

Monthly Report (00)

2021.06 Data Set

Wednesday 14th July, 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.

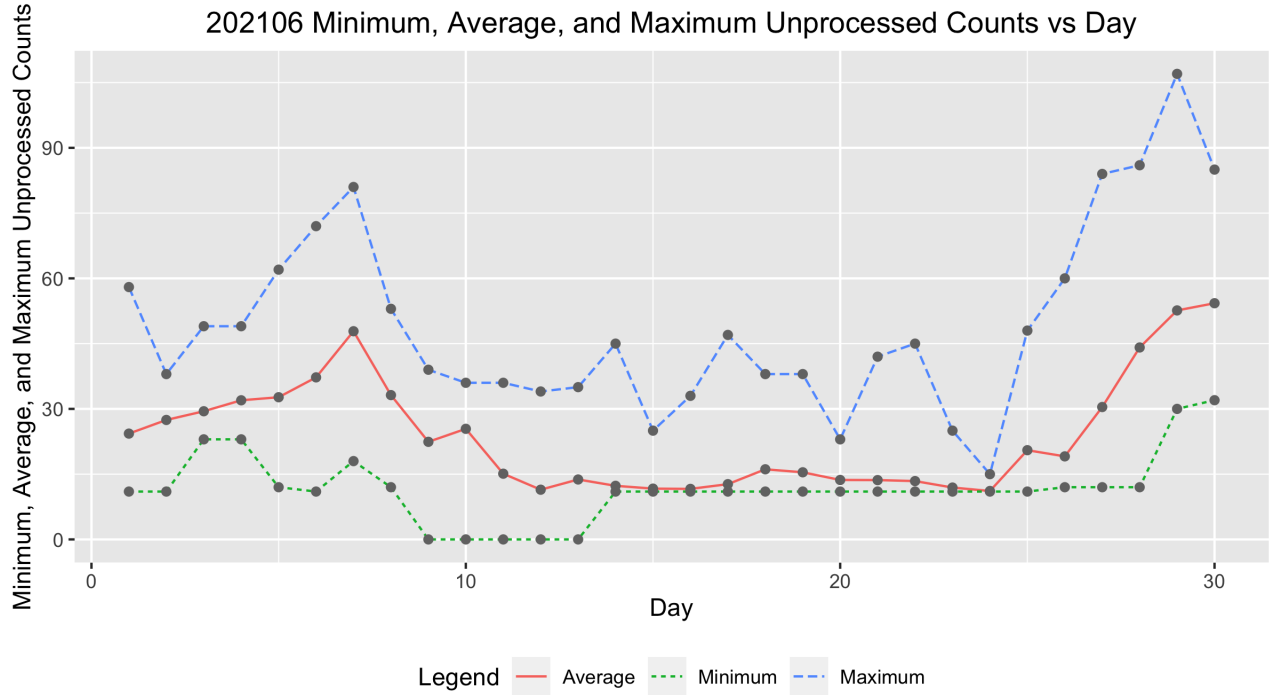


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202106 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	47.0000	11.0000	24.3191	58.0000
2.0000	44.0000	11.0000	27.4545	38.0000
3.0000	46.0000	23.0000	29.4565	49.0000
4.0000	44.0000	23.0000	31.9773	49.0000
5.0000	53.0000	12.0000	32.6792	62.0000
6.0000	53.0000	11.0000	37.2453	72.0000
7.0000	47.0000	18.0000	47.8511	81.0000
8.0000	41.0000	12.0000	33.1707	53.0000
9.0000	42.0000	0.0000	22.4286	39.0000
10.0000	48.0000	0.0000	25.4167	36.0000
11.0000	39.0000	0.0000	15.1026	36.0000
12.0000	47.0000	0.0000	11.4255	34.0000
13.0000	45.0000	0.0000	13.7778	35.0000
14.0000	47.0000	11.0000	12.3191	45.0000
15.0000	46.0000	11.0000	11.6739	25.0000
16.0000	44.0000	11.0000	11.6136	33.0000
17.0000	40.0000	11.0000	12.7000	47.0000
18.0000	43.0000	11.0000	16.1163	38.0000
19.0000	42.0000	11.0000	15.4286	38.0000
20.0000	42.0000	11.0000	13.6667	23.0000
21.0000	44.0000	11.0000	13.6364	42.0000
22.0000	39.0000	11.0000	13.4103	45.0000
23.0000	51.0000	11.0000	11.9216	25.0000
24.0000	46.0000	11.0000	11.1304	15.0000
25.0000	45.0000	11.0000	20.5111	48.0000
26.0000	47.0000	12.0000	19.0851	60.0000
27.0000	49.0000	12.0000	30.4286	84.0000
28.0000	43.0000	12.0000	44.1163	86.0000
29.0000	46.0000	30.0000	52.6304	107.0000
30.0000	42.0000	32.0000	54.2857	85.0000

3 Error Tables

Data are for the month of June 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	2.4083	3.1327	0.5000	1.0000
2009.01	5.6095	5.0027	6.2163	1.3000	1.3000
2009.02	4.8141	4.2790	5.3492	0.7000	1.2000
2009.03	6.4424	6.1909	6.6939	0.3000	0.6000
2009.04	7.3622	7.0967	7.6277	0.4000	1.2000
2009.05	7.3463	7.0545	7.6380	1.6000	2.9000
2009.06	6.6462	6.3083	6.9841	3.2000	6.3000
2009.07	6.2053	5.9549	6.4558	3.6000	5.5000
2009.08	6.8690	6.5971	7.1409	0.0000	0.0000
2009.09	7.2328	6.9744	7.4912	4.5000	7.1000
2009.10	6.9577	6.5907	7.3247	4.5000	7.7000
2009.11	7.1970	6.9998	7.3942	3.3000	6.9000
2009.12	6.5932	6.4065	6.7799	10.4000	16.3000
2010.01	21.0594	18.6635	23.4553	13.3000	19.5000
2010.02	16.4111	14.1806	18.6416	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	18.2901	16.0237	20.5566	15.4000	24.0000
2010.04	20.6464	18.2155	23.0773	7.0000	10.4000
2010.05	24.3229	23.8937	24.7521	8.4000	8.7000
2010.06	20.6524	20.3103	20.9946	11.0000	13.6000
2010.07	21.1104	20.8045	21.4164	15.2000	16.1000
2010.08	22.6118	22.2422	22.9814	18.3000	19.6000
2010.09	24.7007	24.2958	25.1055	22.8000	25.2000
2010.10	24.0436	23.6306	24.4566	21.0000	23.5000
2010.11	25.4444	24.9844	25.9044	20.9000	21.6000
2010.12	22.3975	21.9502	22.8448	13.9000	14.5000
2011.01	75.1307	73.6011	76.6604	17.7000	18.7000
2011.02	63.7087	62.3775	65.0399	29.1000	29.6000
2011.03	68.9866	67.6747	70.2986	48.0000	55.8000
2011.04	78.7476	77.3383	80.1568	47.3000	54.4000
2011.05	78.7046	77.3842	80.0249	37.3000	41.5000
2011.06	66.7973	65.6358	67.9588	35.2000	37.0000
2011.07	67.5836	66.4370	68.7301	41.5000	43.8000
2011.08	73.2248	72.0568	74.3928	42.4000	50.5000
2011.09	78.7341	77.3762	80.0920	73.8000	78.0000
2011.10	76.6274	75.3462	77.9086	78.9000	88.0000
2011.11	80.8927	79.2187	82.5668	84.6000	96.7000
2011.12	70.0052	68.5746	71.4357	65.8000	73.0000
2012.01	80.5941	79.0121	82.1761	55.8000	58.2000
2012.02	67.1357	65.7728	68.4987	29.2000	33.1000
2012.03	73.4984	72.2004	74.7963	53.1000	64.1000
2012.04	82.6388	81.1962	84.0814	51.4000	55.2000
2012.05	84.2237	82.8407	85.6067	61.8000	69.0000
2012.06	70.7511	69.5567	71.9455	59.7000	64.5000
2012.07	72.0315	70.8563	73.2068	64.2000	51.3000
2012.08	75.2537	74.0500	76.4575	57.7000	63.1000
2012.09	81.3920	79.9836	82.8004	57.7000	61.5000
2012.10	80.0913	78.6295	81.5532	48.3000	53.3000
2012.11	84.5542	82.8592	86.2491	56.7000	61.4000
2012.12	73.3561	71.7670	74.9452	37.4000	40.8000
2013.01	89.5741	87.8637	91.2846	63.8000	62.9000
2013.02	74.7679	73.2647	76.2711	37.8000	38.0000
2013.03	79.2901	77.6761	80.9041	50.6000	57.9000
2013.04	90.0999	88.5148	91.6850	70.6000	72.4000
2013.05	89.7345	88.1369	91.3321	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	76.9482	75.5903	78.3061	51.0000	52.5000
2013.07	77.3597	76.1183	78.6011	57.0000	57.0000
2013.08	82.4072	81.0818	83.7327	60.0000	66.0000
2013.09	87.7912	86.2247	89.3576	34.6000	36.9000
2013.10	85.3695	83.7859	86.9531	74.5000	85.6000
2013.11	88.5108	86.5219	90.4997	73.9000	77.6000
2013.12	78.9558	77.2671	80.6445	77.8000	90.3000
2014.01	104.4017	102.2035	106.5999	77.4000	82.0000
2014.02	88.8975	87.1439	90.6511	93.9000	102.8000
2014.03	96.4890	94.7295	98.2485	80.9000	92.2000
2014.04	109.8047	107.8837	111.7257	76.9000	84.7000
2014.05	110.0276	108.1508	111.9043	72.3000	75.2000
2014.06	94.1612	92.5707	95.7517	67.2000	71.0000
2014.07	94.3223	92.7511	95.8934	72.5000	72.5000
2014.08	100.6320	99.0609	102.2031	71.2000	74.7000
2014.09	108.3748	106.4646	110.2850	83.2000	87.6000
2014.10	104.9903	103.0572	106.9234	59.5000	60.6000
2014.11	110.0489	107.7614	112.3365	65.8000	71.1000
2014.12	96.0721	93.8475	98.2968	75.8000	78.0000
2015.01	64.4938	63.2044	65.7832	65.9000	67.0000
2015.02	53.5921	52.4123	54.7719	42.4000	44.8000
2015.03	58.9399	57.8635	60.0163	38.0000	38.4000
2015.04	66.6935	65.5052	67.8819	49.0000	54.4000
2015.05	67.0908	65.9849	68.1967	56.3000	58.8000
2015.06	57.3100	56.2823	58.3377	50.2000	68.3000
2015.07	56.9406	55.9741	57.9071	47.9000	65.8000
2015.08	61.9189	60.8828	62.9549	39.5000	57.2000
2015.09	65.8641	64.6708	67.0573	49.2000	72.1000
2015.10	64.2746	63.0359	65.5132	39.3000	48.3000
2015.11	68.0210	66.5431	69.4990	39.6000	55.9000
2015.12	59.4629	58.1513	60.7744	36.4000	44.8000
2016.01	35.3203	34.5853	36.0554	33.7000	43.3000
2016.02	29.4701	28.8566	30.0835	38.3000	46.8000
2016.03	31.8755	31.2404	32.5105	30.5000	38.9000
2016.04	35.9658	35.2824	36.6492	26.6000	30.9000
2016.05	36.2893	35.6287	36.9499	33.7000	48.4000
2016.06	30.6405	30.1186	31.1625	13.1000	19.5000
2016.07	31.0022	30.5060	31.4983	21.2000	27.5000
2016.08	33.3566	32.7720	33.9411	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	36.3058	35.6453	36.9662	27.7000	37.1000
2016.10	35.0666	34.3933	35.7399	22.7000	31.7000
2016.11	36.7158	35.9500	37.4815	14.0000	22.2000
2016.12	32.5016	31.8063	33.1970	11.1000	20.0000
2017.01	19.1724	18.7693	19.5755	18.4000	26.2000
2017.02	16.0632	15.7108	16.4156	14.4000	20.6000
2017.03	17.5315	17.1980	17.8651	11.3000	15.5000
2017.04	19.9813	19.6297	20.3329	21.6000	33.2000
2017.05	19.8391	19.4973	20.1810	12.5000	18.1000
2017.06	16.7457	16.4671	17.0244	15.5000	19.3000
2017.07	17.0142	16.7431	17.2853	11.5000	16.3000
2017.08	18.2622	17.9420	18.5824	22.8000	35.7000
2017.09	20.2558	19.8181	20.6936	34.6000	42.9000
2017.10	19.0348	18.6408	19.4288	10.5000	11.0000
2017.11	19.7655	19.3476	20.1834	4.2000	5.6000
2017.12	17.4116	17.1469	17.6764	4.0000	4.6000
2018.01	5.3351	5.2214	5.4489	3.1000	6.3000
2018.02	4.4293	4.3221	4.5364	6.8000	11.8000
2018.03	4.7507	4.6549	4.8465	1.1000	1.2000
2018.04	5.3618	5.2546	5.4690	4.7000	7.5000
2018.05	5.4123	5.3113	5.5134	8.4000	14.0000
2018.06	4.5838	4.5032	4.6644	10.2000	13.6000
2018.07	4.6578	4.6052	4.7104	0.5000	1.7000
2018.08	4.9451	4.8608	5.0295	5.9000	9.5000
2018.09	5.2720	5.1735	5.3705	1.6000	2.9000
2018.10	5.2232	5.1209	5.3254	2.5000	5.6000
2018.11	5.4484	5.3352	5.5616	3.1000	4.2000
2018.12	4.8988	4.8030	4.9945	1.6000	2.3000
2019.01	3.5169	3.4500	3.5838	5.4000	2.3000
2019.02	2.9863	2.9276	3.0451	0.1000	1.2000
2019.03	3.1658	3.1116	3.2200	6.1000	12.1000
2019.04	3.6015	3.5331	3.6698	6.2000	9.3000
2019.05	3.5175	3.4563	3.5787	7.0000	11.9000
2019.06	2.9864	2.9364	3.0365	0.7000	1.5000
2019.07	3.0402	2.9951	3.0854	0.4000	2.2000
2019.08	3.2815	3.2333	3.3298	0.3000	0.8000
2019.09	3.5731	3.5174	3.6288	0.5000	1.0000
2019.10	3.4412	3.3833	3.4990	0.2000	0.5000
2019.11	3.6558	3.5864	3.7253	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	3.1925	3.1300	3.2551	0.8000	1.0000
2020.01	7.7669	7.6162	7.9175	4.0000	5.3000
2020.02	6.5137	6.3848	6.6427	0.1000	0.0000
2020.03	6.9712	6.8420	7.1005	1.2000	1.5000
2020.04	7.9857	7.8559	8.1156	3.0000	5.1000
2020.05	7.8827	7.7602	8.0052	0.1000	0.4000
2020.06	6.7372	6.6348	6.8397	3.9000	6.4000
2020.07	6.7519	6.6538	6.8499	4.2000	7.7000
2020.08	7.1663	7.0688	7.2638	5.3000	7.8000
2020.09	7.8069	7.6842	7.9297	0.4000	0.9000
2020.10	7.6913	7.5672	7.8153	9.9000	13.6000
2020.11	8.1750	8.0467	8.3033	21.2000	33.1000
2020.12	7.2444	7.1217	7.3672	15.4000	19.8000
2021.01	17.8402	17.5340	18.1465	7.0000	15.8000
2021.02	15.1855	14.9189	15.4520	5.8000	10.7000
2021.03	16.4329	16.1732	16.6925	11.0000	17.2000
2021.04	18.7702	18.4897	19.0508	18.5000	28.8000
2021.05	18.7621	18.4979	19.0263	15.9000	22.9000
2021.06	16.0045	15.7719	16.2371	19.9000	24.1000

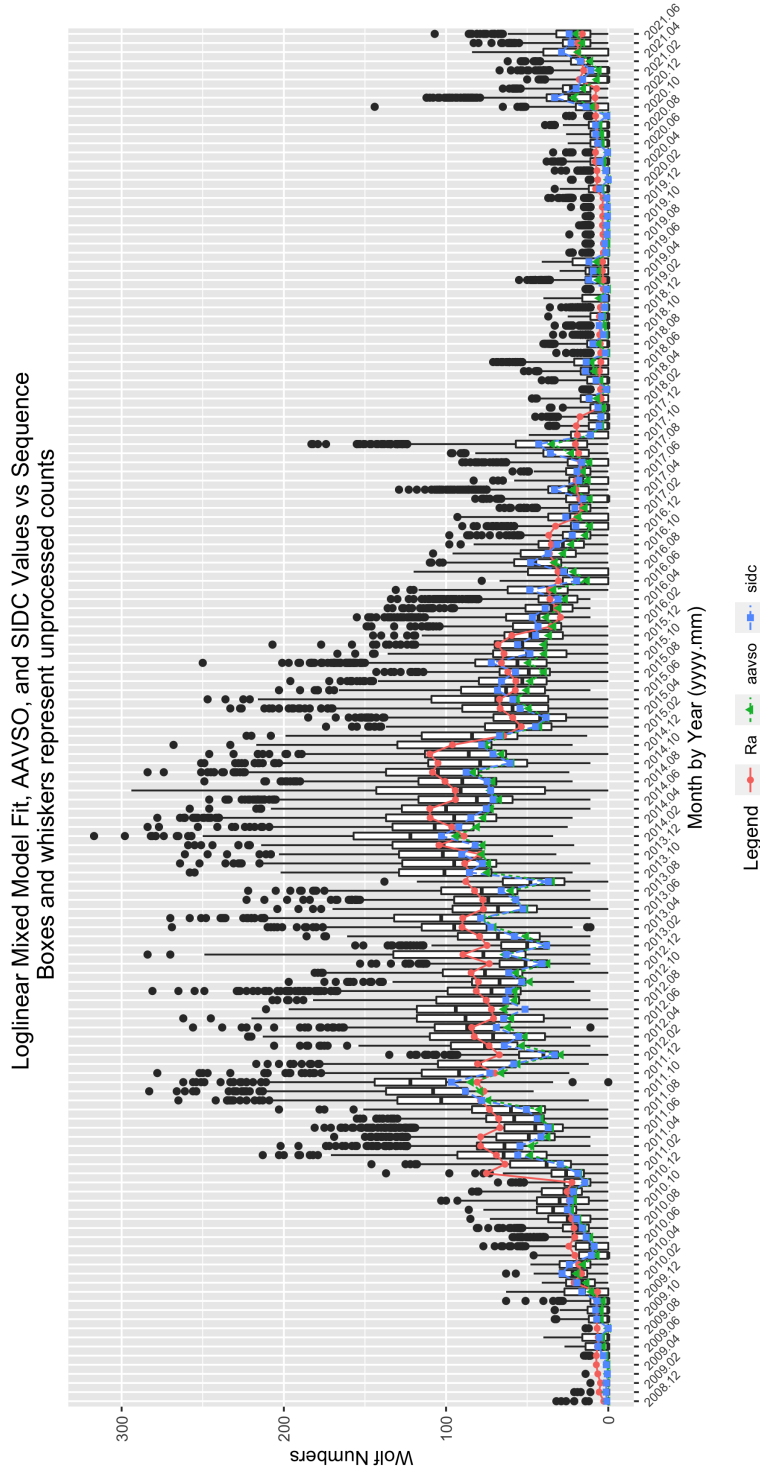


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202106 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t)$
(Intercept)	1.4236	0.3093	4.6024	0.0000
seeF	-0.2188	0.0057	-38.2370	0.0000
seeG	-0.1196	0.0050	-23.9414	0.0000
seeM	-0.2014	0.0240	-8.4076	0.0000
seeP	-0.3219	0.0082	-39.3473	0.0000
sidc1	-0.0015	0.0336	-0.0436	0.9652
year2009	0.6535	0.3104	2.1052	0.0353
year2010	1.8801	0.3083	6.0994	0.0000
year2011	3.0051	0.3082	9.7520	0.0000
year2012	3.0430	0.3081	9.8752	0.0000
year2013	3.1387	0.3081	10.1857	0.0000
year2014	3.3356	0.3081	10.8250	0.0000
year2015	2.8501	0.3082	9.2491	0.0000
year2016	2.2334	0.3082	7.2469	0.0000
year2017	1.6262	0.3082	5.2761	0.0000
year2018	0.3375	0.3085	1.0939	0.2740
year2019	-0.0877	0.3087	-0.2842	0.7762
year2020	0.7141	0.3084	2.3156	0.0206
year2021	1.5528	0.3084	5.0353	0.0000
mon2	-0.1718	0.0091	-18.9581	0.0000
mon3	-0.0976	0.0084	-11.5696	0.0000
mon4	0.0211	0.0081	2.6048	0.0092
mon5	0.0172	0.0080	2.1569	0.0310
mon6	-0.1487	0.0083	-17.8563	0.0000
mon7	-0.1453	0.0082	-17.6607	0.0000
mon8	-0.0727	0.0081	-9.0239	0.0000
mon9	0.0095	0.0081	1.1696	0.2422
mon10	-0.0155	0.0083	-1.8761	0.0606
mon11	0.0452	0.0086	5.2828	0.0000
mon12	-0.0799	0.0088	-9.1095	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: 202106 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:142757	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 : 6.533	Mean :15.72		Mean :0.2533
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: 202106 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.00	Min. : 0.00	Min. : 0.00	Length:142757	Length:142757
1st Qu.: 0.00	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.00	Median : 7.00	Median : 26.00	Mode :character	Mode :character
Mean : 2.65	Mean : 15.52	Mean : 42.02		
3rd Qu.: 4.00	3rd Qu.: 23.00	3rd Qu.: 68.00		
Max. :19.00	Max. :204.00	Max. :317.00		

Table 6: 202106 Summary of Sunspot Numbers

inst	filter	unit
Length:142757	Length:142757	Length:142757
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202106 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 : 90.88	Mean : 32.95	Mean : 884.1	Mean : 182.5
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

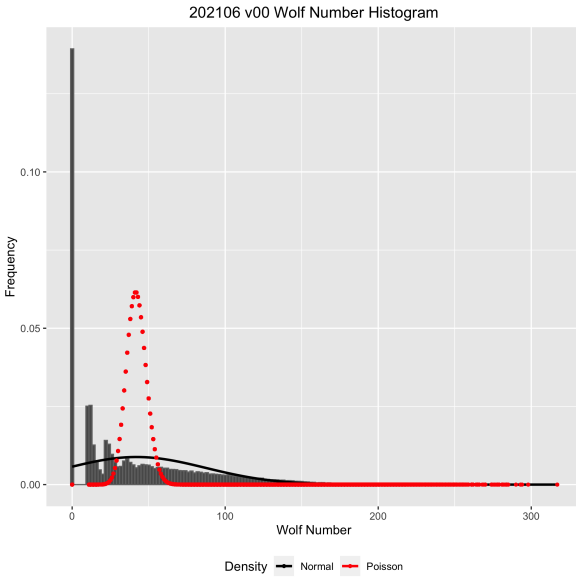


Figure 3: Box plots of raw Wolf number (w) by observer rank.

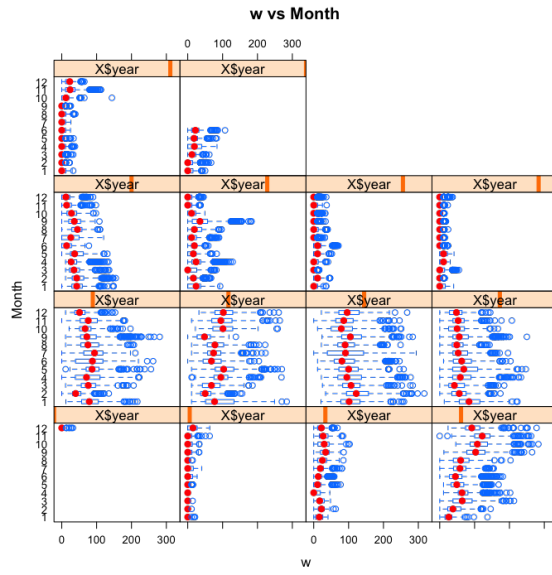


Figure 4: Box plots of raw Wolf number (w) by month and year.

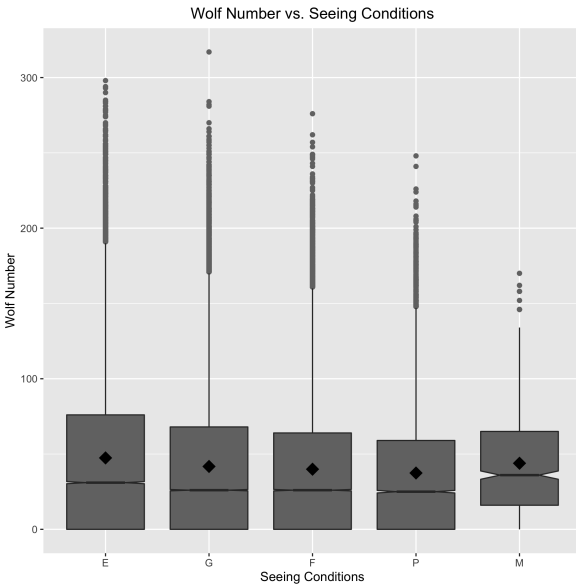


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

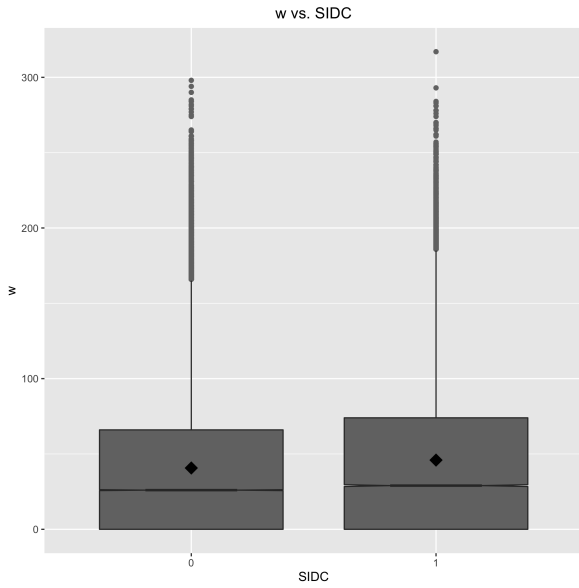


Figure 6: Box plots of raw Wolf number (w) by organization.

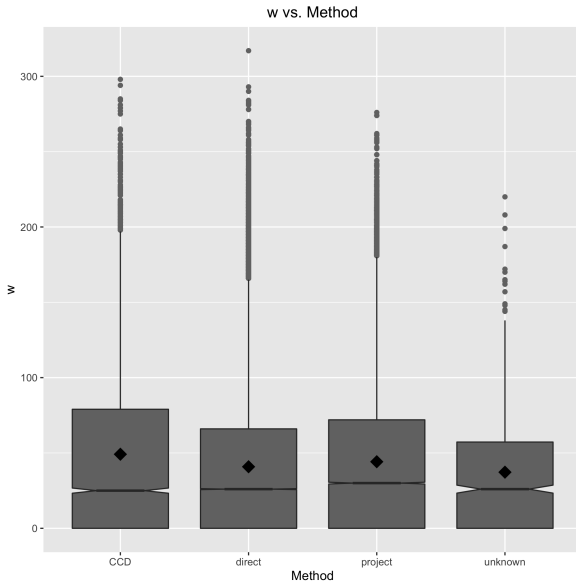


Figure 7: Box plots of raw Wolf number (w) by observer rank.

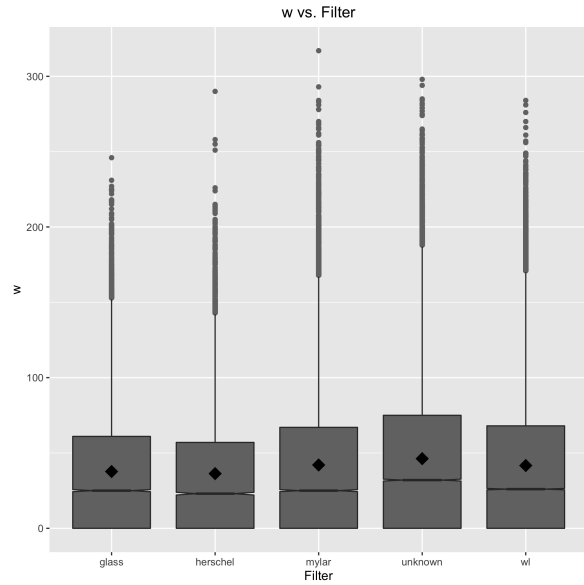


Figure 8: Box plots of raw Wolf number (w) by month and year.

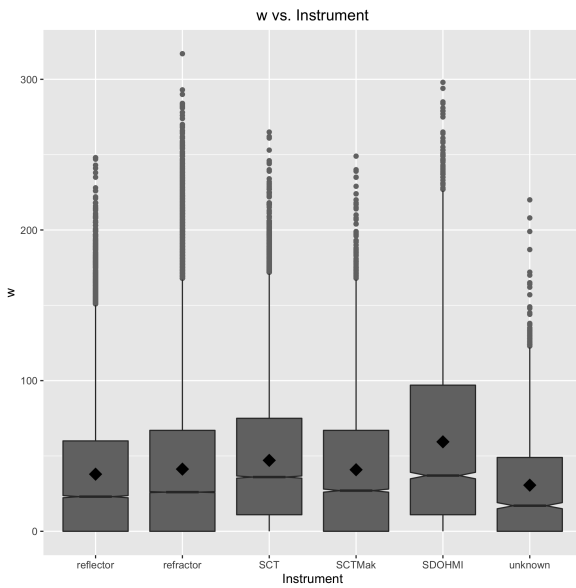


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

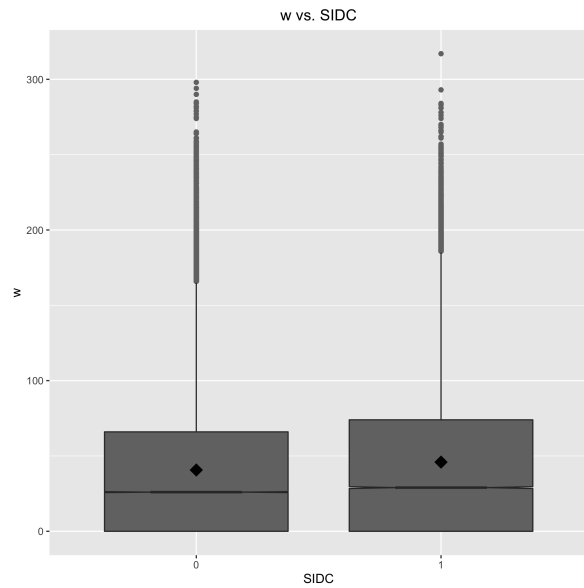


Figure 10: Box plots of raw Wolf number (w) by organization.

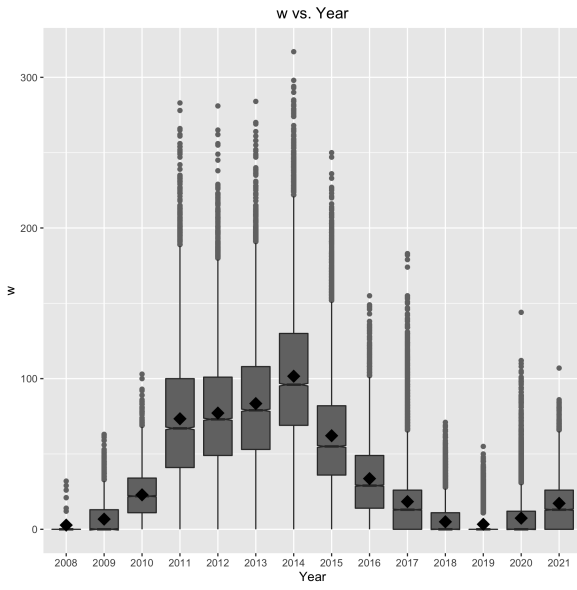


Figure 11: Box plots of raw Wolf number (w) by year.

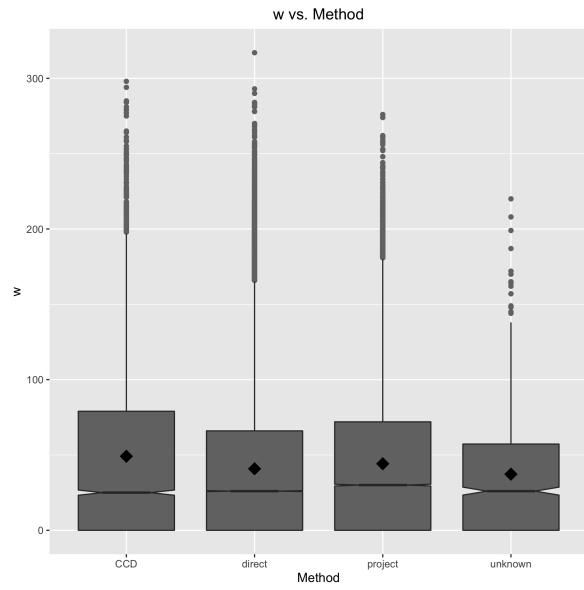


Figure 12: Box plots of raw Wolf number (w) by observing method.