

**Monthly Report (00)**  
**202112 Data Set**

**Thursday 13<sup>th</sup> January, 2022**

**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.

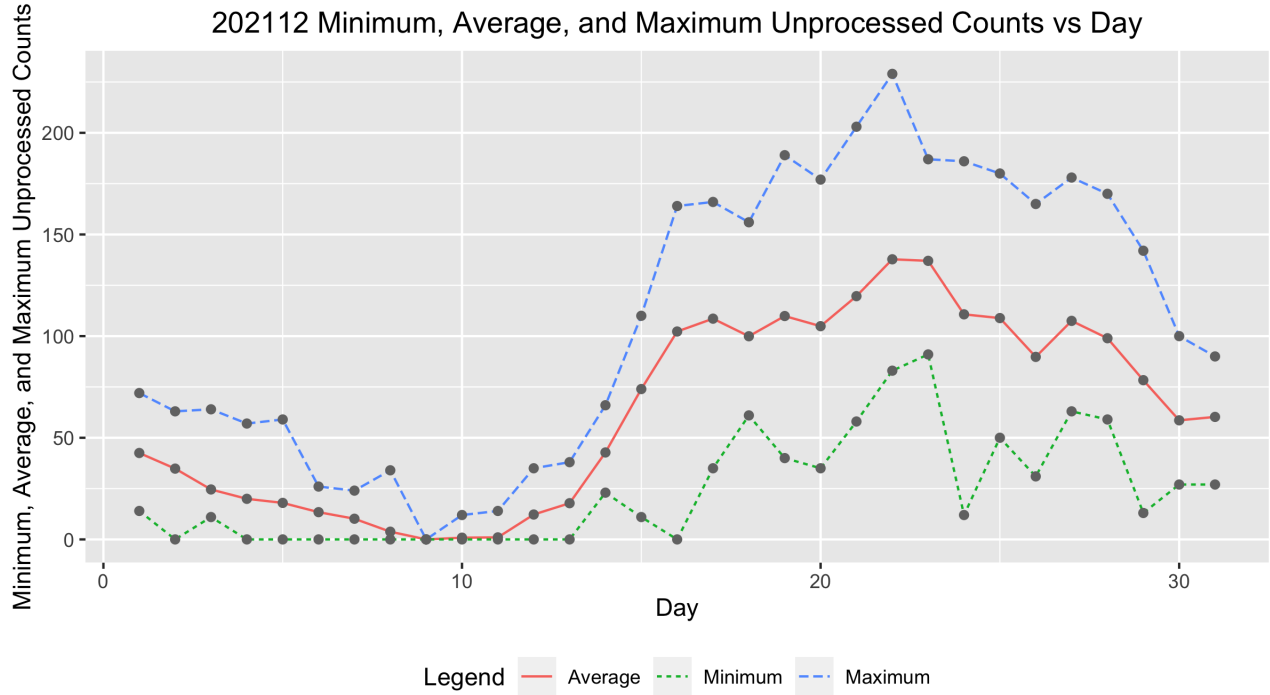


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202112 Daily Raw Counts

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Day	Submissions	Minimum	Average	Maximum
1.0000	35.0000	14.0000	42.5143	72.0000
2.0000	34.0000	0.0000	34.8235	63.0000
3.0000	35.0000	11.0000	24.5714	64.0000
4.0000	31.0000	0.0000	19.9677	57.0000
5.0000	30.0000	0.0000	17.9667	59.0000
6.0000	29.0000	0.0000	13.4138	26.0000
7.0000	29.0000	0.0000	10.1724	24.0000
8.0000	30.0000	0.0000	3.8000	34.0000
9.0000	27.0000	0.0000	0.0000	0.0000
10.0000	27.0000	0.0000	0.8519	12.0000
11.0000	37.0000	0.0000	1.0000	14.0000
12.0000	37.0000	0.0000	12.2432	35.0000
13.0000	33.0000	0.0000	17.8182	38.0000
14.0000	35.0000	23.0000	42.7714	66.0000
15.0000	29.0000	11.0000	73.9655	110.0000
16.0000	30.0000	0.0000	102.2667	164.0000
17.0000	34.0000	35.0000	108.5882	166.0000
18.0000	33.0000	61.0000	99.9394	156.0000
19.0000	34.0000	40.0000	109.8824	189.0000
20.0000	36.0000	35.0000	104.8889	177.0000
21.0000	41.0000	58.0000	119.6585	203.0000
22.0000	39.0000	83.0000	137.7949	229.0000
23.0000	30.0000	91.0000	137.0333	187.0000
24.0000	28.0000	12.0000	110.7143	186.0000
25.0000	23.0000	50.0000	108.8696	180.0000
26.0000	32.0000	31.0000	89.7812	165.0000
27.0000	28.0000	63.0000	107.5000	178.0000
28.0000	30.0000	59.0000	98.9667	170.0000
29.0000	30.0000	13.0000	78.3333	142.0000
30.0000	31.0000	27.0000	58.5806	100.0000
31.0000	30.0000	27.0000	60.2667	90.0000

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### 3 Error Tables

Data are for the month of December 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	2.4095	3.1315	0.5000	1.0000
2009.01	5.3897	4.8083	5.9712	1.3000	1.3000
2009.02	4.6225	4.1100	5.1350	0.7000	1.2000
2009.03	6.1729	5.9408	6.4049	0.3000	0.6000
2009.04	7.0649	6.8205	7.3093	0.4000	1.2000
2009.05	7.0569	6.7867	7.3272	1.6000	2.9000
2009.06	6.3851	6.0678	6.7025	3.2000	6.3000
2009.07	6.1634	5.9210	6.4059	3.6000	5.5000
2009.08	6.6615	6.4085	6.9144	0.0000	0.0000
2009.09	7.3946	7.1398	7.6493	4.5000	7.1000
2009.10	6.8881	6.5338	7.2424	4.5000	7.7000
2009.11	7.0875	6.8928	7.2823	3.3000	6.9000
2009.12	6.9822	6.7840	7.1805	10.4000	16.3000
2010.01	20.4448	18.1275	22.7621	13.3000	19.5000
2010.02	15.8787	13.7285	18.0290	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	17.7288	15.5379	19.9197	15.4000	24.0000
2010.04	20.0089	17.6603	22.3575	7.0000	10.4000
2010.05	23.6213	23.2024	24.0402	8.4000	8.7000
2010.06	20.0504	19.7153	20.3855	11.0000	13.6000
2010.07	21.1979	20.8875	21.5083	15.2000	16.1000
2010.08	22.1382	21.7735	22.5028	18.3000	19.6000
2010.09	25.5192	25.0989	25.9395	22.8000	25.2000
2010.10	24.0748	23.6588	24.4909	21.0000	23.5000
2010.11	25.3179	24.8603	25.7755	20.9000	21.6000
2010.12	23.9612	23.4819	24.4405	13.9000	14.5000
2011.01	73.4542	71.9599	74.9485	17.7000	18.7000
2011.02	62.1923	60.8941	63.4904	29.1000	29.6000
2011.03	67.4055	66.1150	68.6961	48.0000	55.8000
2011.04	76.9933	75.6006	78.3860	47.3000	54.4000
2011.05	77.0882	75.7889	78.3875	37.3000	41.5000
2011.06	65.3778	64.2321	66.5235	35.2000	37.0000
2011.07	68.3784	67.2095	69.5473	41.5000	43.8000
2011.08	72.2682	71.1044	73.4320	42.4000	50.5000
2011.09	81.9581	80.5329	83.3834	73.8000	78.0000
2011.10	77.3591	76.0553	78.6629	78.9000	88.0000
2011.11	81.0844	79.3991	82.7697	84.6000	96.7000
2011.12	75.4561	73.9097	77.0026	65.8000	73.0000
2012.01	78.9768	77.4202	80.5334	55.8000	58.2000
2012.02	65.6753	64.3356	67.0149	29.2000	33.1000
2012.03	71.8888	70.6116	73.1660	53.1000	64.1000
2012.04	80.8244	79.3956	82.2531	51.4000	55.2000
2012.05	82.4998	81.1305	83.8690	61.8000	69.0000
2012.06	69.3454	68.1616	70.5292	59.7000	64.5000
2012.07	72.9863	71.7833	74.1893	64.2000	51.3000
2012.08	74.3085	73.1067	75.5104	57.7000	63.1000
2012.09	84.7905	83.3134	86.2677	57.7000	61.5000
2012.10	80.8649	79.3798	82.3501	48.3000	53.3000
2012.11	84.8330	83.1193	86.5466	56.7000	61.4000
2012.12	79.1365	77.4121	80.8610	37.4000	40.8000
2013.01	87.7512	86.0637	89.4386	63.8000	62.9000
2013.02	73.0942	71.6158	74.5727	37.8000	38.0000
2013.03	77.4894	75.9014	79.0775	50.6000	57.9000
2013.04	88.1339	86.5698	89.6981	70.6000	72.4000
2013.05	87.9303	86.3472	89.5134	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	75.3915	74.0477	76.7354	51.0000	52.5000
2013.07	78.3188	77.0501	79.5876	57.0000	57.0000
2013.08	81.3644	80.0446	82.6842	60.0000	66.0000
2013.09	91.4364	89.7933	93.0796	34.6000	36.9000
2013.10	86.2167	84.6063	87.8271	74.5000	85.6000
2013.11	88.8106	86.8002	90.8209	73.9000	77.6000
2013.12	85.1815	83.3496	87.0133	77.8000	90.3000
2014.01	102.3893	100.2207	104.5579	77.4000	82.0000
2014.02	87.0488	85.3205	88.7772	93.9000	102.8000
2014.03	94.4288	92.6948	96.1629	80.9000	92.2000
2014.04	107.5586	105.6625	109.4548	76.9000	84.7000
2014.05	107.8795	106.0285	109.7305	72.3000	75.2000
2014.06	92.3092	90.7403	93.8782	67.2000	71.0000
2014.07	95.6241	94.0188	97.2294	72.5000	72.5000
2014.08	99.4851	97.9219	101.0483	71.2000	74.7000
2014.09	113.0405	111.0332	115.0479	83.2000	87.6000
2014.10	106.1446	104.1789	108.1104	59.5000	60.6000
2014.11	110.5614	108.2518	112.8710	65.8000	71.1000
2014.12	103.7010	101.2887	106.1134	75.8000	78.0000
2015.01	63.1957	61.9269	64.4644	65.9000	67.0000
2015.02	52.4899	51.3284	53.6515	42.4000	44.8000
2015.03	57.6830	56.6249	58.7410	38.0000	38.4000
2015.04	65.2803	64.1101	66.4505	49.0000	54.4000
2015.05	65.7135	64.6240	66.8030	56.3000	58.8000
2015.06	56.1103	55.1018	57.1188	50.2000	68.3000
2015.07	57.6221	56.6428	58.6015	47.9000	65.8000
2015.08	61.1094	60.0858	62.1331	39.5000	57.2000
2015.09	68.6357	67.3891	69.8824	49.2000	72.1000
2015.10	64.8923	63.6385	66.1461	39.3000	48.3000
2015.11	68.2289	66.7387	69.7190	39.6000	55.9000
2015.12	64.1349	62.7052	65.5647	36.4000	44.8000
2016.01	34.5971	33.8752	35.3190	33.7000	43.3000
2016.02	28.8141	28.2126	29.4155	38.3000	46.8000
2016.03	31.1676	30.5446	31.7907	30.5000	38.9000
2016.04	35.1922	34.5209	35.8634	26.6000	30.9000
2016.05	35.5332	34.8843	36.1821	33.7000	48.4000
2016.06	29.9844	29.4723	30.4964	13.1000	19.5000
2016.07	31.3452	30.8419	31.8485	21.2000	27.5000
2016.08	32.9069	32.3280	33.4857	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	37.8407	37.1499	38.5316	27.7000	37.1000
2016.10	35.4270	34.7445	36.1095	22.7000	31.7000
2016.11	36.8444	36.0739	37.6149	14.0000	22.2000
2016.12	35.0803	34.3264	35.8343	11.1000	20.0000
2017.01	18.6930	18.2984	19.0877	18.4000	26.2000
2017.02	15.6316	15.2876	15.9755	14.4000	20.6000
2017.03	17.0509	16.7253	17.3765	11.3000	15.5000
2017.04	19.4325	19.0893	19.7756	21.6000	33.2000
2017.05	19.3205	18.9864	19.6546	12.5000	18.1000
2017.06	16.3098	16.0355	16.5841	15.5000	19.3000
2017.07	17.1312	16.8553	17.4071	11.5000	16.3000
2017.08	17.9392	17.6221	18.2562	22.8000	35.7000
2017.09	20.9895	20.5323	21.4467	34.6000	42.9000
2017.10	19.1142	18.7156	19.5127	10.5000	11.0000
2017.11	19.7185	19.2984	20.1386	4.2000	5.6000
2017.12	18.6646	18.3780	18.9511	4.0000	4.6000
2018.01	5.2306	5.1176	5.3436	3.1000	6.3000
2018.02	4.3357	4.2284	4.4429	6.8000	11.8000
2018.03	4.6441	4.5499	4.7383	1.1000	1.2000
2018.04	5.2404	5.1332	5.3476	4.7000	7.5000
2018.05	5.2925	5.1916	5.3935	8.4000	14.0000
2018.06	4.4777	4.3981	4.5572	10.2000	13.6000
2018.07	4.7026	4.6489	4.7563	0.5000	1.7000
2018.08	4.8700	4.7860	4.9541	5.9000	9.5000
2018.09	5.4837	5.3800	5.5873	1.6000	2.9000
2018.10	5.2677	5.1637	5.3717	2.5000	5.6000
2018.11	5.4608	5.3465	5.5752	3.1000	4.2000
2018.12	5.2769	5.1732	5.3807	1.6000	2.3000
2019.01	3.4473	3.3809	3.5136	5.4000	2.3000
2019.02	2.9218	2.8639	2.9797	0.1000	1.2000
2019.03	3.0941	3.0405	3.1477	6.1000	12.1000
2019.04	3.5265	3.4588	3.5942	6.2000	9.3000
2019.05	3.4472	3.3867	3.5077	7.0000	11.9000
2019.06	2.9283	2.8787	2.9778	0.7000	1.5000
2019.07	3.0770	3.0309	3.1232	0.4000	2.2000
2019.08	3.2355	3.1871	3.2838	0.3000	0.8000
2019.09	3.7232	3.6643	3.7821	0.5000	1.0000
2019.10	3.4696	3.4099	3.5294	0.2000	0.5000
2019.11	3.6693	3.5984	3.7401	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	3.4531	3.3843	3.5218	0.8000	1.0000
2020.01	7.6316	7.4798	7.7833	4.0000	5.3000
2020.02	6.3785	6.2493	6.5076	0.1000	0.0000
2020.03	6.8292	6.6995	6.9589	1.2000	1.5000
2020.04	7.8180	7.6878	7.9482	3.0000	5.1000
2020.05	7.7272	7.6046	7.8498	0.1000	0.4000
2020.06	6.6050	6.5021	6.7080	3.9000	6.4000
2020.07	6.8411	6.7403	6.9419	4.2000	7.7000
2020.08	7.0759	6.9776	7.1742	5.3000	7.8000
2020.09	8.1150	7.9830	8.2471	0.4000	0.9000
2020.10	7.7705	7.6413	7.8997	9.9000	13.6000
2020.11	8.1828	8.0507	8.3148	21.2000	33.1000
2020.12	7.7445	7.6092	7.8797	15.4000	19.8000
2021.01	26.2619	25.7987	26.7252	7.0000	15.8000
2021.02	22.3136	21.9168	22.7105	5.8000	10.7000
2021.03	24.0783	23.6966	24.4599	11.0000	17.2000
2021.04	27.4772	27.0642	27.8902	18.5000	28.8000
2021.05	27.4626	27.0821	27.8432	15.9000	22.9000
2021.06	23.5246	23.1810	23.8681	19.9000	24.1000
2021.07	24.3341	23.9594	24.7088	23.8000	35.6000
2021.08	25.8321	25.4401	26.2241	15.7000	19.5000
2021.09	29.6578	29.1869	30.1287	39.1000	52.5000
2021.10	28.8499	28.3335	29.3664	27.1000	37.0000
2021.11	31.9790	31.3086	32.6493	27.2000	35.1000
2021.12	31.6518	30.8733	32.4303	50.6000	69.0000

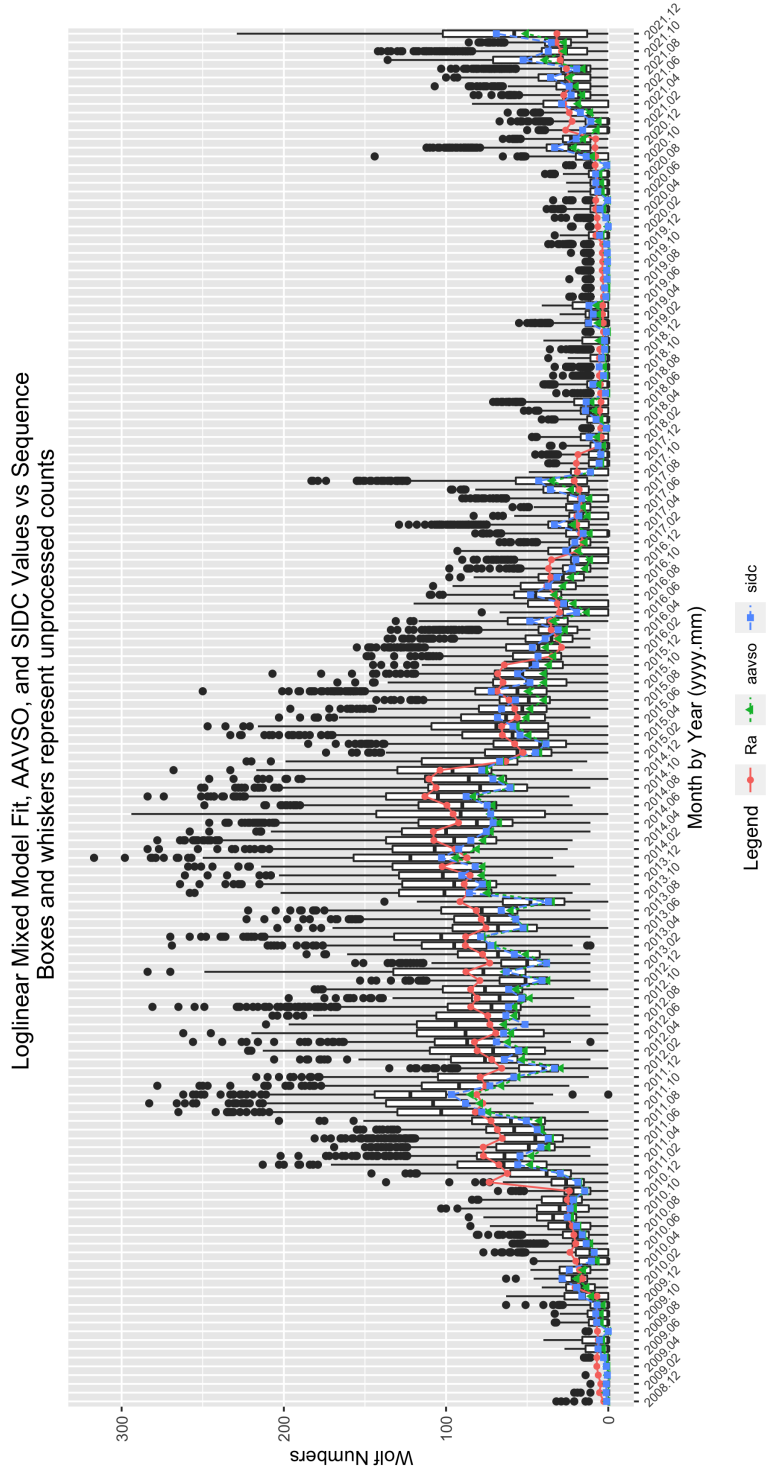


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202112 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t )$
(Intercept)	1.3956	0.3156	4.4214	0.0000
seeF	-0.2265	0.0057	-39.5929	0.0000
seeG	-0.1239	0.0050	-24.8019	0.0000
seeM	-0.1972	0.0244	-8.0881	0.0000
seeP	-0.3257	0.0082	-39.8814	0.0000
sidc1	0.0521	0.0212	2.4573	0.0140
year2009	0.7088	0.3165	2.2394	0.0251
year2010	1.9457	0.3143	6.1904	0.0000
year2011	3.0783	0.3142	9.7968	0.0000
year2012	3.1174	0.3142	9.9215	0.0000
year2013	3.2135	0.3142	10.2274	0.0000
year2014	3.4117	0.3142	10.8583	0.0000
year2015	2.9259	0.3142	9.3119	0.0000
year2016	2.3092	0.3142	7.3484	0.0000
year2017	1.6973	0.3143	5.4006	0.0000
year2018	0.4145	0.3146	1.3175	0.1877
year2019	-0.0090	0.3148	-0.0286	0.9772
year2020	0.7953	0.3144	2.5293	0.0114
year2021	2.0495	0.3143	6.5212	0.0000
mon2	-0.1737	0.0092	-18.7951	0.0000
mon3	-0.0998	0.0086	-11.6074	0.0000
mon4	0.0192	0.0083	2.3159	0.0206
mon5	0.0162	0.0081	1.9949	0.0461
mon6	-0.1499	0.0085	-17.6630	0.0000
mon7	-0.1133	0.0082	-13.7412	0.0000
mon8	-0.0656	0.0081	-8.0776	0.0000
mon9	0.0709	0.0081	8.7636	0.0000
mon10	0.0148	0.0083	1.7828	0.0746
mon11	0.0694	0.0086	8.0982	0.0000
mon12	0.0172	0.0086	1.9999	0.0455

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: 202112 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:149922	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 : 6.667	Mean :15.71		Mean :0.2491
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: 202112 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.00	Min. : 0.00	Min. : 0.00	Length:149922	Length:149922
1st Qu.: 0.00	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.00	Median : 7.00	Median : 27.00	Mode :character	Mode :character
Mean : 2.64	Mean : 15.37	Mean : 41.77		
3rd Qu.: 4.00	3rd Qu.: 22.00	3rd Qu.: 67.00		
Max. :19.00	Max. :204.00	Max. :317.00		

Table 6: 202112 Summary of Sunspot Numbers

inst	filter	unit
Length:149922	Length:149922	Length:149922
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202112 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.: 4.70	1st Qu.: 35.0	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 900.0	Median : 57.5
Mean : 91.47	Mean : 34.41	Mean : 889.2	Mean : 181.6
3rd Qu.: 104.00	3rd Qu.: 23.00	3rd Qu.:1200.0	3rd Qu.: 75.0
Max. :1524.00	Max. :2010.00	Max. :9990.0	Max. :4591.0

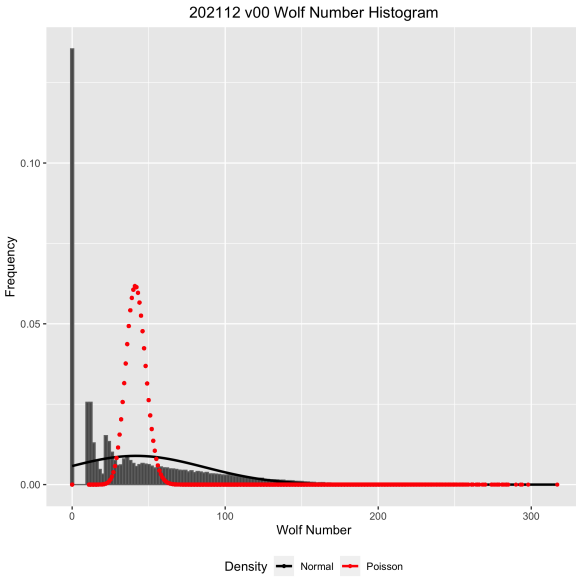


Figure 3: Box plots of raw Wolf number (w) by observer rank.

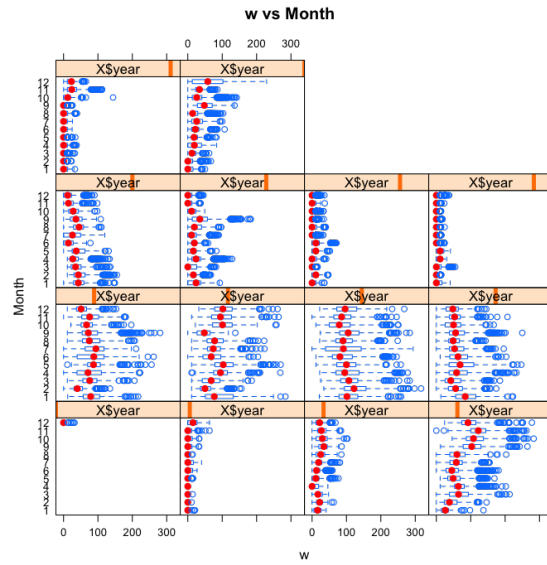


Figure 4: Box plots of raw Wolf number (w) by month and year.

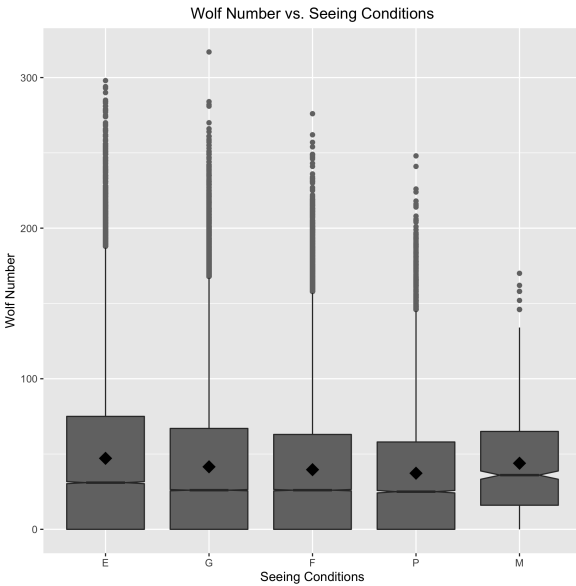


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

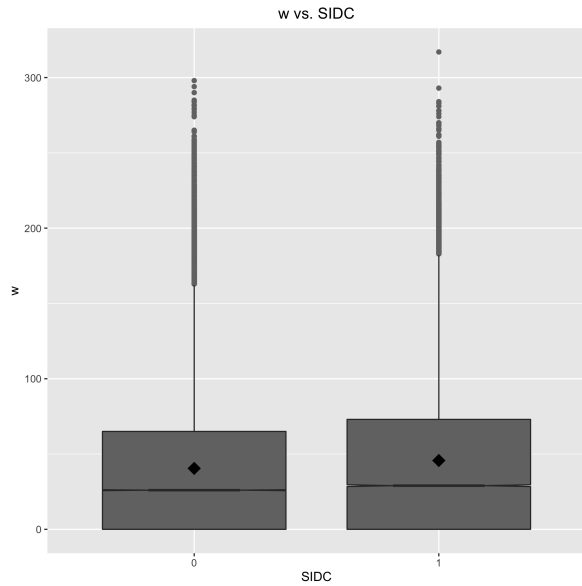


Figure 6: Box plots of raw Wolf number (w) by organization.

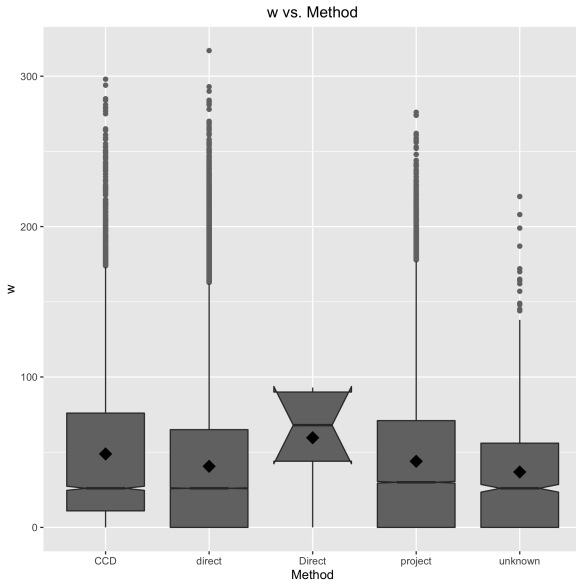


Figure 7: Box plots of raw Wolf number (w) by observer rank.

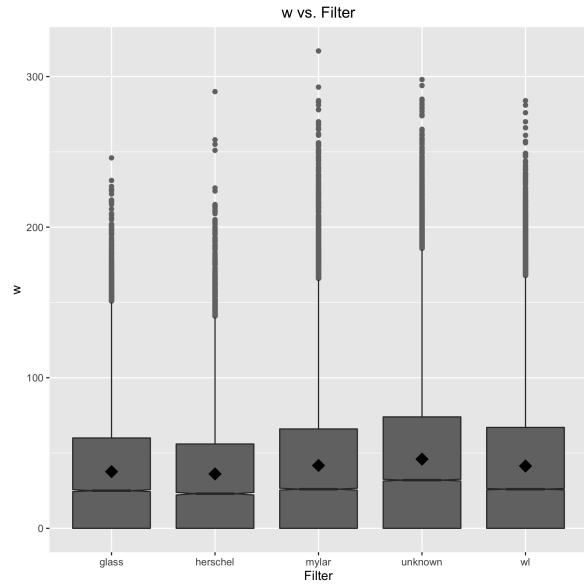


Figure 8: Box plots of raw Wolf number (w) by month and year.

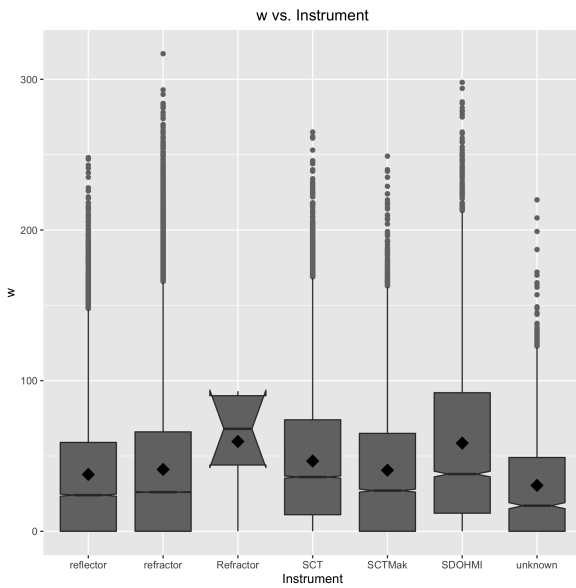


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

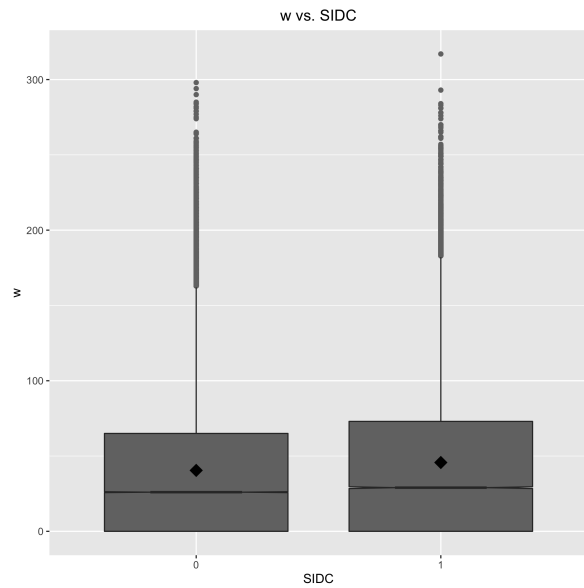


Figure 10: Box plots of raw Wolf number (w) by organization.



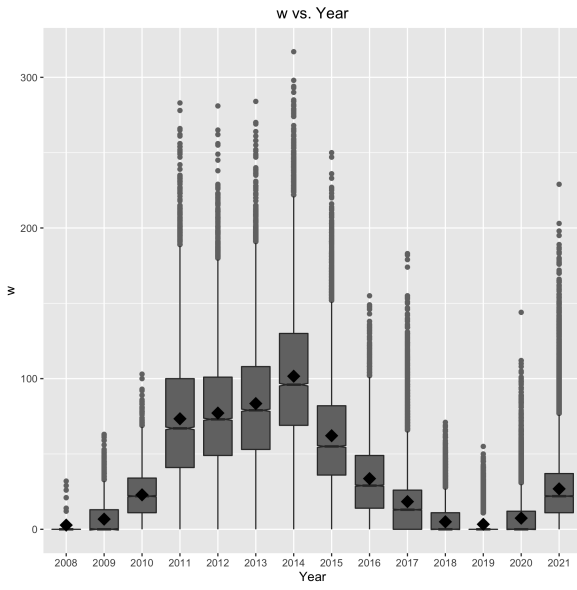


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

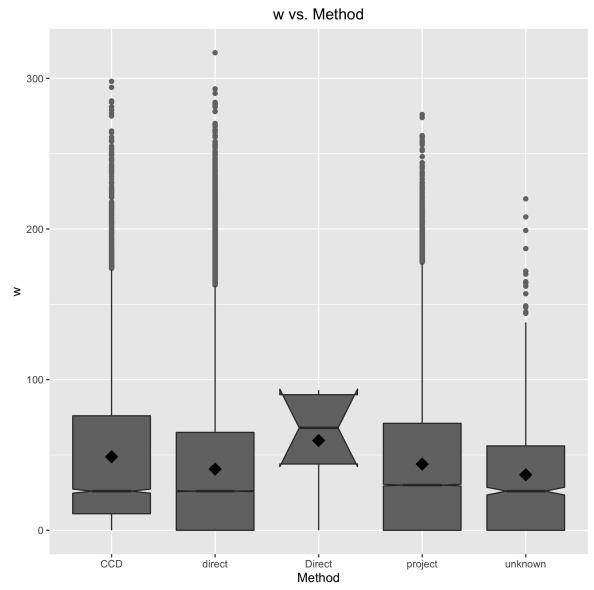


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.