

**Monthly Report (00)**  
**202111 Data Set**

**Monday 13<sup>th</sup> December, 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.

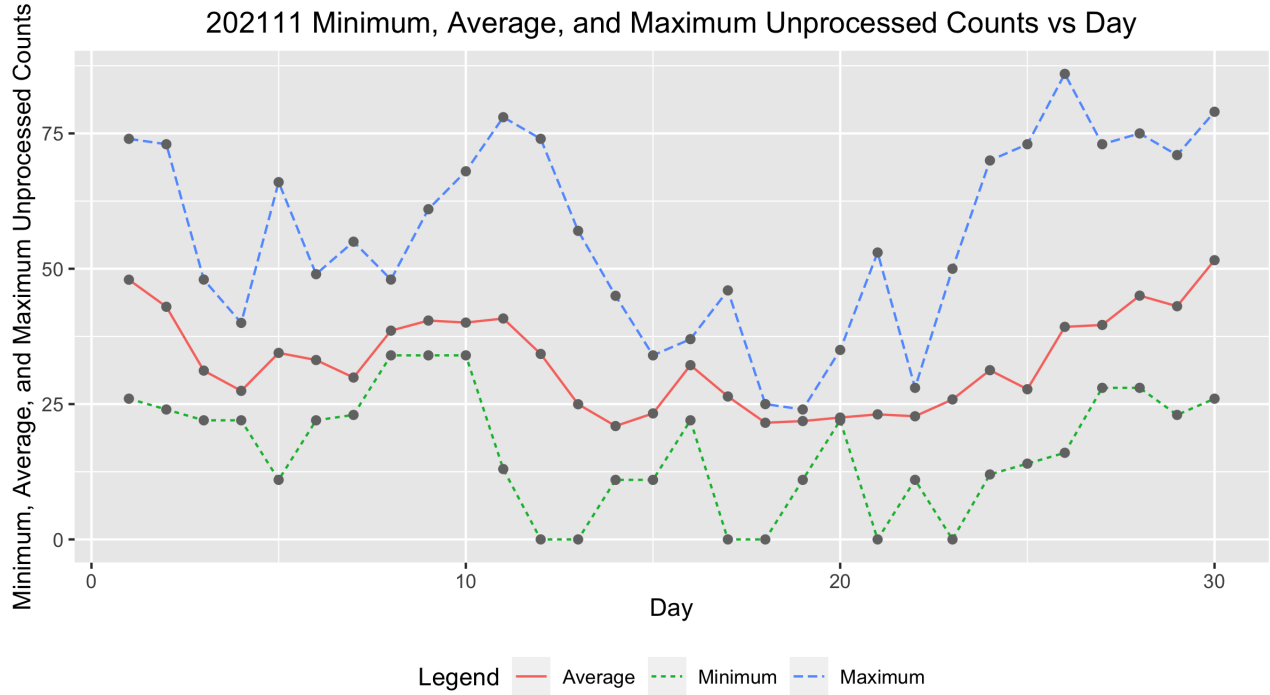


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202111 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	41.0000	26.0000	47.9756	74.0000
2.0000	43.0000	24.0000	42.9767	73.0000
3.0000	38.0000	22.0000	31.1842	48.0000
4.0000	36.0000	22.0000	27.4444	40.0000
5.0000	44.0000	11.0000	34.4545	66.0000
6.0000	43.0000	22.0000	33.1395	49.0000
7.0000	42.0000	23.0000	29.9048	55.0000
8.0000	39.0000	34.0000	38.5641	48.0000
9.0000	37.0000	34.0000	40.4324	61.0000
10.0000	38.0000	34.0000	40.0526	68.0000
11.0000	37.0000	13.0000	40.8108	78.0000
12.0000	42.0000	0.0000	34.2619	74.0000
13.0000	41.0000	0.0000	24.9756	57.0000
14.0000	36.0000	11.0000	20.9444	45.0000
15.0000	29.0000	11.0000	23.2759	34.0000
16.0000	37.0000	22.0000	32.1892	37.0000
17.0000	42.0000	0.0000	26.4048	46.0000
18.0000	38.0000	0.0000	21.5526	25.0000
19.0000	37.0000	11.0000	21.8649	24.0000
20.0000	41.0000	22.0000	22.5122	35.0000
21.0000	31.0000	0.0000	23.0968	53.0000
22.0000	32.0000	11.0000	22.7500	28.0000
23.0000	35.0000	0.0000	25.8571	50.0000
24.0000	34.0000	12.0000	31.2647	70.0000
25.0000	31.0000	14.0000	27.7419	73.0000
26.0000	30.0000	16.0000	39.2667	86.0000
27.0000	39.0000	28.0000	39.6154	73.0000
28.0000	31.0000	28.0000	45.0323	75.0000
29.0000	39.0000	23.0000	43.0769	71.0000
30.0000	41.0000	26.0000	51.5854	79.0000

### 3 Error Tables

Data are for the month of November 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	2.4139	3.1271	0.5000	1.0000
2009.01	5.5138	4.9266	6.1010	1.3000	1.3000
2009.02	4.7273	4.2099	5.2448	0.7000	1.2000
2009.03	6.2980	6.0576	6.5384	0.3000	0.6000
2009.04	7.2019	6.9490	7.4548	0.4000	1.2000
2009.05	7.1950	6.9166	7.4735	1.6000	2.9000
2009.06	6.5036	6.1785	6.8286	3.2000	6.3000
2009.07	6.2790	6.0300	6.5280	3.6000	5.5000
2009.08	6.7815	6.5215	7.0415	0.0000	0.0000
2009.09	7.5328	7.2702	7.7954	4.5000	7.1000
2009.10	7.0321	6.6686	7.3955	4.5000	7.7000
2009.11	7.2683	7.0709	7.4657	3.3000	6.9000
2009.12	6.5744	6.3899	6.7590	10.4000	16.3000
2010.01	20.6399	18.3276	22.9521	13.3000	19.5000
2010.02	16.0645	13.9163	18.2128	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	17.9105	15.7256	20.0955	15.4000	24.0000
2010.04	20.2149	17.8721	22.5578	7.0000	10.4000
2010.05	23.7953	23.3784	24.2122	8.4000	8.7000
2010.06	20.1917	19.8574	20.5260	11.0000	13.6000
2010.07	21.3276	21.0186	21.6365	15.2000	16.1000
2010.08	22.2733	21.9092	22.6374	18.3000	19.6000
2010.09	25.6834	25.2636	26.1031	22.8000	25.2000
2010.10	24.2622	23.8463	24.6781	21.0000	23.5000
2010.11	25.6042	25.1440	26.0645	20.9000	21.6000
2010.12	22.2628	21.8220	22.7036	13.9000	14.5000
2011.01	73.9572	72.4642	75.4502	17.7000	18.7000
2011.02	62.6445	61.3481	63.9409	29.1000	29.6000
2011.03	67.7969	66.5108	69.0830	48.0000	55.8000
2011.04	77.4221	76.0336	78.8107	47.3000	54.4000
2011.05	77.4847	76.1889	78.7804	37.3000	41.5000
2011.06	65.7292	64.5882	66.8701	35.2000	37.0000
2011.07	68.6895	67.5257	69.8533	41.5000	43.8000
2011.08	72.5682	71.4104	73.7259	42.4000	50.5000
2011.09	82.2998	80.8852	83.7144	73.8000	78.0000
2011.10	77.8192	76.5185	79.1199	78.9000	88.0000
2011.11	81.8807	80.1919	83.5695	84.6000	96.7000
2011.12	69.9624	68.5376	71.3873	65.8000	73.0000
2012.01	79.3880	77.8329	80.9432	55.8000	58.2000
2012.02	66.0347	64.6963	67.3732	29.2000	33.1000
2012.03	72.2715	70.9963	73.5468	53.1000	64.1000
2012.04	81.2656	79.8424	82.6887	51.4000	55.2000
2012.05	82.9189	81.5551	84.2826	61.8000	69.0000
2012.06	69.6625	68.4845	70.8404	59.7000	64.5000
2012.07	73.2833	72.0856	74.4811	64.2000	51.3000
2012.08	74.6223	73.4258	75.8187	57.7000	63.1000
2012.09	85.1889	83.7147	86.6630	57.7000	61.5000
2012.10	81.3528	79.8690	82.8366	48.3000	53.3000
2012.11	85.6790	83.9612	87.3969	56.7000	61.4000
2012.12	73.3955	71.8083	74.9828	37.4000	40.8000
2013.01	88.2150	86.5318	89.8982	63.8000	62.9000
2013.02	73.5310	72.0545	75.0076	37.8000	38.0000
2013.03	77.9667	76.3797	79.5537	50.6000	57.9000
2013.04	88.6292	87.0693	90.1891	70.6000	72.4000
2013.05	88.3810	86.8044	89.9575	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	75.7818	74.4425	77.1210	51.0000	52.5000
2013.07	78.6837	77.4192	79.9481	57.0000	57.0000
2013.08	81.7481	80.4314	83.0647	60.0000	66.0000
2013.09	91.9102	90.2693	93.5510	34.6000	36.9000
2013.10	86.7661	85.1561	88.3761	74.5000	85.6000
2013.11	89.7280	87.7108	91.7452	73.9000	77.6000
2013.12	79.0083	77.3198	80.6968	77.8000	90.3000
2014.01	102.8354	100.6723	104.9984	77.4000	82.0000
2014.02	87.4566	85.7316	89.1815	93.9000	102.8000
2014.03	94.9330	93.2019	96.6642	80.9000	92.2000
2014.04	108.0872	106.1944	109.9800	76.9000	84.7000
2014.05	108.3905	106.5428	110.2382	72.3000	75.2000
2014.06	92.7279	91.1623	94.2936	67.2000	71.0000
2014.07	95.9658	94.3662	97.5655	72.5000	72.5000
2014.08	99.8577	98.3004	101.4150	71.2000	74.7000
2014.09	113.4998	111.4986	115.5010	83.2000	87.6000
2014.10	106.7160	104.7532	108.6788	59.5000	60.6000
2014.11	111.6026	109.2870	113.9182	65.8000	71.1000
2014.12	96.1324	93.9106	98.3542	75.8000	78.0000
2015.01	63.5277	62.2607	64.7947	65.9000	67.0000
2015.02	52.7722	51.6119	53.9326	42.4000	44.8000
2015.03	57.9990	56.9418	59.0562	38.0000	38.4000
2015.04	65.6493	64.4820	66.8165	49.0000	54.4000
2015.05	66.0789	64.9912	67.1666	56.3000	58.8000
2015.06	56.4312	55.4237	57.4387	50.2000	68.3000
2015.07	57.9152	56.9364	58.8940	47.9000	65.8000
2015.08	61.3985	60.3761	62.4209	39.5000	57.2000
2015.09	68.9729	67.7276	70.2182	49.2000	72.1000
2015.10	65.3160	64.0615	66.5706	39.3000	48.3000
2015.11	68.9365	67.4437	70.4293	39.6000	55.9000
2015.12	59.5102	58.2012	60.8193	36.4000	44.8000
2016.01	34.7934	34.0716	35.5152	33.7000	43.3000
2016.02	28.9934	28.3914	29.5954	38.3000	46.8000
2016.03	31.3556	30.7327	31.9785	30.5000	38.9000
2016.04	35.3891	34.7185	36.0598	26.6000	30.9000
2016.05	35.7354	35.0869	36.3838	33.7000	48.4000
2016.06	30.1602	29.6482	30.6722	13.1000	19.5000
2016.07	31.5190	31.0163	32.0216	21.2000	27.5000
2016.08	33.0788	32.5011	33.6564	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	38.0235	37.3347	38.7124	27.7000	37.1000
2016.10	35.6463	34.9644	36.3281	22.7000	31.7000
2016.11	37.2181	36.4447	37.9915	14.0000	22.2000
2016.12	32.5259	31.8317	33.2200	11.1000	20.0000
2017.01	18.8839	18.4880	19.2798	18.4000	26.2000
2017.02	15.7998	15.4540	16.1455	14.4000	20.6000
2017.03	17.2379	16.9109	17.5649	11.3000	15.5000
2017.04	19.6432	19.2987	19.9878	21.6000	33.2000
2017.05	19.5285	19.1931	19.8638	12.5000	18.1000
2017.06	16.4839	16.2099	16.7579	15.5000	19.3000
2017.07	17.2991	17.0236	17.5747	11.5000	16.3000
2017.08	18.1108	17.7949	18.4268	22.8000	35.7000
2017.09	21.1734	20.7245	21.6224	34.6000	42.9000
2017.10	19.3292	18.9326	19.7259	10.5000	11.0000
2017.11	20.0236	19.6016	20.4456	4.2000	5.6000
2017.12	17.4097	17.1456	17.6739	4.0000	4.6000
2018.01	5.2491	5.1382	5.3600	3.1000	6.3000
2018.02	4.3519	4.2477	4.4561	6.8000	11.8000
2018.03	4.6689	4.5751	4.7627	1.1000	1.2000
2018.04	5.2669	5.1624	5.3713	4.7000	7.5000
2018.05	5.3204	5.2221	5.4186	8.4000	14.0000
2018.06	4.5050	4.4263	4.5838	10.2000	13.6000
2018.07	4.7278	4.6745	4.7811	0.5000	1.7000
2018.08	4.8968	4.8138	4.9799	5.9000	9.5000
2018.09	5.5156	5.4129	5.6183	1.6000	2.9000
2018.10	5.2994	5.1960	5.4028	2.5000	5.6000
2018.11	5.5148	5.4003	5.6293	3.1000	4.2000
2018.12	4.8929	4.7976	4.9883	1.6000	2.3000
2019.01	3.4607	3.3951	3.5264	5.4000	2.3000
2019.02	2.9364	2.8789	2.9939	0.1000	1.2000
2019.03	3.1127	3.0598	3.1656	6.1000	12.1000
2019.04	3.5421	3.4754	3.6087	6.2000	9.3000
2019.05	3.4642	3.4044	3.5241	7.0000	11.9000
2019.06	2.9425	2.8935	2.9915	0.7000	1.5000
2019.07	3.0916	3.0459	3.1374	0.4000	2.2000
2019.08	3.2525	3.2047	3.3003	0.3000	0.8000
2019.09	3.7414	3.6831	3.7997	0.5000	1.0000
2019.10	3.4934	3.4344	3.5523	0.2000	0.5000
2019.11	3.7035	3.6331	3.7738	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	3.1993	3.1365	3.2622	0.8000	1.0000
2020.01	7.6608	7.5113	7.8103	4.0000	5.3000
2020.02	6.4131	6.2853	6.5408	0.1000	0.0000
2020.03	6.8677	6.7401	6.9953	1.2000	1.5000
2020.04	7.8659	7.7375	7.9943	3.0000	5.1000
2020.05	7.7726	7.6517	7.8936	0.1000	0.4000
2020.06	6.6423	6.5413	6.7433	3.9000	6.4000
2020.07	6.8754	6.7752	6.9756	4.2000	7.7000
2020.08	7.1160	7.0187	7.2133	5.3000	7.8000
2020.09	8.1672	8.0377	8.2967	0.4000	0.9000
2020.10	7.8138	7.6869	7.9407	9.9000	13.6000
2020.11	8.2532	8.1243	8.3821	21.2000	33.1000
2020.12	7.1795	7.0574	7.3016	15.4000	19.8000
2021.01	24.0663	23.6570	24.4756	7.0000	15.8000
2021.02	20.4610	20.1058	20.8161	5.8000	10.7000
2021.03	22.1069	21.7662	22.4477	11.0000	17.2000
2021.04	25.2623	24.8899	25.6347	18.5000	28.8000
2021.05	25.2300	24.8838	25.5763	15.9000	22.9000
2021.06	21.6266	21.3167	21.9365	19.9000	24.1000
2021.07	22.3802	22.0369	22.7234	23.8000	35.6000
2021.08	23.7693	23.4051	24.1336	15.7000	19.5000
2021.09	27.2582	26.8228	27.6936	39.1000	52.5000
2021.10	26.1541	25.7262	26.5820	27.1000	37.0000
2021.11	27.8990	27.4576	28.3403	27.2000	35.1000

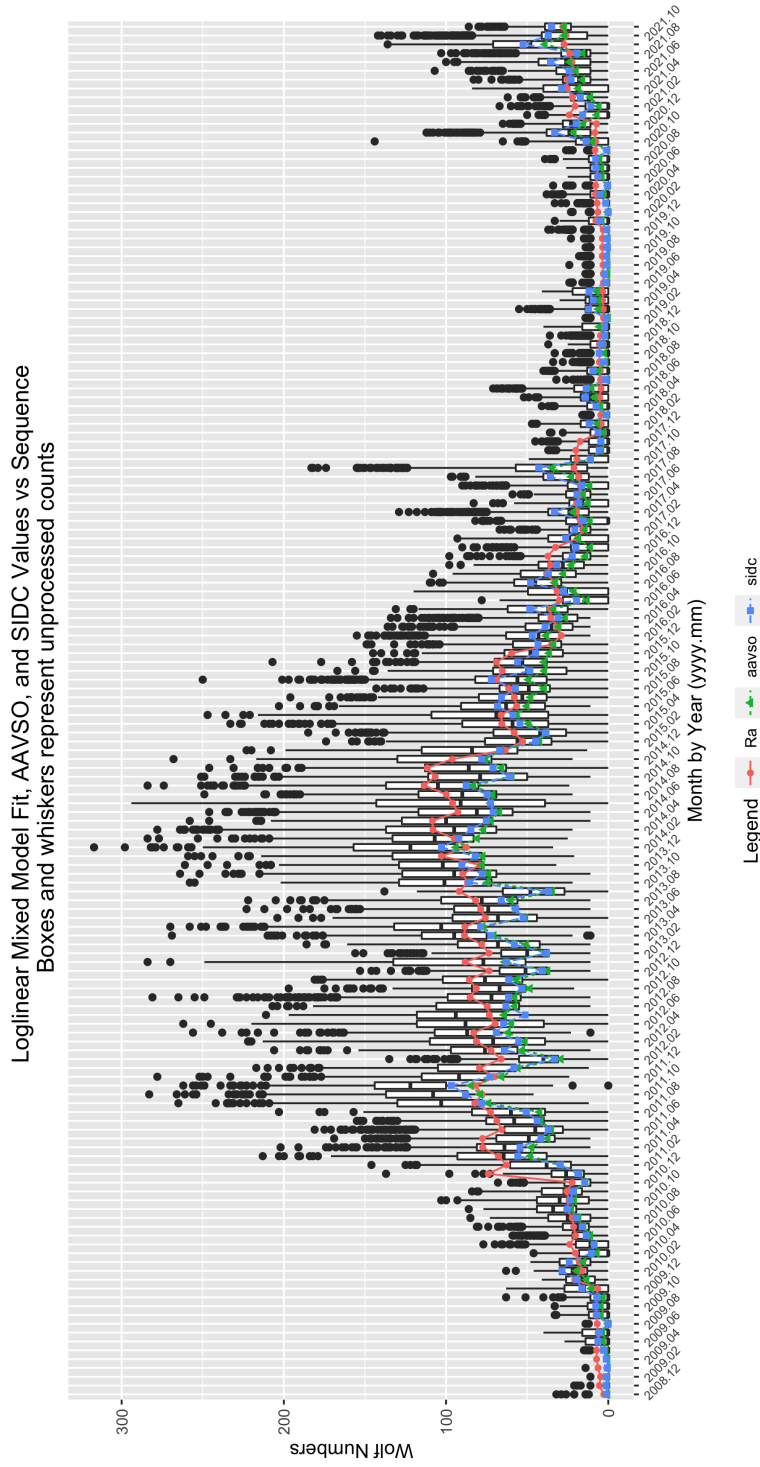


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202111 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t )$
(Intercept)	1.4289	0.3116	4.5852	0.0000
seeF	-0.2208	0.0057	-38.8981	0.0000
seeG	-0.1218	0.0050	-24.5586	0.0000
seeM	-0.1978	0.0241	-8.2095	0.0000
seeP	-0.3185	0.0081	-39.2900	0.0000
sidc1	-0.0057	0.0217	-0.2622	0.7932
year2009	0.6512	0.3128	2.0817	0.0374
year2010	1.8754	0.3107	6.0368	0.0000
year2011	3.0066	0.3106	9.6813	0.0000
year2012	3.0456	0.3105	9.8073	0.0000
year2013	3.1416	0.3105	10.1165	0.0000
year2014	3.3387	0.3105	10.7513	0.0000
year2015	2.8535	0.3106	9.1883	0.0000
year2016	2.2369	0.3106	7.2021	0.0000
year2017	1.6296	0.3106	5.2463	0.0000
year2018	0.3405	0.3109	1.0952	0.2734
year2019	-0.0822	0.3111	-0.2640	0.7917
year2020	0.7224	0.3108	2.3243	0.0201
year2021	1.8836	0.3106	6.0636	0.0000
mon2	-0.1732	0.0091	-18.9585	0.0000
mon3	-0.0989	0.0085	-11.6438	0.0000
mon4	0.0199	0.0082	2.4331	0.0150
mon5	0.0170	0.0080	2.1091	0.0349
mon6	-0.1489	0.0084	-17.7564	0.0000
mon7	-0.1130	0.0082	-13.8626	0.0000
mon8	-0.0655	0.0080	-8.1608	0.0000
mon9	0.0710	0.0080	8.8768	0.0000
mon10	0.0160	0.0082	1.9571	0.0503
mon11	0.0740	0.0085	8.7429	0.0000
mon12	-0.0638	0.0088	-7.2282	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: 202111 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:148935	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 : 6.632	Mean :15.71		Mean :0.2494
3rd Qu.:2019	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:0.0000
Max. :2021	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202111 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:148935	Length:148935
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 7.00	Median : 27.00	Mode :character	Mode :character
Mean : 2.631	Mean : 15.32	Mean : 41.62		
3rd Qu.: 4.000	3rd Qu.: 22.00	3rd Qu.: 66.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202111 Summary of Sunspot Numbers

inst	filter	unit
Length:148935	Length:148935	Length:148935
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202111 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0	Min. : 0.0
1st Qu.: 60.00	1st Qu.: 4.70	1st Qu.: 35	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 900	Median : 57.5
Mean : 91.42	Mean : 34.16	Mean : 889	Mean : 181.6
3rd Qu.: 104.00	3rd Qu.: 23.00	3rd Qu.:1200	3rd Qu.: 75.0
Max. :1524.00	Max. :2010.00	Max. :9990	Max. :4591.0

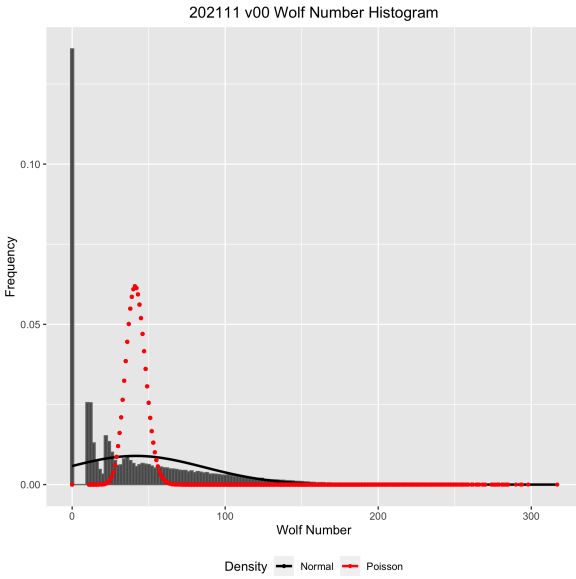


Figure 3: Box plots of raw Wolf number ( $w$ ) by observer rank.

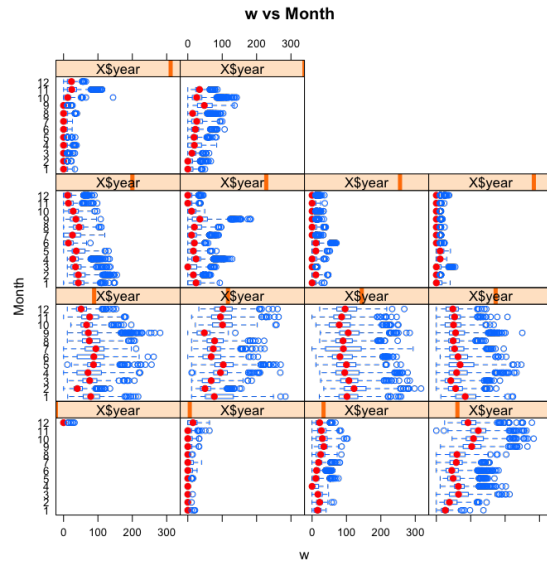


Figure 4: Box plots of raw Wolf number ( $w$ ) by month and year.

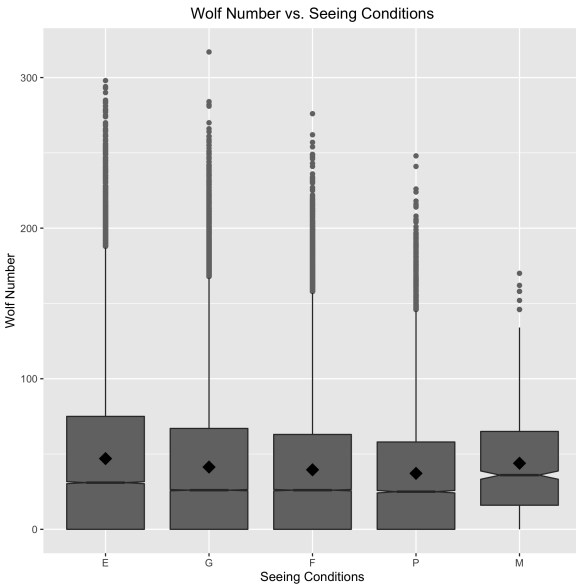


Figure 5: Box plots of raw Wolf number ( $w$ ) by seeing condition.

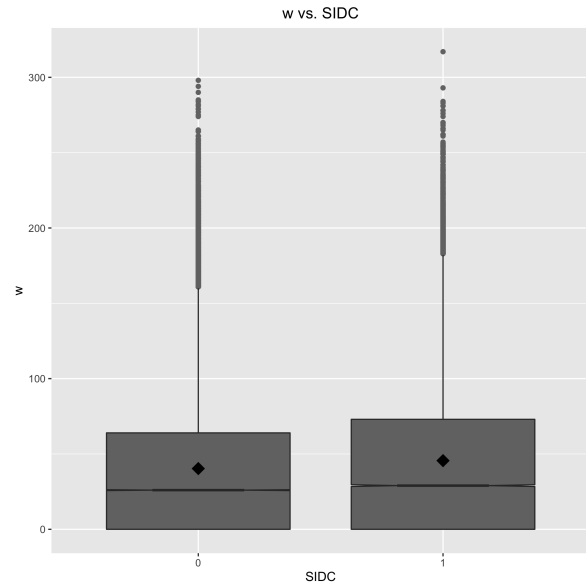


Figure 6: Box plots of raw Wolf number ( $w$ ) by organization.

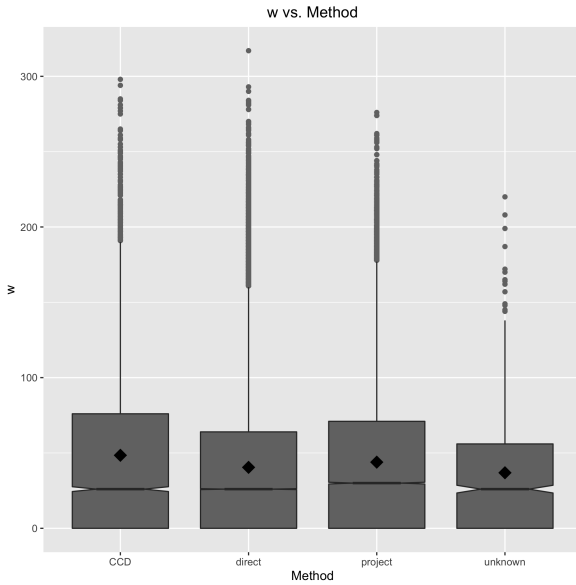


Figure 7: Box plots of raw Wolf number ( $w$ ) by observer rank.

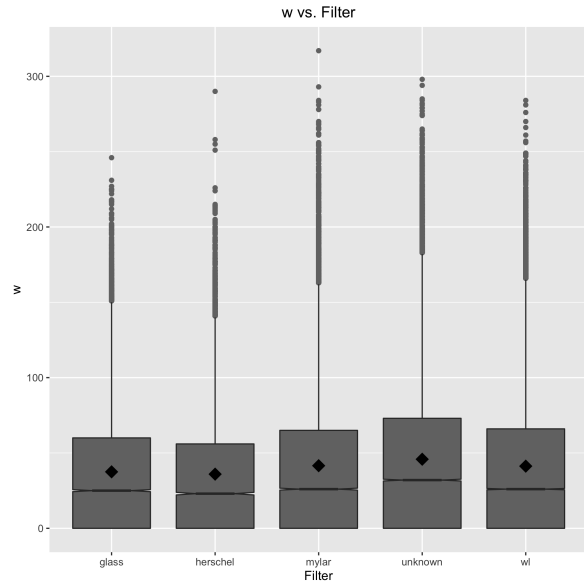


Figure 8: Box plots of raw Wolf number ( $w$ ) by month and year.

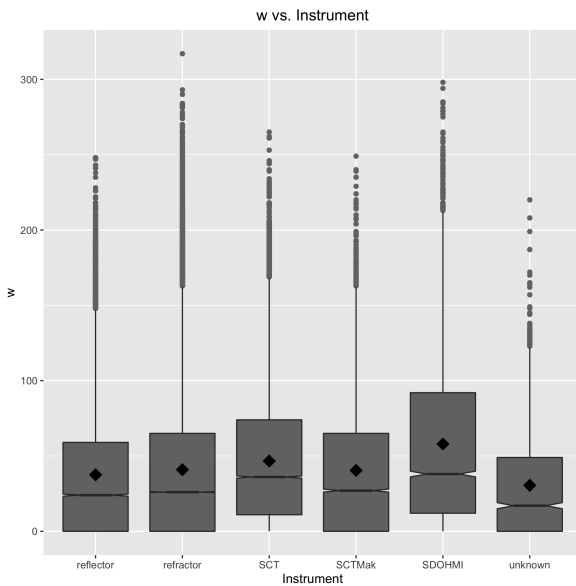


Figure 9: Box plots of raw Wolf number ( $w$ ) by seeing condition.

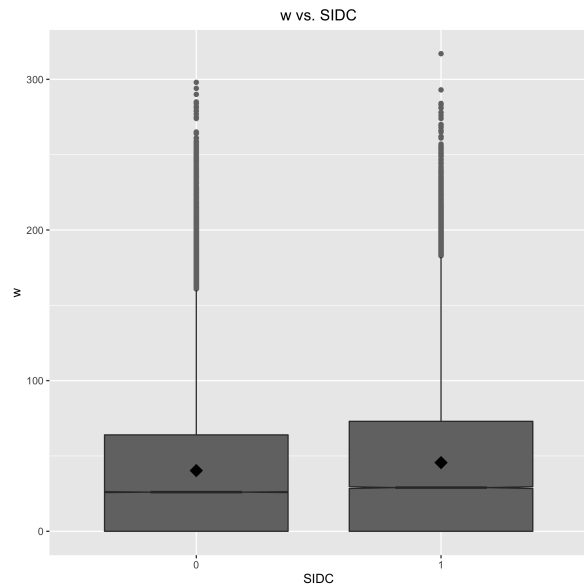


Figure 10: Box plots of raw Wolf number ( $w$ ) by organization.



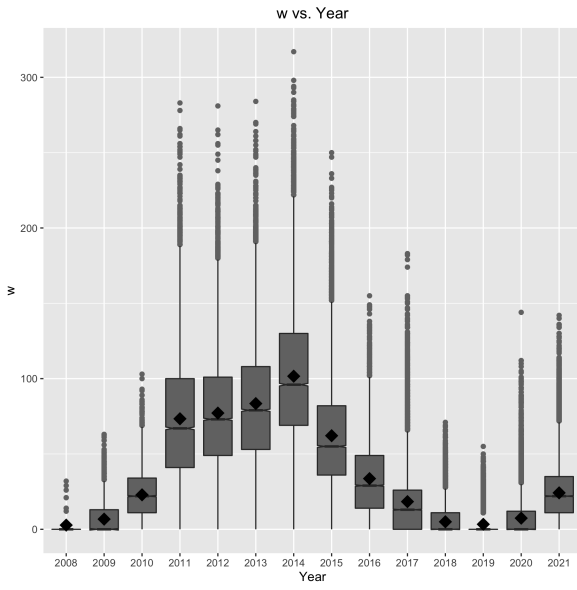


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

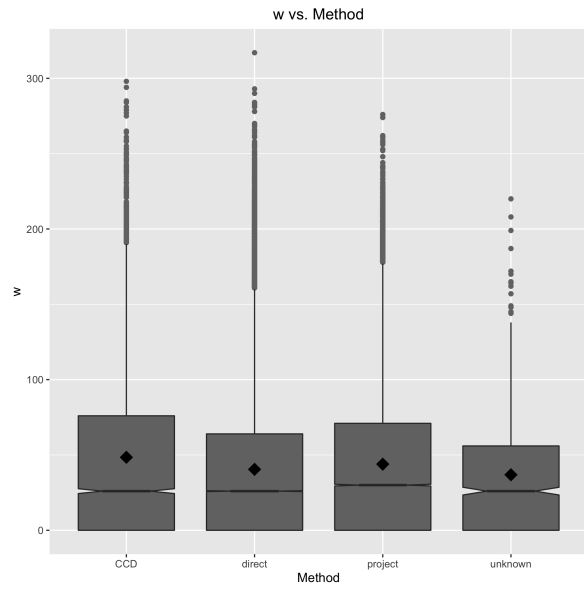


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.