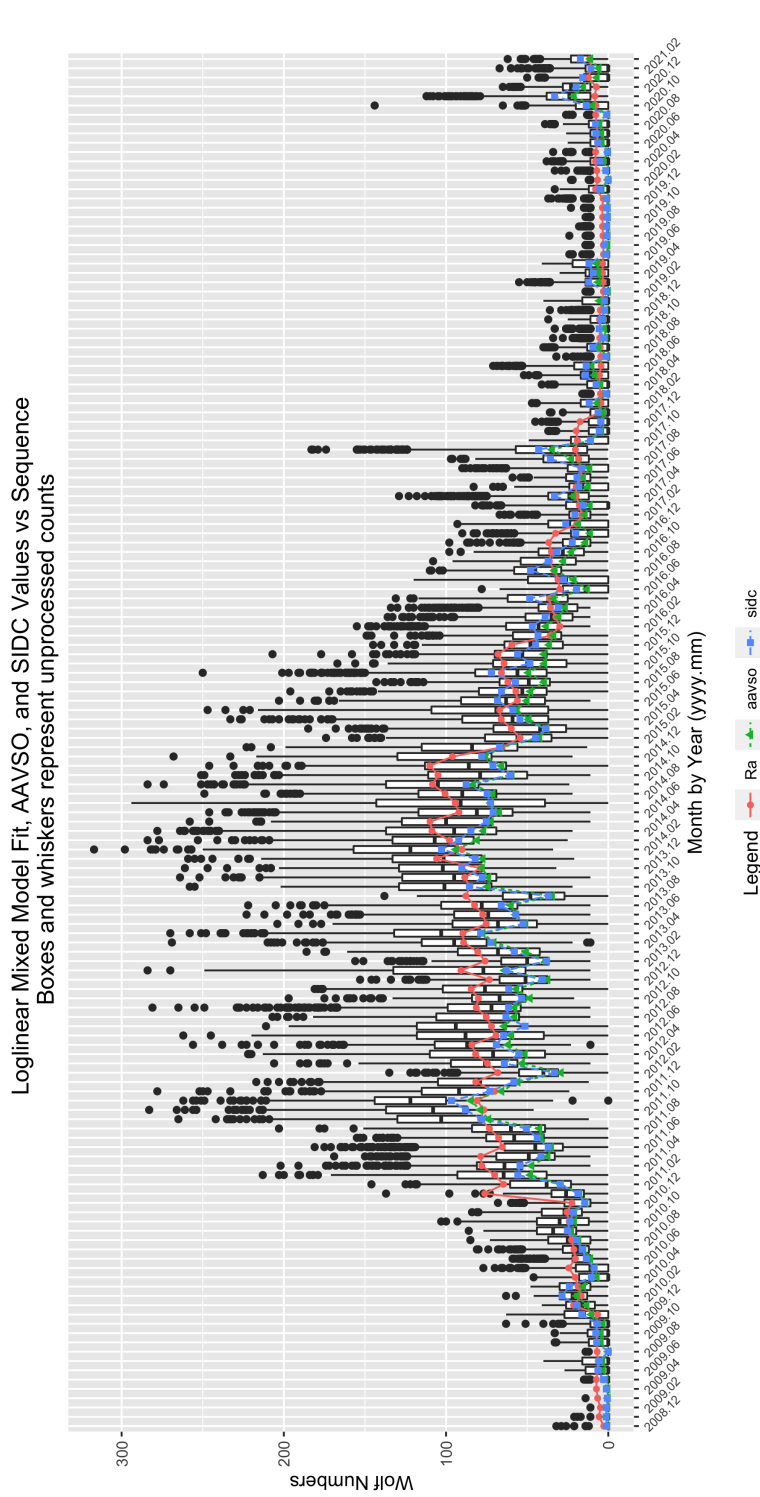


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202103 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t)$
(Intercept)	1.4511	0.3096	4.6871	0.0000
seeF	-0.2186	0.0058	-37.9008	0.0000
seeG	-0.1183	0.0050	-23.5115	0.0000
seeM	-0.2025	0.0240	-8.4457	0.0000
seeP	-0.3227	0.0082	-39.1391	0.0000
sidc1	0.0155	0.0633	0.2446	0.8068
year2009	0.6511	0.3104	2.0974	0.0360
year2010	1.8802	0.3083	6.0996	0.0000
year2011	3.0027	0.3082	9.7442	0.0000
year2012	3.0399	0.3081	9.8652	0.0000
year2013	3.1359	0.3081	10.1766	0.0000
year2014	3.3328	0.3081	10.8159	0.0000
year2015	2.8473	0.3082	9.2399	0.0000
year2016	2.2306	0.3082	7.2379	0.0000
year2017	1.6234	0.3082	5.2668	0.0000
year2018	0.3346	0.3085	1.0845	0.2782
year2019	-0.0926	0.3087	-0.2999	0.7642
year2020	0.7063	0.3084	2.2902	0.0220
year2021	1.1333	0.3089	3.6687	0.0002
mon2	-0.1707	0.0091	-18.8326	0.0000
mon3	-0.0966	0.0084	-11.4489	0.0000
mon4	-0.0027	0.0082	-0.3304	0.7411
mon5	0.0023	0.0081	0.2788	0.7804
mon6	-0.1853	0.0085	-21.8581	0.0000
mon7	-0.1591	0.0082	-19.3109	0.0000
mon8	-0.0865	0.0081	-10.7288	0.0000
mon9	-0.0044	0.0081	-0.5383	0.5904
mon10	-0.0294	0.0083	-3.5426	0.0004
mon11	0.0314	0.0086	3.6602	0.0003
mon12	-0.0938	0.0088	-10.6951	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: 202103 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:138680	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 : 6.578	Mean :15.72		Mean :0.2554
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: 202103 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.0	Length:138680	Length:138680
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.0	Class :character	Class :character
Median : 2.000	Median : 7.00	Median : 27.0	Mode :character	Mode :character
Mean : 2.682	Mean : 15.78	Mean : 42.6		
3rd Qu.: 4.000	3rd Qu.: 23.00	3rd Qu.: 69.0		
Max. :19.000	Max. :204.00	Max. :317.0		

Table 6: 202103 Summary of Sunspot Numbers

inst	filter	unit
Length:138680	Length:138680	Length:138680
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202103 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 : 90.43	Mean : 32.18	Mean : 880.1	Mean : 183.4
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

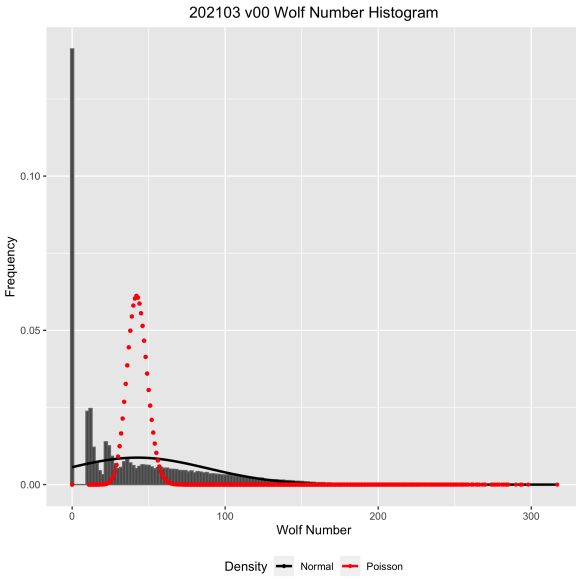


Figure 3: Box plots of raw Wolf number (w) by observer rank.

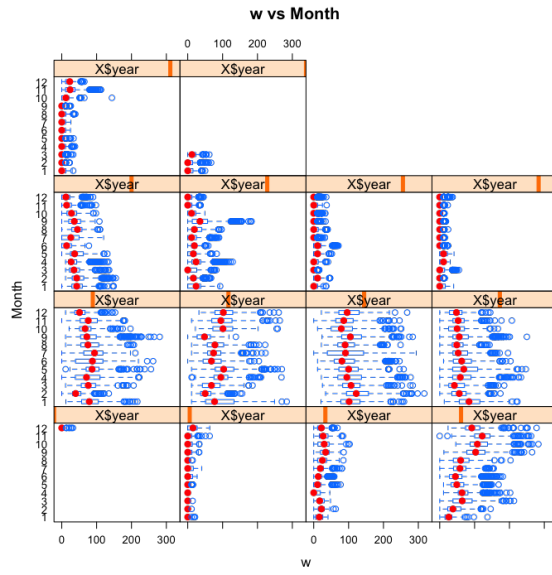


Figure 4: Box plots of raw Wolf number (w) by month and year.

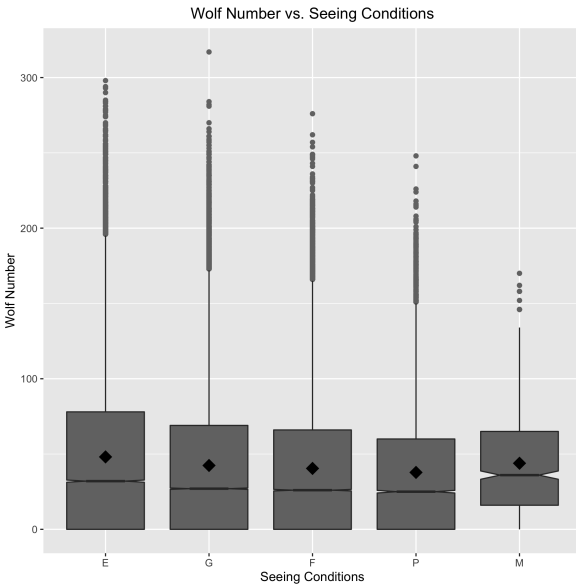


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

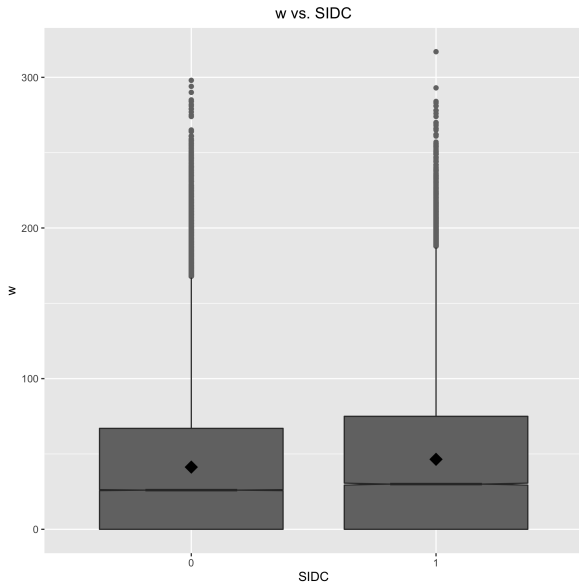


Figure 6: Box plots of raw Wolf number (w) by organization.

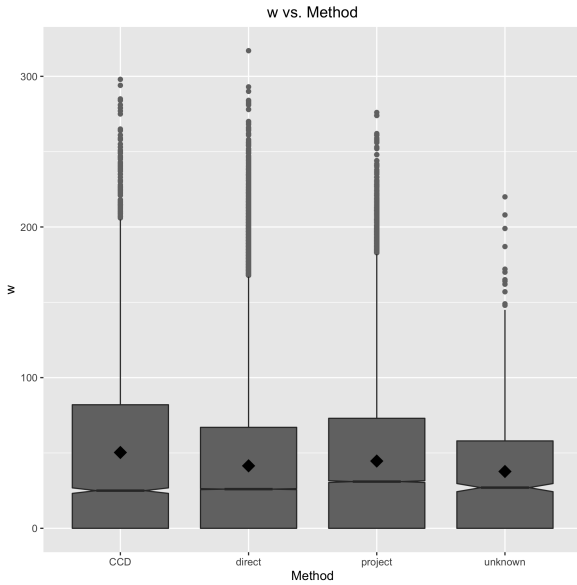


Figure 7: Box plots of raw Wolf number (w) by observer rank.

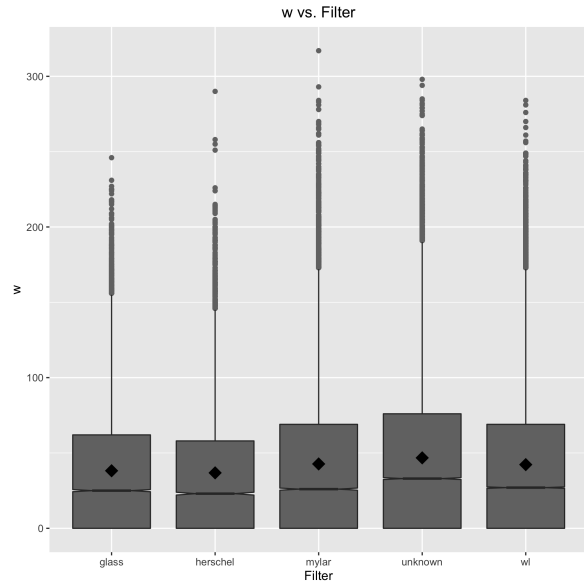


Figure 8: Box plots of raw Wolf number (w) by month and year.

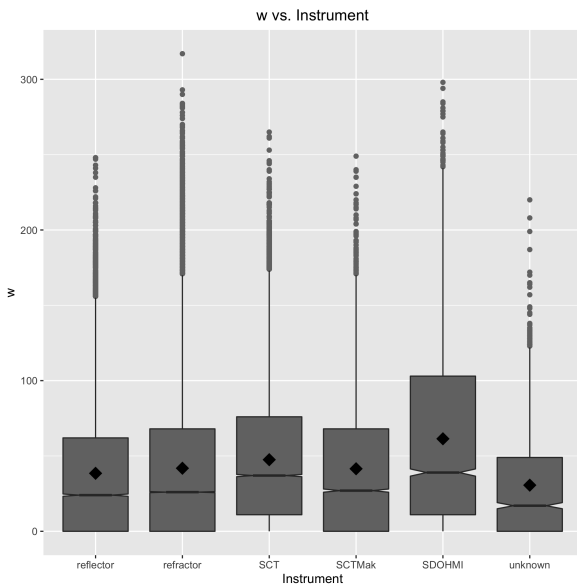


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

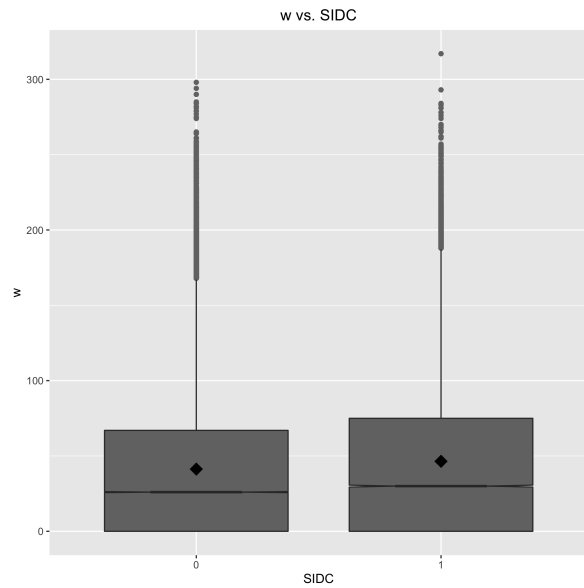


Figure 10: Box plots of raw Wolf number (w) by organization.

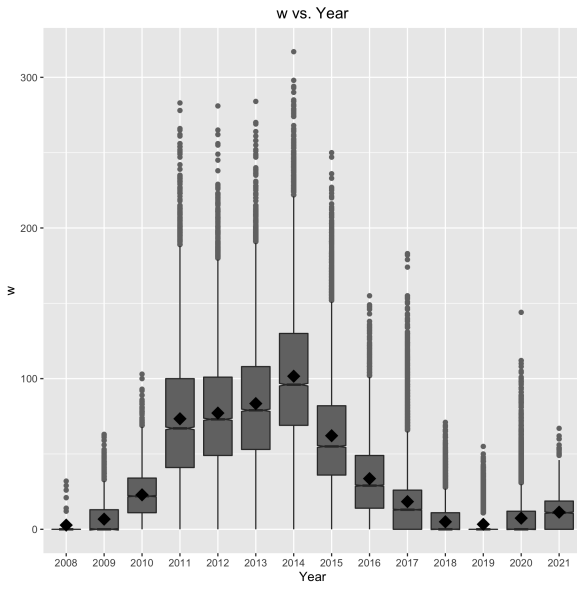


Figure 11: Box plots of raw Wolf number (w) by year.

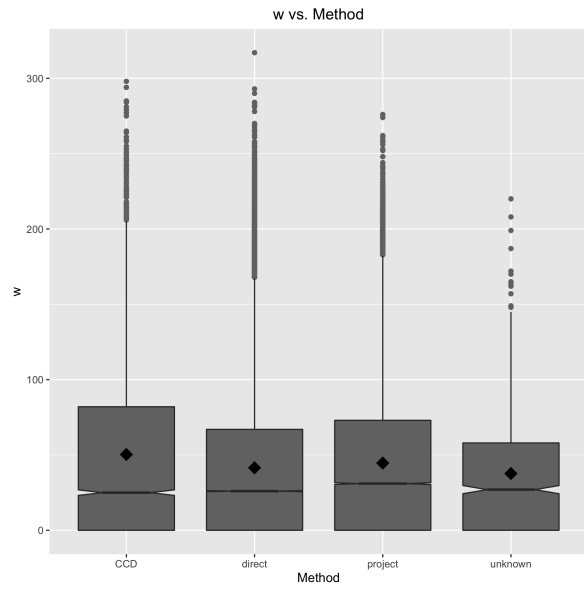


Figure 12: Box plots of raw Wolf number (w) by observing method.