

**Monthly Report (00)**  
**2021.08 Data Set**

Monday 13<sup>th</sup> September, 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.

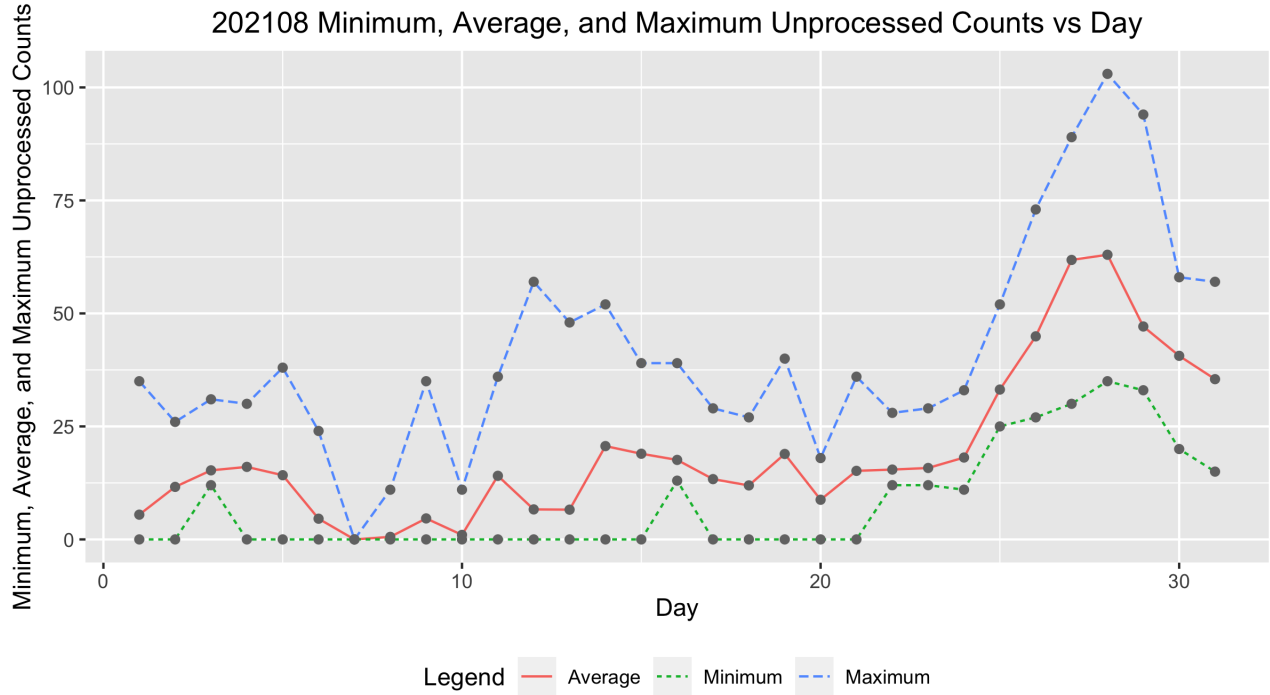


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202108 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	42.0000	0.0000	5.4762	35.0000
2.0000	48.0000	0.0000	11.6250	26.0000
3.0000	43.0000	12.0000	15.2791	31.0000
4.0000	43.0000	0.0000	16.0465	30.0000
5.0000	44.0000	0.0000	14.2045	38.0000
6.0000	43.0000	0.0000	4.5814	24.0000
7.0000	32.0000	0.0000	0.0000	0.0000
8.0000	39.0000	0.0000	0.5641	11.0000
9.0000	48.0000	0.0000	4.6458	35.0000
10.0000	44.0000	0.0000	1.0000	11.0000
11.0000	41.0000	0.0000	14.0732	36.0000
12.0000	39.0000	0.0000	6.6410	57.0000
13.0000	41.0000	0.0000	6.5854	48.0000
14.0000	40.0000	0.0000	20.6500	52.0000
15.0000	47.0000	0.0000	18.9574	39.0000
16.0000	44.0000	13.0000	17.5909	39.0000
17.0000	38.0000	0.0000	13.3421	29.0000
18.0000	38.0000	0.0000	11.9474	27.0000
19.0000	43.0000	0.0000	18.9070	40.0000
20.0000	36.0000	0.0000	8.7778	18.0000
21.0000	47.0000	0.0000	15.1702	36.0000
22.0000	42.0000	12.0000	15.4524	28.0000
23.0000	41.0000	12.0000	15.8049	29.0000
24.0000	43.0000	11.0000	18.1163	33.0000
25.0000	45.0000	25.0000	33.1556	52.0000
26.0000	41.0000	27.0000	44.9268	73.0000
27.0000	49.0000	30.0000	61.8367	89.0000
28.0000	45.0000	35.0000	62.9778	103.0000
29.0000	46.0000	33.0000	47.1087	94.0000
30.0000	39.0000	20.0000	40.6154	58.0000
31.0000	44.0000	15.0000	35.4545	57.0000

### 3 Error Tables

Data are for the month of August 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 25<sup>th</sup> through the 75<sup>th</sup> quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25<sup>th</sup> quartile, and 1.5 times the IQR above the 75<sup>th</sup> 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	2.4102	3.1308	0.5000	1.0000
2009.01	5.5857	4.9847	6.1868	1.3000	1.3000
2009.02	4.7919	4.2620	5.3217	0.7000	1.2000
2009.03	6.4028	6.1544	6.6511	0.3000	0.6000
2009.04	7.3186	7.0568	7.5804	0.4000	1.2000
2009.05	7.3059	7.0179	7.5939	1.6000	2.9000
2009.06	6.6075	6.2733	6.9417	3.2000	6.3000
2009.07	6.3678	6.1122	6.6235	3.6000	5.5000
2009.08	6.8762	6.6065	7.1458	0.0000	0.0000
2009.09	7.2304	6.9740	7.4869	4.5000	7.1000
2009.10	6.9554	6.5903	7.3204	4.5000	7.7000
2009.11	7.1993	7.0025	7.3961	3.3000	6.9000
2009.12	6.5947	6.4084	6.7810	10.4000	16.3000
2010.01	20.9118	18.5452	23.2784	13.3000	19.5000
2010.02	16.2893	14.0876	18.4909	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	18.1570	15.9189	20.3951	15.4000	24.0000
2010.04	20.4950	18.0947	22.8954	7.0000	10.4000
2010.05	24.1356	23.7104	24.5609	8.4000	8.7000
2010.06	20.4899	20.1503	20.8295	11.0000	13.6000
2010.07	21.6136	21.3003	21.9270	15.2000	16.1000
2010.08	22.5803	22.2110	22.9495	18.3000	19.6000
2010.09	24.6387	24.2354	25.0420	22.8000	25.2000
2010.10	23.9837	23.5719	24.3955	21.0000	23.5000
2010.11	25.3834	24.9250	25.8417	20.9000	21.6000
2010.12	22.3448	21.8993	22.7903	13.9000	14.5000
2011.01	74.7574	73.2385	76.2762	17.7000	18.7000
2011.02	63.3680	62.0476	64.6883	29.1000	29.6000
2011.03	68.6016	67.2976	69.9057	48.0000	55.8000
2011.04	78.3242	76.9214	79.7269	47.3000	54.4000
2011.05	78.3055	76.9923	79.6186	37.3000	41.5000
2011.06	66.4395	65.2839	67.5952	35.2000	37.0000
2011.07	69.3535	68.1765	70.5305	41.5000	43.8000
2011.08	73.2770	72.1072	74.4468	42.4000	50.5000
2011.09	78.7300	77.3717	80.0884	73.8000	78.0000
2011.10	76.6252	75.3441	77.9064	78.9000	88.0000
2011.11	80.8823	79.2096	82.5550	84.6000	96.7000
2011.12	70.0006	68.5714	71.4298	65.8000	73.0000
2012.01	80.2117	78.6366	81.7869	55.8000	58.2000
2012.02	66.7765	65.4209	68.1320	29.2000	33.1000
2012.03	73.0960	71.8055	74.3865	53.1000	64.1000
2012.04	82.1817	80.7452	83.6181	51.4000	55.2000
2012.05	83.7998	82.4230	85.1766	61.8000	69.0000
2012.06	70.3845	69.1961	71.5729	59.7000	64.5000
2012.07	73.9566	72.7496	75.1636	64.2000	51.3000
2012.08	75.3403	74.1346	76.5459	57.7000	63.1000
2012.09	81.4049	79.9958	82.8141	57.7000	61.5000
2012.10	80.1105	78.6483	81.5727	48.3000	53.3000
2012.11	84.5722	82.8762	86.2681	56.7000	61.4000
2012.12	73.3792	71.7895	74.9689	37.4000	40.8000
2013.01	89.1149	87.4126	90.8171	63.8000	62.9000
2013.02	74.3497	72.8544	75.8449	37.8000	38.0000
2013.03	78.8406	77.2351	80.4461	50.6000	57.9000
2013.04	89.5982	88.0213	91.1750	70.6000	72.4000
2013.05	89.2687	87.6786	90.8588	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	76.5460	75.1945	77.8974	51.0000	52.5000
2013.07	79.4074	78.1322	80.6827	57.0000	57.0000
2013.08	82.5059	81.1784	83.8333	60.0000	66.0000
2013.09	87.7936	86.2267	89.3605	34.6000	36.9000
2013.10	85.3865	83.8020	86.9709	74.5000	85.6000
2013.11	88.5362	86.5466	90.5258	73.9000	77.6000
2013.12	78.9748	77.2860	80.6635	77.8000	90.3000
2014.01	103.8732	101.6859	106.0606	77.4000	82.0000
2014.02	88.4152	86.6709	90.1595	93.9000	102.8000
2014.03	95.9734	94.2233	97.7235	80.9000	92.2000
2014.04	109.2350	107.3227	111.1473	76.9000	84.7000
2014.05	109.4865	107.6192	111.3538	72.3000	75.2000
2014.06	93.6713	92.0890	95.2536	67.2000	71.0000
2014.07	96.8254	95.2119	98.4389	72.5000	72.5000
2014.08	100.7714	99.1989	102.3439	71.2000	74.7000
2014.09	108.4030	106.4923	110.3137	83.2000	87.6000
2014.10	105.0068	103.0742	106.9395	59.5000	60.6000
2014.11	110.0729	107.7856	112.3602	65.8000	71.1000
2014.12	96.0971	93.8722	98.3219	75.8000	78.0000
2015.01	64.1657	62.8831	65.4484	65.9000	67.0000
2015.02	53.3160	52.1422	54.4899	42.4000	44.8000
2015.03	58.6319	57.5612	59.7027	38.0000	38.4000
2015.04	66.3513	65.1702	67.5324	49.0000	54.4000
2015.05	66.7665	65.6661	67.8669	56.3000	58.8000
2015.06	57.0215	55.9998	58.0431	50.2000	68.3000
2015.07	58.4549	57.4635	59.4464	47.9000	65.8000
2015.08	61.9806	60.9443	63.0170	39.5000	57.2000
2015.09	65.8824	64.6899	67.0749	49.2000	72.1000
2015.10	64.2870	63.0487	65.5254	39.3000	48.3000
2015.11	68.0409	66.5629	69.5190	39.6000	55.9000
2015.12	59.4849	58.1728	60.7969	36.4000	44.8000
2016.01	35.1396	34.4083	35.8708	33.7000	43.3000
2016.02	29.3089	28.6989	29.9189	38.3000	46.8000
2016.03	31.6960	31.0647	32.3273	30.5000	38.9000
2016.04	35.7694	35.0900	36.4488	26.6000	30.9000
2016.05	36.1059	35.4489	36.7629	33.7000	48.4000
2016.06	30.4721	29.9532	30.9909	13.1000	19.5000
2016.07	31.8240	31.3155	32.3326	21.2000	27.5000
2016.08	33.3944	32.8099	33.9789	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	36.3102	35.6504	36.9700	27.7000	37.1000
2016.10	35.0671	34.3941	35.7400	22.7000	31.7000
2016.11	36.7205	35.9553	37.4857	14.0000	22.2000
2016.12	32.4969	31.8021	33.1917	11.1000	20.0000
2017.01	19.0779	18.6772	19.4787	18.4000	26.2000
2017.02	15.9788	15.6284	16.3292	14.4000	20.6000
2017.03	17.4356	17.1041	17.7671	11.3000	15.5000
2017.04	19.8715	19.5221	20.2210	21.6000	33.2000
2017.05	19.7370	19.3972	20.0768	12.5000	18.1000
2017.06	16.6580	16.3810	16.9350	15.5000	19.3000
2017.07	17.4607	17.1823	17.7390	11.5000	16.3000
2017.08	18.2831	17.9626	18.6037	22.8000	35.7000
2017.09	20.2530	19.8160	20.6899	34.6000	42.9000
2017.10	19.0311	18.6369	19.4253	10.5000	11.0000
2017.11	19.7669	19.3485	20.1852	4.2000	5.6000
2017.12	17.4138	17.1489	17.6786	4.0000	4.6000
2018.01	5.2964	5.1836	5.4092	3.1000	6.3000
2018.02	4.3945	4.2882	4.5007	6.8000	11.8000
2018.03	4.7134	4.6182	4.8086	1.1000	1.2000
2018.04	5.3218	5.2155	5.4280	4.7000	7.5000
2018.05	5.3725	5.2723	5.4728	8.4000	14.0000
2018.06	4.5494	4.4694	4.6294	10.2000	13.6000
2018.07	4.7684	4.7143	4.8224	0.5000	1.7000
2018.08	4.9377	4.8533	5.0221	5.9000	9.5000
2018.09	5.2617	5.1632	5.3603	1.6000	2.9000
2018.10	5.2096	5.1074	5.3119	2.5000	5.6000
2018.11	5.4340	5.3208	5.5472	3.1000	4.2000
2018.12	4.8873	4.7917	4.9829	1.6000	2.3000
2019.01	3.4999	3.4332	3.5665	5.4000	2.3000
2019.02	2.9717	2.9132	3.0301	0.1000	1.2000
2019.03	3.1488	3.0948	3.2027	6.1000	12.1000
2019.04	3.5817	3.5136	3.6498	6.2000	9.3000
2019.05	3.4993	3.4382	3.5604	7.0000	11.9000
2019.06	2.9695	2.9195	3.0196	0.7000	1.5000
2019.07	3.1195	3.0730	3.1661	0.4000	2.2000
2019.08	3.2844	3.2359	3.3329	0.3000	0.8000
2019.09	3.5733	3.5173	3.6292	0.5000	1.0000
2019.10	3.4414	3.3834	3.4994	0.2000	0.5000
2019.11	3.6571	3.5875	3.7266	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	3.1960	3.1334	3.2587	0.8000	1.0000
2020.01	7.7377	7.5873	7.8881	4.0000	5.3000
2020.02	6.4862	6.3575	6.6149	0.1000	0.0000
2020.03	6.9403	6.8113	7.0692	1.2000	1.5000
2020.04	7.9507	7.8207	8.0808	3.0000	5.1000
2020.05	7.8518	7.7291	7.9744	0.1000	0.4000
2020.06	6.7091	6.6064	6.8118	3.9000	6.4000
2020.07	6.9360	6.8342	7.0378	4.2000	7.7000
2020.08	7.1784	7.0798	7.2771	5.3000	7.8000
2020.09	7.8052	7.6816	7.9289	0.4000	0.9000
2020.10	7.6878	7.5628	7.8128	9.9000	13.6000
2020.11	8.1558	8.0272	8.2843	21.2000	33.1000
2020.12	7.2123	7.0895	7.3351	15.4000	19.8000
2021.01	19.9071	19.5658	20.2485	7.0000	15.8000
2021.02	16.9369	16.6410	17.2329	5.8000	10.7000
2021.03	18.3175	18.0327	18.6024	11.0000	17.2000
2021.04	20.9270	20.6174	21.2366	18.5000	28.8000
2021.05	20.9085	20.6177	21.1994	15.9000	22.9000
2021.06	17.9187	17.6562	18.1812	19.9000	24.1000
2021.07	18.4711	18.1912	18.7511	23.8000	35.6000
2021.08	19.4841	19.1958	19.7724	15.7000	19.5000

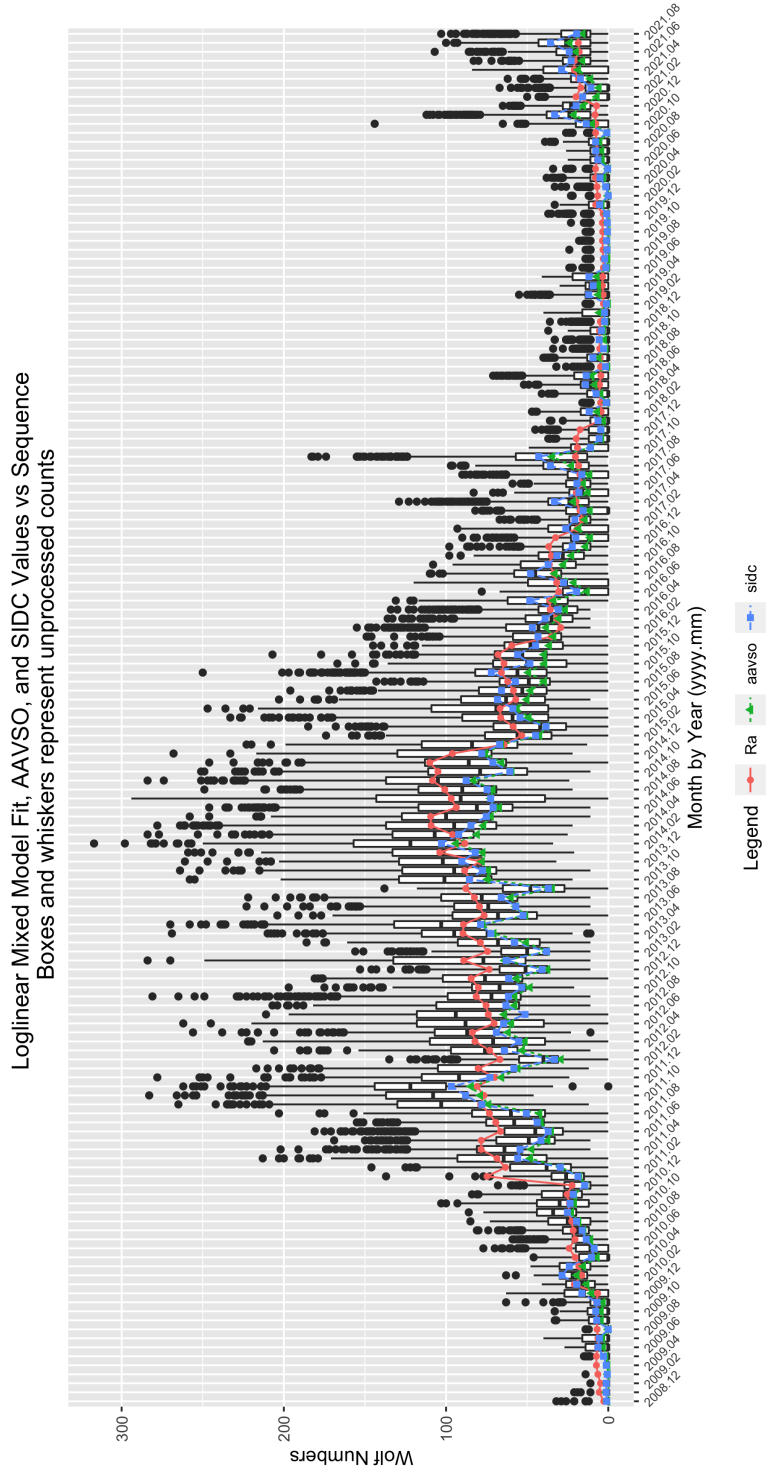


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202108 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t )$
(Intercept)	1.4200	0.3101	4.5788	0.0000
seeF	-0.2193	0.0057	-38.4285	0.0000
seeG	-0.1200	0.0050	-24.0874	0.0000
seeM	-0.2007	0.0240	-8.3631	0.0000
seeP	-0.3220	0.0082	-39.4477	0.0000
sidc1	-0.0069	0.0271	-0.2535	0.7999
year2009	0.6542	0.3112	2.1018	0.0356
year2010	1.8783	0.3091	6.0768	0.0000
year2011	3.0058	0.3090	9.7280	0.0000
year2012	3.0441	0.3090	9.8519	0.0000
year2013	3.1396	0.3090	10.1613	0.0000
year2014	3.3365	0.3090	10.7987	0.0000
year2015	2.8514	0.3090	9.2282	0.0000
year2016	2.2345	0.3090	7.2309	0.0000
year2017	1.6275	0.3091	5.2661	0.0000
year2018	0.3368	0.3093	1.0887	0.2763
year2019	-0.0849	0.3096	-0.2742	0.7839
year2020	0.7181	0.3092	2.3224	0.0202
year2021	1.6761	0.3091	5.4220	0.0000
mon2	-0.1723	0.0091	-18.9620	0.0000
mon3	-0.0982	0.0085	-11.6092	0.0000
mon4	0.0206	0.0081	2.5299	0.0114
mon5	0.0170	0.0080	2.1261	0.0335
mon6	-0.1489	0.0083	-17.8414	0.0000
mon7	-0.1142	0.0081	-14.0683	0.0000
mon8	-0.0665	0.0080	-8.3289	0.0000
mon9	0.0146	0.0081	1.7930	0.0730
mon10	-0.0104	0.0083	-1.2510	0.2109
mon11	0.0504	0.0086	5.8755	0.0000
mon12	-0.0746	0.0088	-8.4899	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 contribute to both institutions tend to differ from those observers contributing only to the AAVSO.

## 5 Supporting Information

Table 4: 202108 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:145394	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 : 6.551	Mean :15.72		Mean :0.2515
3rd Qu.:2019	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: 202108 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.0	Length:145394	Length:145394
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.0	Class :character	Class :character
Median : 2.000	Median : 7.00	Median : 26.0	Mode :character	Mode :character
Mean : 2.632	Mean : 15.38	Mean : 41.7		
3rd Qu.: 4.000	3rd Qu.: 23.00	3rd Qu.: 67.0		
Max. :19.000	Max. :204.00	Max. :317.0		

Table 6: 202108 Summary of Sunspot Numbers

inst	filter	unit
Length:145394	Length:145394	Length:145394
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202108 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 60.00	1st Qu.: 4.00	1st Qu.: 34.0	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 910.0	Median : 57.5
Mean : 91.12	Mean : 33.47	Mean : 886.4	Mean : 182.1
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

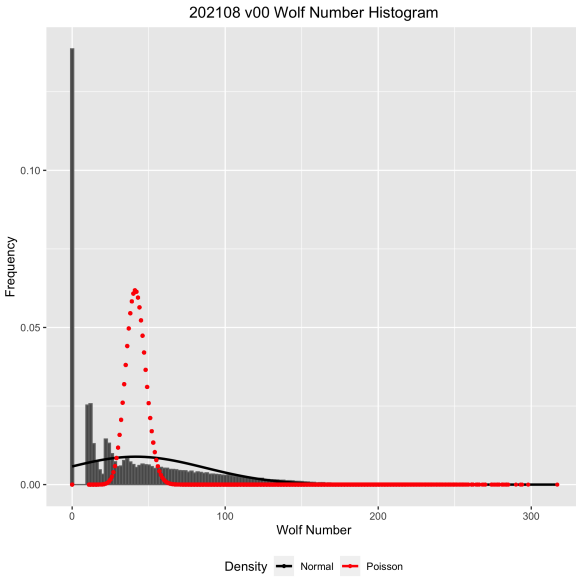


Figure 3: Box plots of raw Wolf number ( $w$ ) by observer rank.

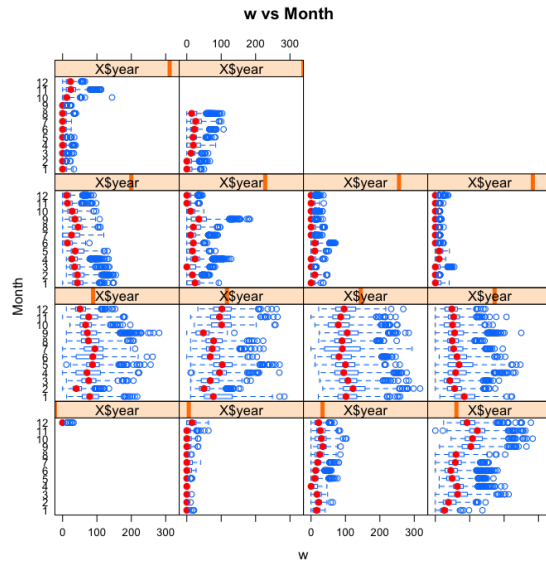


Figure 4: Box plots of raw Wolf number ( $w$ ) by month and year.

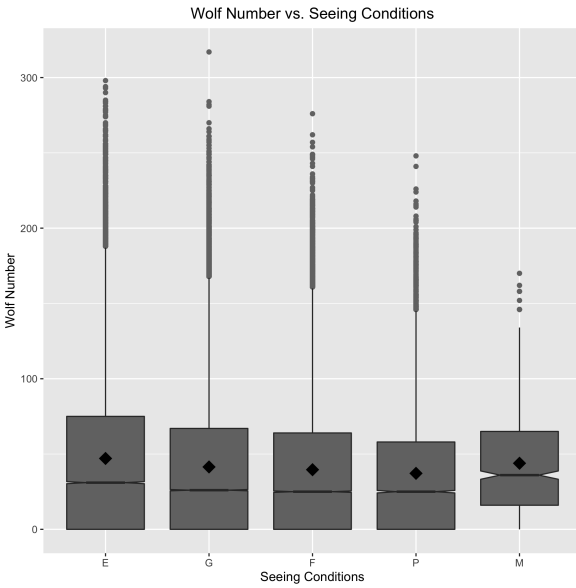


Figure 5: Box plots of raw Wolf number ( $w$ ) by seeing condition.

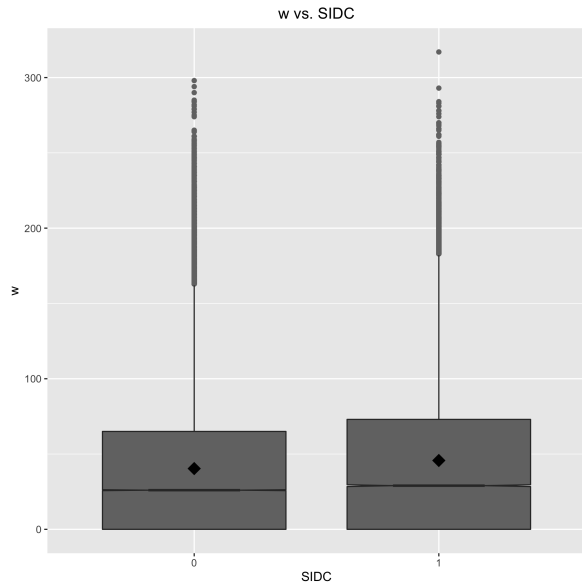


Figure 6: Box plots of raw Wolf number ( $w$ ) by organization.

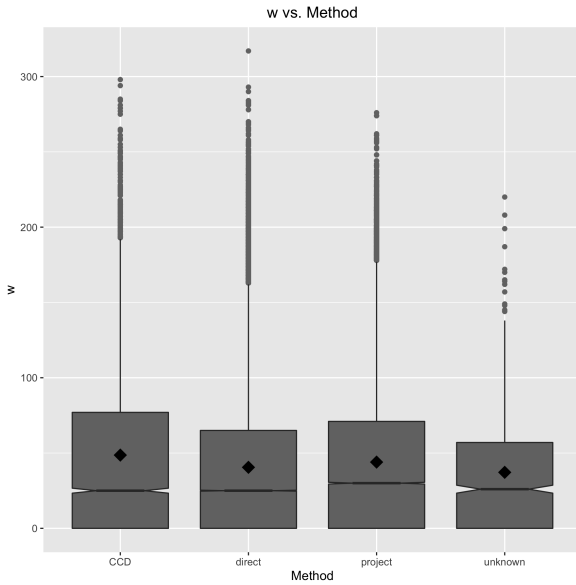


Figure 7: Box plots of raw Wolf number (w) by observer rank.

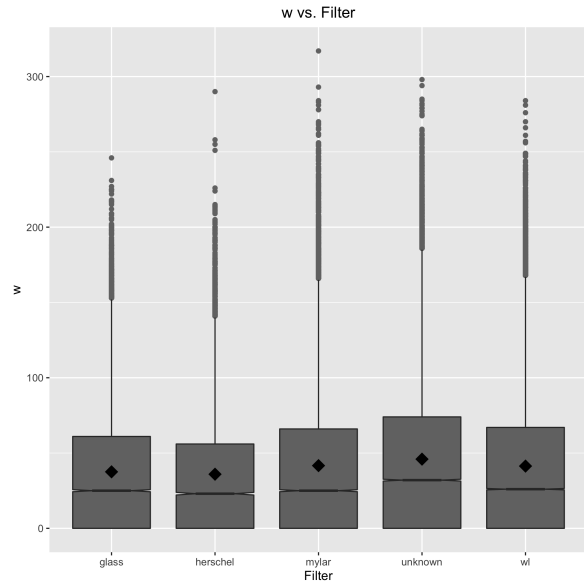


Figure 8: Box plots of raw Wolf number (w) by month and year.

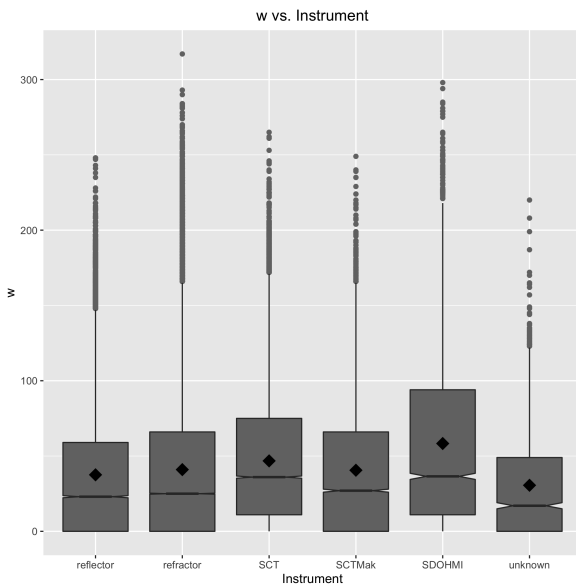


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

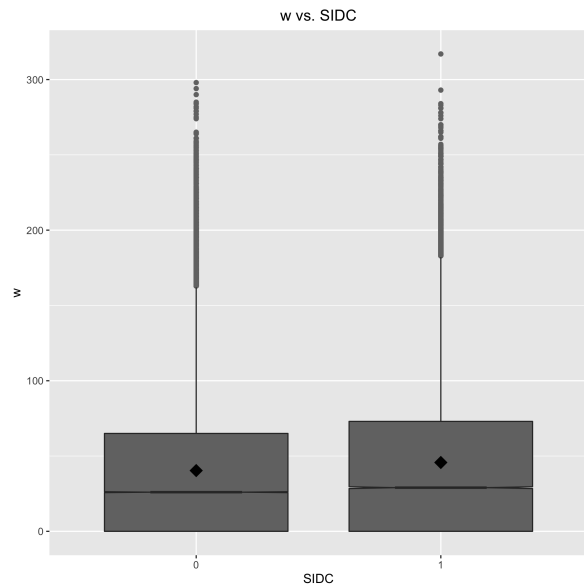


Figure 10: Box plots of raw Wolf number (w) by organization.



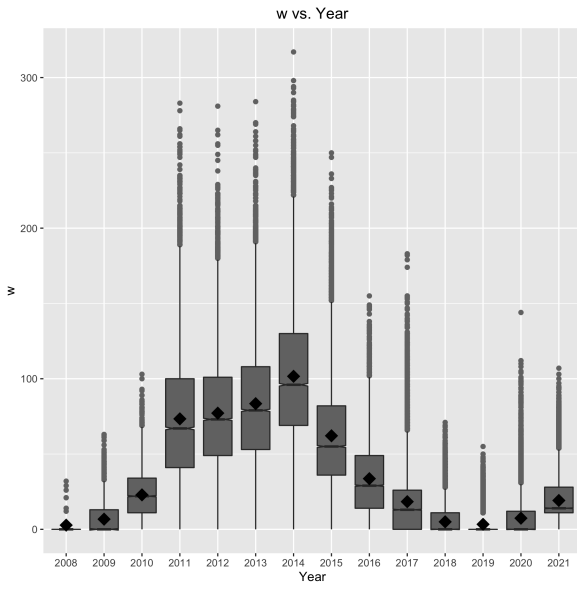


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

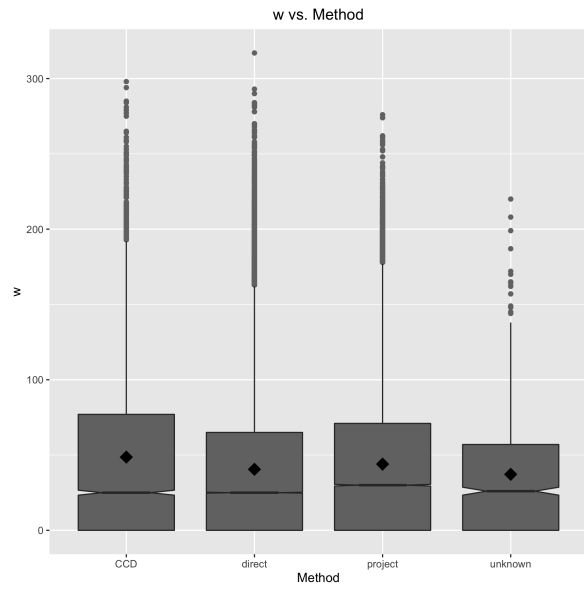


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.