

Monthly Report (00)

2021.05 Data Set

Monday 14th June, 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.

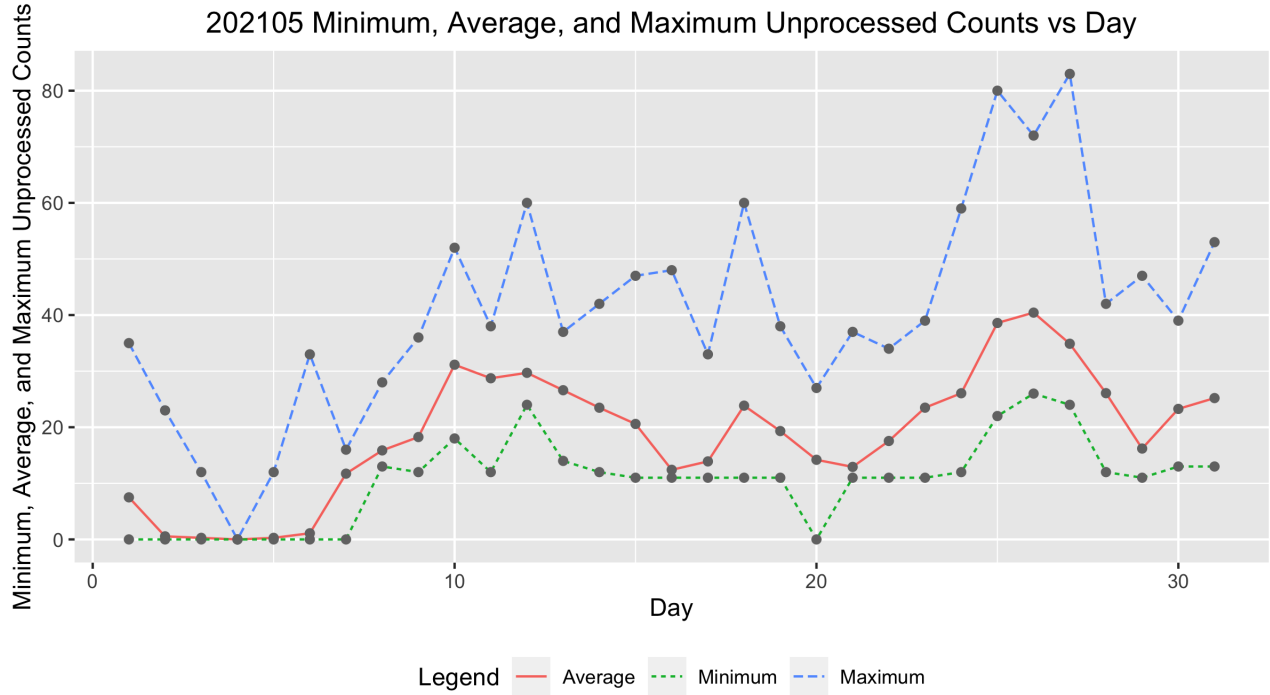


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202105 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	48.0000	0.0000	7.5000	35.0000
2.0000	42.0000	0.0000	0.5476	23.0000
3.0000	43.0000	0.0000	0.2791	12.0000
4.0000	41.0000	0.0000	0.0000	0.0000
5.0000	43.0000	0.0000	0.2791	12.0000
6.0000	42.0000	0.0000	1.0952	33.0000
7.0000	44.0000	0.0000	11.7273	16.0000
8.0000	46.0000	13.0000	15.8696	28.0000
9.0000	48.0000	12.0000	18.2500	36.0000
10.0000	49.0000	18.0000	31.1429	52.0000
11.0000	45.0000	12.0000	28.7333	38.0000
12.0000	47.0000	24.0000	29.7021	60.0000
13.0000	50.0000	14.0000	26.6000	37.0000
14.0000	52.0000	12.0000	23.4808	42.0000
15.0000	46.0000	11.0000	20.5870	47.0000
16.0000	39.0000	11.0000	12.4103	48.0000
17.0000	43.0000	11.0000	13.9070	33.0000
18.0000	40.0000	11.0000	23.8500	60.0000
19.0000	50.0000	11.0000	19.3200	38.0000
20.0000	46.0000	0.0000	14.1957	27.0000
21.0000	41.0000	11.0000	12.9268	37.0000
22.0000	42.0000	11.0000	17.5476	34.0000
23.0000	43.0000	11.0000	23.4884	39.0000
24.0000	49.0000	12.0000	26.0612	59.0000
25.0000	49.0000	22.0000	38.5918	80.0000
26.0000	53.0000	26.0000	40.4340	72.0000
27.0000	44.0000	24.0000	34.8864	83.0000
28.0000	39.0000	12.0000	26.0769	42.0000
29.0000	40.0000	11.0000	16.2000	47.0000
30.0000	41.0000	13.0000	23.2683	39.0000
31.0000	45.0000	13.0000	25.2000	53.0000

3 Error Tables

Data are for the month of May 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	2.4068	3.1342	0.5000	1.0000
2009.01	5.6312	5.0195	6.2429	1.3000	1.3000
2009.02	4.8345	4.2949	5.3741	0.7000	1.2000
2009.03	6.4762	6.2217	6.7306	0.3000	0.6000
2009.04	7.4004	7.1317	7.6692	0.4000	1.2000
2009.05	7.3822	7.0869	7.6776	1.6000	2.9000
2009.06	6.5002	6.1679	6.8324	3.2000	6.3000
2009.07	6.2063	5.9545	6.4582	3.6000	5.5000
2009.08	6.8703	6.5961	7.1445	0.0000	0.0000
2009.09	7.2345	6.9743	7.4947	4.5000	7.1000
2009.10	6.9594	6.5903	7.3285	4.5000	7.7000
2009.11	7.1951	6.9974	7.3928	3.3000	6.9000
2009.12	6.5909	6.4038	6.7780	10.4000	16.3000
2010.01	21.1855	18.7657	23.6053	13.3000	19.5000
2010.02	16.5140	14.2601	18.7679	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	18.4048	16.1145	20.6950	15.4000	24.0000
2010.04	20.7757	18.3193	23.2321	7.0000	10.4000
2010.05	24.4773	24.0443	24.9104	8.4000	8.7000
2010.06	20.2241	19.8887	20.5596	11.0000	13.6000
2010.07	21.1499	20.8430	21.4569	15.2000	16.1000
2010.08	22.6547	22.2839	23.0255	18.3000	19.6000
2010.09	24.7469	24.3406	25.1532	22.8000	25.2000
2010.10	24.0879	23.6735	24.5022	21.0000	23.5000
2010.11	25.4876	25.0259	25.9493	20.9000	21.6000
2010.12	22.4345	21.9853	22.8836	13.9000	14.5000
2011.01	75.4524	73.9114	76.9934	17.7000	18.7000
2011.02	63.9946	62.6506	65.3386	29.1000	29.6000
2011.03	69.3319	68.0121	70.6516	48.0000	55.8000
2011.04	79.1374	77.7208	80.5540	47.3000	54.4000
2011.05	79.0859	77.7576	80.4143	37.3000	41.5000
2011.06	65.3124	64.1759	66.4488	35.2000	37.0000
2011.07	67.6064	66.4587	68.7540	41.5000	43.8000
2011.08	73.2477	72.0789	74.4165	42.4000	50.5000
2011.09	78.7483	77.3893	80.1072	73.8000	78.0000
2011.10	76.6427	75.3604	77.9250	78.9000	88.0000
2011.11	80.9085	79.2321	82.5849	84.6000	96.7000
2011.12	70.0175	68.5854	71.4496	65.8000	73.0000
2012.01	80.9449	79.3558	82.5341	55.8000	58.2000
2012.02	67.4534	66.0836	68.8231	29.2000	33.1000
2012.03	73.8533	72.5484	75.1581	53.1000	64.1000
2012.04	83.0381	81.5891	84.4870	51.4000	55.2000
2012.05	84.6135	83.2242	86.0029	61.8000	69.0000
2012.06	69.1547	67.9867	70.3227	59.7000	64.5000
2012.07	72.0214	70.8457	73.1971	64.2000	51.3000
2012.08	75.2473	74.0434	76.4512	57.7000	63.1000
2012.09	81.3836	79.9751	82.7922	57.7000	61.5000
2012.10	80.0764	78.6145	81.5383	48.3000	53.3000
2012.11	84.5373	82.8426	86.2320	56.7000	61.4000
2012.12	73.3397	71.7507	74.9287	37.4000	40.8000
2013.01	89.9753	88.2573	91.6933	63.8000	62.9000
2013.02	75.1320	73.6214	76.6427	37.8000	38.0000
2013.03	79.6751	78.0532	81.2970	50.6000	57.9000
2013.04	90.5393	88.9462	92.1324	70.6000	72.4000
2013.05	90.1454	88.5406	91.7502	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	75.2158	73.8880	76.5436	51.0000	52.5000
2013.07	77.3555	76.1139	78.5972	57.0000	57.0000
2013.08	82.3968	81.0713	83.7224	60.0000	66.0000
2013.09	87.7855	86.2189	89.3522	34.6000	36.9000
2013.10	85.3560	83.7725	86.9396	74.5000	85.6000
2013.11	88.4877	86.4994	90.4760	73.9000	77.6000
2013.12	78.9422	77.2534	80.6310	77.8000	90.3000
2014.01	104.8595	102.6517	107.0673	77.4000	82.0000
2014.02	89.3250	87.5631	91.0869	93.9000	102.8000
2014.03	96.9480	95.1797	98.7162	80.9000	92.2000
2014.04	110.3233	108.3933	112.2533	76.9000	84.7000
2014.05	110.5274	108.6417	112.4130	72.3000	75.2000
2014.06	92.0335	90.4785	93.5885	67.2000	71.0000
2014.07	94.3065	92.7354	95.8775	72.5000	72.5000
2014.08	100.6130	99.0412	102.1848	71.2000	74.7000
2014.09	108.3561	106.4458	110.2664	83.2000	87.6000
2014.10	104.9719	103.0387	106.9052	59.5000	60.6000
2014.11	110.0139	107.7267	112.3011	65.8000	71.1000
2014.12	96.0522	93.8274	98.2770	75.8000	78.0000
2015.01	64.7831	63.4876	66.0786	65.9000	67.0000
2015.02	53.8426	52.6571	55.0280	42.4000	44.8000
2015.03	59.2192	58.1372	60.3013	38.0000	38.4000
2015.04	66.9979	65.8022	68.1936	49.0000	54.4000
2015.05	67.3969	66.2854	68.5083	56.3000	58.8000
2015.06	56.0053	54.9995	57.0112	50.2000	68.3000
2015.07	56.9281	55.9604	57.8957	47.9000	65.8000
2015.08	61.9103	60.8733	62.9473	39.5000	57.2000
2015.09	65.8476	64.6534	67.0417	49.2000	72.1000
2015.10	64.2640	63.0252	65.5028	39.3000	48.3000
2015.11	68.0133	66.5352	69.4914	39.6000	55.9000
2015.12	59.4576	58.1459	60.7694	36.4000	44.8000
2016.01	35.4808	34.7423	36.2193	33.7000	43.3000
2016.02	29.6156	28.9991	30.2322	38.3000	46.8000
2016.03	32.0334	31.3949	32.6718	30.5000	38.9000
2016.04	36.1405	35.4533	36.8277	26.6000	30.9000
2016.05	36.4516	35.7875	37.1156	33.7000	48.4000
2016.06	29.9547	29.4441	30.4652	13.1000	19.5000
2016.07	30.9959	30.4992	31.4925	21.2000	27.5000
2016.08	33.3582	32.7731	33.9432	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	36.3114	35.6504	36.9725	27.7000	37.1000
2016.10	35.0673	34.3935	35.7411	22.7000	31.7000
2016.11	36.7206	35.9546	37.4867	14.0000	22.2000
2016.12	32.5038	31.8081	33.1995	11.1000	20.0000
2017.01	19.2609	18.8557	19.6660	18.4000	26.2000
2017.02	16.1445	15.7903	16.4987	14.4000	20.6000
2017.03	17.6190	17.2837	17.9543	11.3000	15.5000
2017.04	20.0818	19.7282	20.4354	21.6000	33.2000
2017.05	19.9375	19.5939	20.2811	12.5000	18.1000
2017.06	16.3717	16.0992	16.6443	15.5000	19.3000
2017.07	17.0195	16.7483	17.2908	11.5000	16.3000
2017.08	18.2653	17.9451	18.5854	22.8000	35.7000
2017.09	20.2560	19.8196	20.6924	34.6000	42.9000
2017.10	19.0376	18.6440	19.4312	10.5000	11.0000
2017.11	19.7689	19.3512	20.1866	4.2000	5.6000
2017.12	17.4011	17.1360	17.6663	4.0000	4.6000
2018.01	5.3610	5.2464	5.4756	3.1000	6.3000
2018.02	4.4537	4.3454	4.5620	6.8000	11.8000
2018.03	4.7763	4.6799	4.8728	1.1000	1.2000
2018.04	5.3878	5.2794	5.4963	4.7000	7.5000
2018.05	5.4386	5.3364	5.5407	8.4000	14.0000
2018.06	4.4802	4.4011	4.5593	10.2000	13.6000
2018.07	4.6563	4.6035	4.7091	0.5000	1.7000
2018.08	4.9429	4.8580	5.0277	5.9000	9.5000
2018.09	5.2694	5.1705	5.3684	1.6000	2.9000
2018.10	5.2250	5.1225	5.3275	2.5000	5.6000
2018.11	5.4512	5.3378	5.5647	3.1000	4.2000
2018.12	4.8999	4.8037	4.9960	1.6000	2.3000
2019.01	3.5328	3.4653	3.6003	5.4000	2.3000
2019.02	3.0013	2.9421	3.0605	0.1000	1.2000
2019.03	3.1797	3.1250	3.2345	6.1000	12.1000
2019.04	3.6169	3.5481	3.6857	6.2000	9.3000
2019.05	3.5323	3.4706	3.5940	7.0000	11.9000
2019.06	2.9191	2.8701	2.9682	0.7000	1.5000
2019.07	3.0396	2.9942	3.0850	0.4000	2.2000
2019.08	3.2806	3.2321	3.3291	0.3000	0.8000
2019.09	3.5736	3.5176	3.6295	0.5000	1.0000
2019.10	3.4423	3.3843	3.5002	0.2000	0.5000
2019.11	3.6563	3.5867	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	3.1923	3.1297	3.2550	0.8000	1.0000
2020.01	7.7997	7.6482	7.9512	4.0000	5.3000
2020.02	6.5430	6.4134	6.6726	0.1000	0.0000
2020.03	7.0009	6.8709	7.1310	1.2000	1.5000
2020.04	8.0167	7.8861	8.1474	3.0000	5.1000
2020.05	7.9077	7.7847	8.0307	0.1000	0.4000
2020.06	6.5779	6.4776	6.6782	3.9000	6.4000
2020.07	6.7446	6.6465	6.8427	4.2000	7.7000
2020.08	7.1609	7.0630	7.2588	5.3000	7.8000
2020.09	7.8049	7.6817	7.9281	0.4000	0.9000
2020.10	7.6959	7.5717	7.8201	9.9000	13.6000
2020.11	8.1942	8.0642	8.3242	21.2000	33.1000
2020.12	7.2755	7.1509	7.4001	15.4000	19.8000
2021.01	16.0155	15.7377	16.2933	7.0000	15.8000
2021.02	13.6361	13.3936	13.8787	5.8000	10.7000
2021.03	14.7683	14.5297	15.0068	11.0000	17.2000
2021.04	16.8520	16.5953	17.1087	18.5000	28.8000
2021.05	16.8107	16.5666	17.0548	15.9000	22.9000

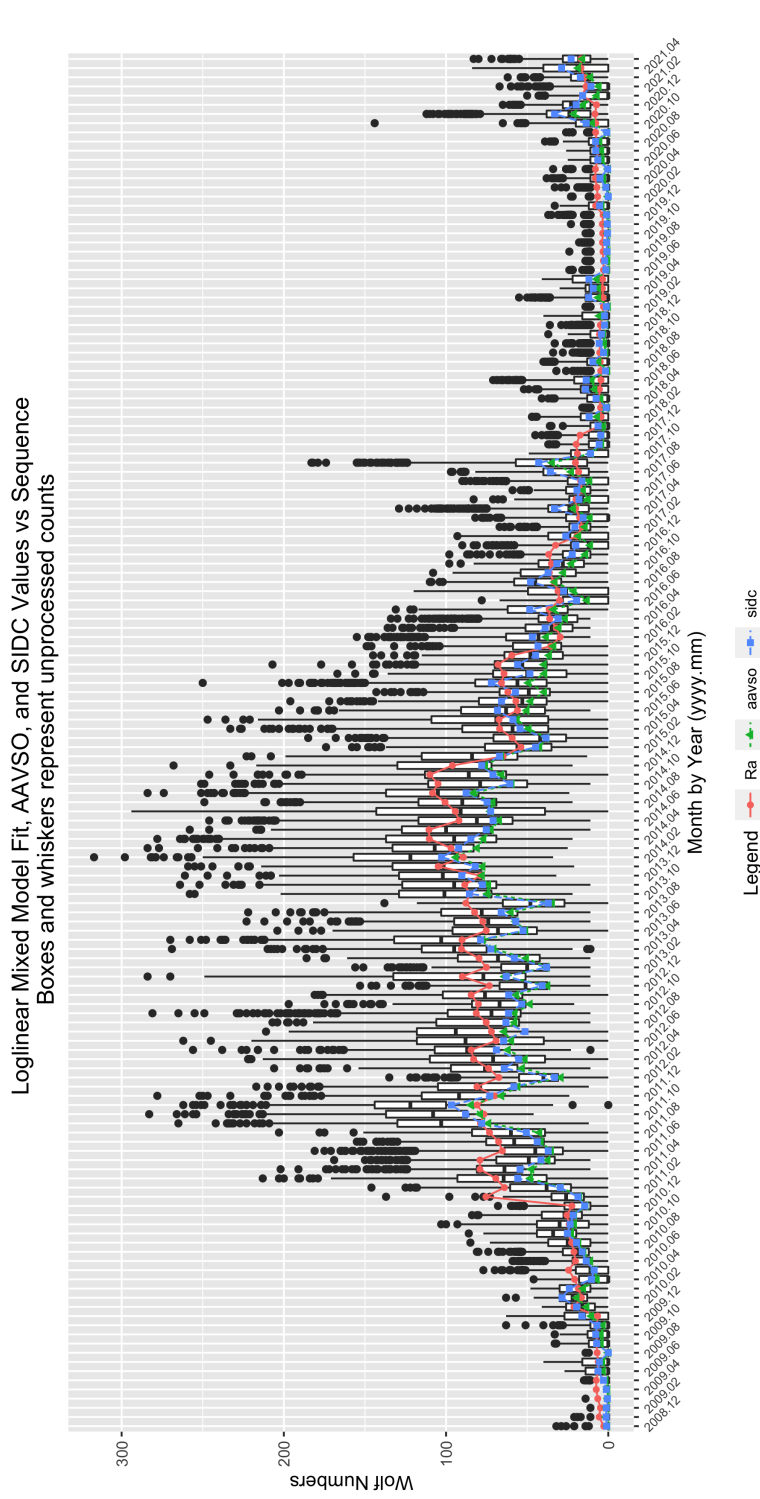


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202105 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t)$
(Intercept)	1.4254	0.3096	4.6037	0.0000
seeF	-0.2191	0.0057	-38.1523	0.0000
seeG	-0.1193	0.0050	-23.7992	0.0000
seeM	-0.2022	0.0240	-8.4301	0.0000
seeP	-0.3225	0.0082	-39.2850	0.0000
sidc1	0.0183	0.0385	0.4763	0.6339
year2009	0.6530	0.3107	2.1017	0.0356
year2010	1.8815	0.3085	6.0983	0.0000
year2011	3.0048	0.3084	9.7423	0.0000
year2012	3.0424	0.3084	9.8643	0.0000
year2013	3.1381	0.3084	10.1748	0.0000
year2014	3.3350	0.3084	10.8133	0.0000
year2015	2.8495	0.3084	9.2388	0.0000
year2016	2.2329	0.3085	7.2388	0.0000
year2017	1.6258	0.3085	5.2698	0.0000
year2018	0.3371	0.3088	1.0916	0.2750
year2019	-0.0891	0.3090	-0.2884	0.7731
year2020	0.7121	0.3087	2.3072	0.0210
year2021	1.4334	0.3087	4.6428	0.0000
mon2	-0.1714	0.0091	-18.8977	0.0000
mon3	-0.0972	0.0084	-11.5173	0.0000
mon4	0.0214	0.0081	2.6402	0.0083
mon5	0.0173	0.0080	2.1597	0.0308
mon6	-0.1761	0.0085	-20.7785	0.0000
mon7	-0.1500	0.0082	-18.2082	0.0000
mon8	-0.0773	0.0081	-9.5947	0.0000
mon9	0.0048	0.0081	0.5963	0.5510
mon10	-0.0202	0.0083	-2.4334	0.0150
mon11	0.0406	0.0086	4.7390	0.0000
mon12	-0.0844	0.0088	-9.6228	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: 202105 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:141405	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 :2016	Mean : 6.538	Mean :15.72		Mean :0.2542
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: 202105 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:141405	Length:141405
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 : 2.658	Mean : 15.6	Mean : 42.19		
3rd Qu.: 4.000	3rd Qu.: 23.0	3rd Qu.: 68.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 202105 Summary of Sunspot Numbers

inst	filter	unit
Length:141405	Length:141405	Length:141405
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202105 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.0	Min. : 0.0	Min. : 0.0
1st Qu.: 51.00	1st Qu.: 4.0	1st Qu.: 33.0	1st Qu.: 40.0
Median : 80.00	Median : 14.0	Median : 910.0	Median : 57.5
Mean : 90.72	Mean : 32.7	Mean : 882.5	Mean : 182.8
3rd Qu.: 104.00	3rd Qu.: 23.0	3rd Qu.:1200.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.0	Max. :9990.0	Max. :4591.0

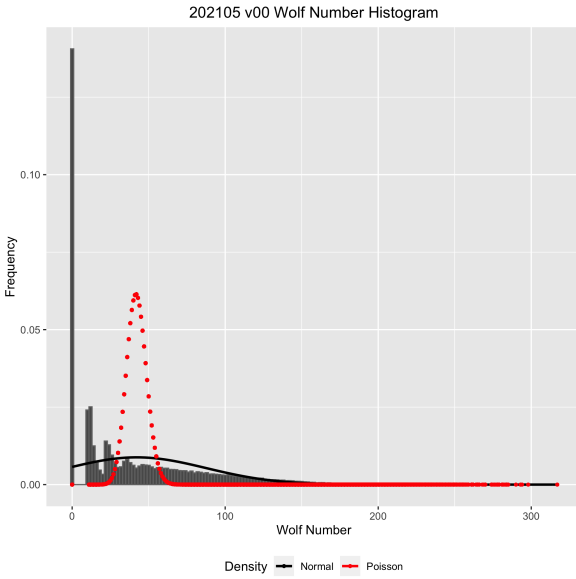


Figure 3: Box plots of raw Wolf number (w) by observer rank.

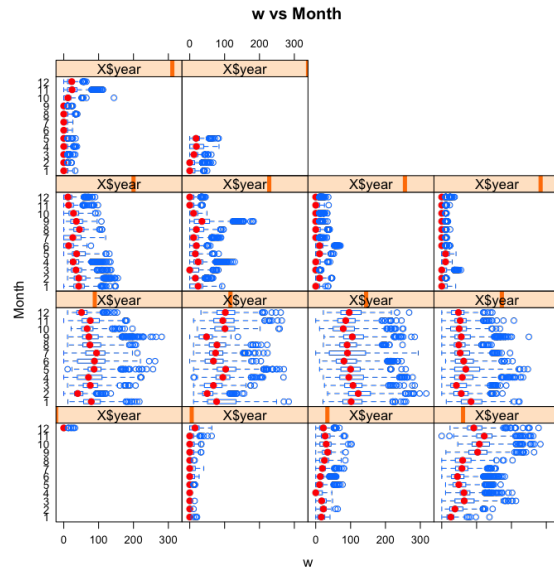


Figure 4: Box plots of raw Wolf number (w) by month and year.

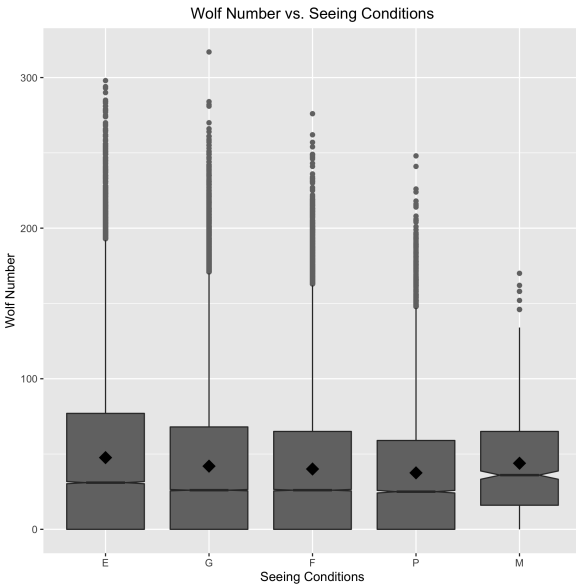


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

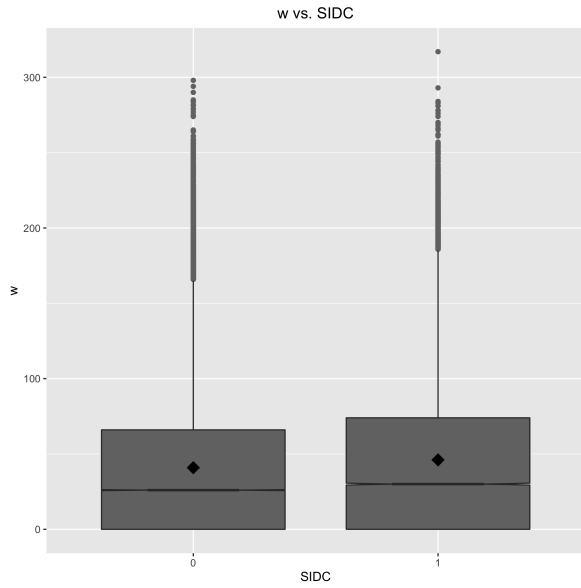


Figure 6: Box plots of raw Wolf number (w) by organization.

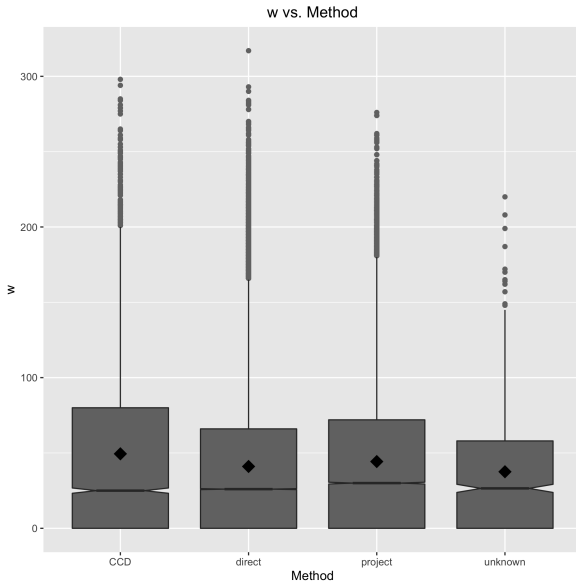


Figure 7: Box plots of raw Wolf number (w) by observer rank.

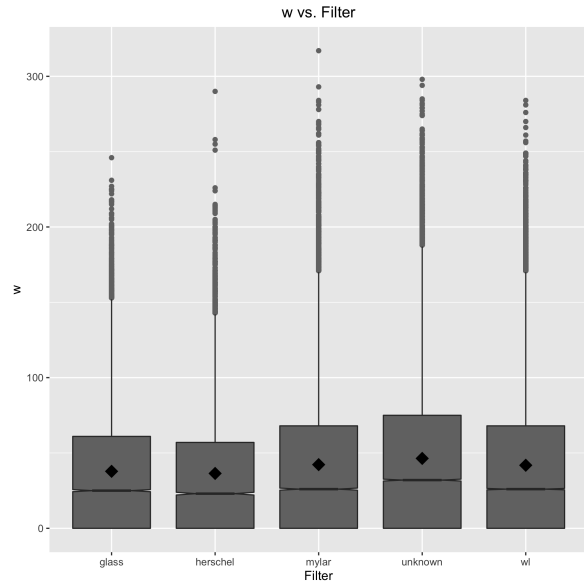


Figure 8: Box plots of raw Wolf number (w) by month and year.

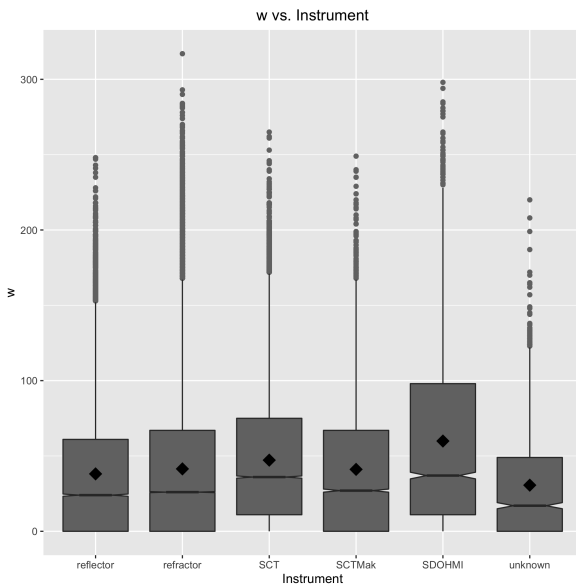


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

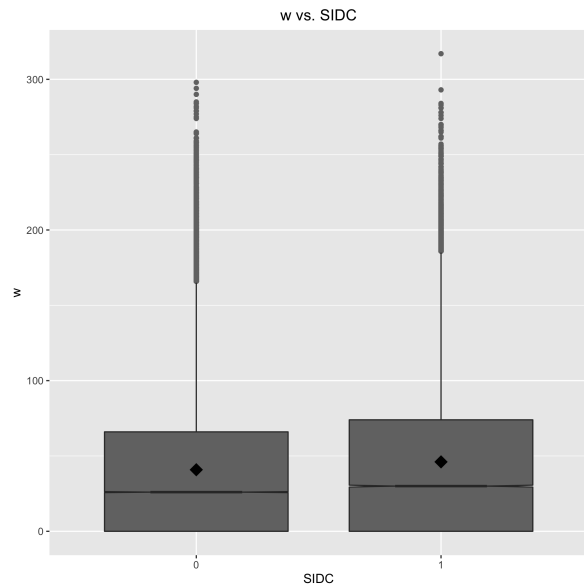


Figure 10: Box plots of raw Wolf number (w) by organization.

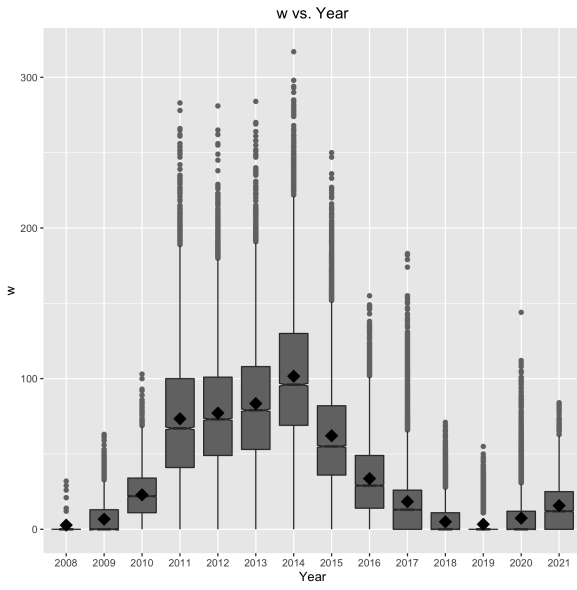


Figure 11: Box plots of raw Wolf number (w) by year.

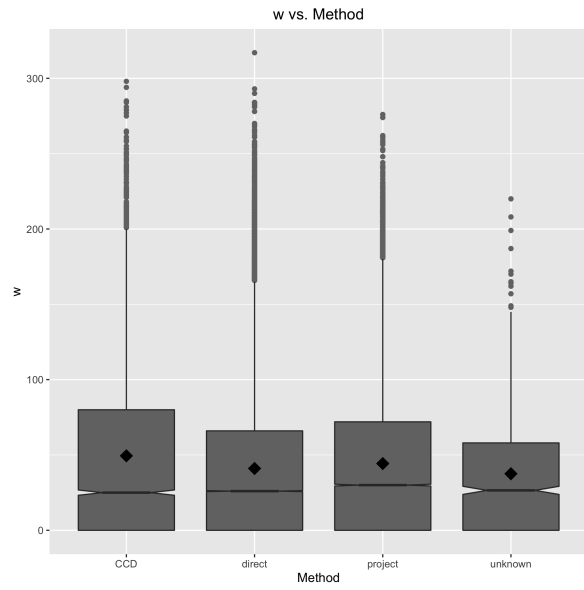


Figure 12: Box plots of raw Wolf number (w) by observing method.