

# Monthly Report (00)

## 2022.01 Data Set

Monday 14<sup>th</sup> February, 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.

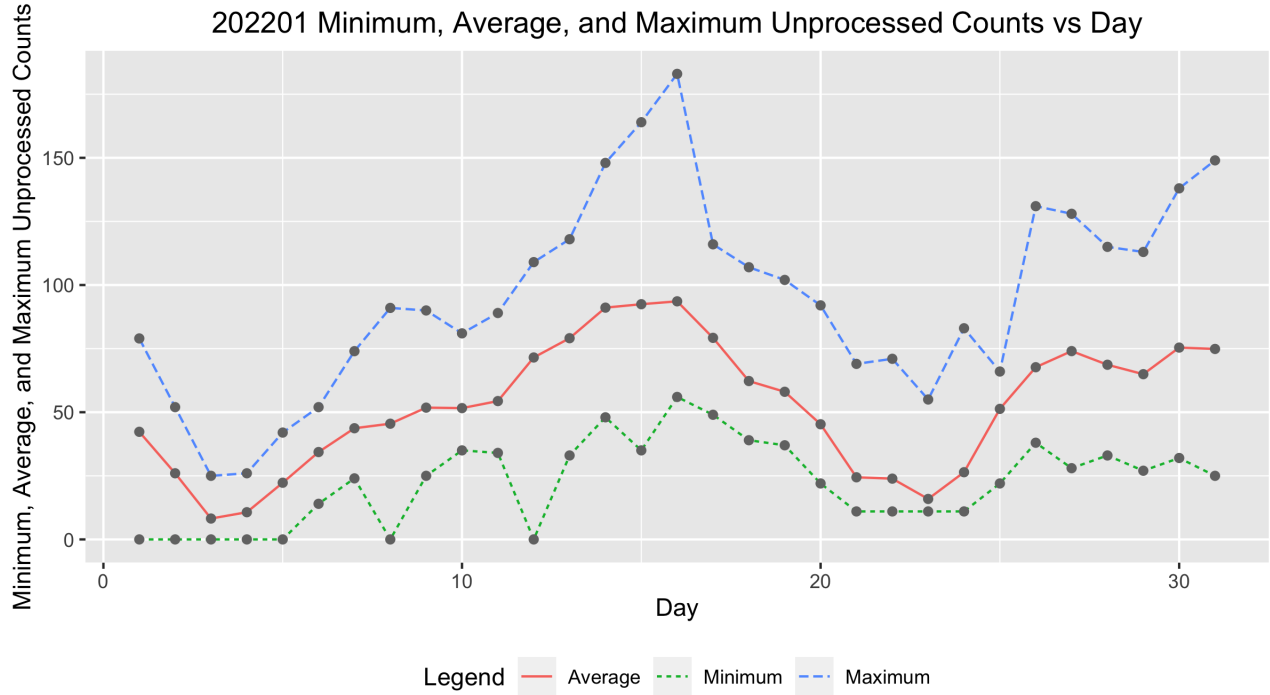


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202201 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	33.0000	0.0000	42.3030	79.0000
2.0000	30.0000	0.0000	26.0000	52.0000
3.0000	34.0000	0.0000	8.2059	25.0000
4.0000	33.0000	0.0000	10.6970	26.0000
5.0000	29.0000	0.0000	22.2759	42.0000
6.0000	35.0000	14.0000	34.3429	52.0000
7.0000	37.0000	24.0000	43.7027	74.0000
8.0000	41.0000	0.0000	45.4878	91.0000
9.0000	30.0000	25.0000	51.8000	90.0000
10.0000	31.0000	35.0000	51.6129	81.0000
11.0000	42.0000	34.0000	54.3810	89.0000
12.0000	39.0000	0.0000	71.5128	109.0000
13.0000	41.0000	33.0000	79.0976	118.0000
14.0000	46.0000	48.0000	91.1087	148.0000
15.0000	37.0000	35.0000	92.4595	164.0000
16.0000	44.0000	56.0000	93.5909	183.0000
17.0000	34.0000	49.0000	79.2353	116.0000
18.0000	43.0000	39.0000	62.2558	107.0000
19.0000	32.0000	37.0000	58.0312	102.0000
20.0000	33.0000	22.0000	45.2727	92.0000
21.0000	38.0000	11.0000	24.4211	69.0000
22.0000	38.0000	11.0000	23.8947	71.0000
23.0000	42.0000	11.0000	15.9048	55.0000
24.0000	31.0000	11.0000	26.4194	83.0000
25.0000	38.0000	22.0000	51.3158	66.0000
26.0000	45.0000	38.0000	67.6889	131.0000
27.0000	40.0000	28.0000	74.0250	128.0000
28.0000	41.0000	33.0000	68.6585	115.0000
29.0000	40.0000	27.0000	64.9500	113.0000
30.0000	49.0000	32.0000	75.4082	138.0000
31.0000	38.0000	25.0000	74.8684	149.0000

### 3 Error Tables

Data are for the month of January 2022. 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	2.4153	3.1256	0.5000	1.0000
2009.01	5.3979	4.8254	5.9703	1.3000	1.3000
2009.02	4.6276	4.1234	5.1319	0.7000	1.2000
2009.03	6.1592	5.9283	6.3902	0.3000	0.6000
2009.04	7.0488	6.8057	7.2920	0.4000	1.2000
2009.05	7.0415	6.7725	7.3104	1.6000	2.9000
2009.06	6.3703	6.0545	6.6862	3.2000	6.3000
2009.07	6.1505	5.9090	6.3920	3.6000	5.5000
2009.08	6.6474	6.3958	6.8991	0.0000	0.0000
2009.09	7.3801	7.1264	7.6338	4.5000	7.1000
2009.10	6.8759	6.5226	7.2293	4.5000	7.7000
2009.11	7.0938	6.9001	7.2876	3.3000	6.9000
2009.12	6.9896	6.7922	7.1869	10.4000	16.3000
2010.01	20.4771	18.1939	22.7604	13.3000	19.5000
2010.02	15.9234	13.8050	18.0417	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	17.7757	15.6152	19.9361	15.4000	24.0000
2010.04	20.0581	17.7425	22.3737	7.0000	10.4000
2010.05	23.6117	23.1955	24.0279	8.4000	8.7000
2010.06	20.0351	19.7001	20.3700	11.0000	13.6000
2010.07	21.1816	20.8720	21.4912	15.2000	16.1000
2010.08	22.1264	21.7618	22.4911	18.3000	19.6000
2010.09	25.5053	25.0854	25.9252	22.8000	25.2000
2010.10	24.0654	23.6492	24.4817	21.0000	23.5000
2010.11	25.3510	24.8926	25.8095	20.9000	21.6000
2010.12	24.0183	23.5381	24.4985	13.9000	14.5000
2011.01	73.4220	71.9295	74.9146	17.7000	18.7000
2011.02	62.1621	60.8654	63.4588	29.1000	29.6000
2011.03	67.3491	66.0647	68.6336	48.0000	55.8000
2011.04	76.9587	75.5661	78.3513	47.3000	54.4000
2011.05	77.0582	75.7605	78.3558	37.3000	41.5000
2011.06	65.3579	64.2140	66.5018	35.2000	37.0000
2011.07	68.3557	67.1890	69.5223	41.5000	43.8000
2011.08	72.2392	71.0774	73.4010	42.4000	50.5000
2011.09	81.9185	80.4975	83.3396	73.8000	78.0000
2011.10	77.3641	76.0609	78.6672	78.9000	88.0000
2011.11	81.2351	79.5484	82.9217	84.6000	96.7000
2011.12	75.6606	74.1114	77.2098	65.8000	73.0000
2012.01	78.9413	77.3871	80.4955	55.8000	58.2000
2012.02	65.6419	64.3043	66.9795	29.2000	33.1000
2012.03	71.8550	70.5803	73.1297	53.1000	64.1000
2012.04	80.7729	79.3460	82.1999	51.4000	55.2000
2012.05	82.4662	81.0988	83.8335	61.8000	69.0000
2012.06	69.3123	68.1310	70.4936	59.7000	64.5000
2012.07	72.9624	71.7619	74.1630	64.2000	51.3000
2012.08	74.2827	73.0828	75.4826	57.7000	63.1000
2012.09	84.7752	83.2998	86.2506	57.7000	61.5000
2012.10	80.8640	79.3801	82.3479	48.3000	53.3000
2012.11	84.9910	83.2762	86.7059	56.7000	61.4000
2012.12	79.3362	77.6087	81.0636	37.4000	40.8000
2013.01	87.7013	86.0161	89.3864	63.8000	62.9000
2013.02	73.0473	71.5709	74.5237	37.8000	38.0000
2013.03	77.4457	75.8597	79.0317	50.6000	57.9000
2013.04	88.0883	86.5277	89.6490	70.6000	72.4000
2013.05	87.8694	86.2906	89.4483	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	75.3585	74.0166	76.7003	51.0000	52.5000
2013.07	78.2903	77.0226	79.5580	57.0000	57.0000
2013.08	81.3519	80.0334	82.6705	60.0000	66.0000
2013.09	91.4148	89.7734	93.0562	34.6000	36.9000
2013.10	86.2200	84.6109	87.8292	74.5000	85.6000
2013.11	88.9878	86.9750	91.0006	73.9000	77.6000
2013.12	85.4091	83.5741	87.2441	77.8000	90.3000
2014.01	102.3360	100.1704	104.5015	77.4000	82.0000
2014.02	87.0023	85.2761	88.7286	93.9000	102.8000
2014.03	94.3764	92.6450	96.1078	80.9000	92.2000
2014.04	107.4936	105.6001	109.3871	76.9000	84.7000
2014.05	107.8340	105.9856	109.6825	72.3000	75.2000
2014.06	92.2742	90.7068	93.8416	67.2000	71.0000
2014.07	95.5967	93.9927	97.2008	72.5000	72.5000
2014.08	99.4595	97.8983	101.0207	71.2000	74.7000
2014.09	113.0258	111.0210	115.0307	83.2000	87.6000
2014.10	106.1543	104.1900	108.1186	59.5000	60.6000
2014.11	110.7821	108.4693	113.0950	65.8000	71.1000
2014.12	103.9572	101.5406	106.3737	75.8000	78.0000
2015.01	63.1646	61.8974	64.4317	65.9000	67.0000
2015.02	52.4627	51.3021	53.6234	42.4000	44.8000
2015.03	57.6616	56.6045	58.7186	38.0000	38.4000
2015.04	65.2563	64.0871	66.4255	49.0000	54.4000
2015.05	65.6907	64.6023	66.7791	56.3000	58.8000
2015.06	56.0853	55.0781	57.0925	50.2000	68.3000
2015.07	57.5944	56.6167	58.5720	47.9000	65.8000
2015.08	61.0736	60.0517	62.0955	39.5000	57.2000
2015.09	68.6089	67.3642	69.8537	49.2000	72.1000
2015.10	64.8837	63.6315	66.1360	39.3000	48.3000
2015.11	68.3607	66.8695	69.8518	39.6000	55.9000
2015.12	64.3095	62.8789	65.7401	36.4000	44.8000
2016.01	34.5765	33.8554	35.2976	33.7000	43.3000
2016.02	28.7958	28.1950	29.3965	38.3000	46.8000
2016.03	31.1514	30.5290	31.7737	30.5000	38.9000
2016.04	35.1754	34.5047	35.8460	26.6000	30.9000
2016.05	35.5161	34.8678	36.1645	33.7000	48.4000
2016.06	29.9734	29.4621	30.4847	13.1000	19.5000
2016.07	31.3353	30.8328	31.8378	21.2000	27.5000
2016.08	32.8908	32.3128	33.4688	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	37.8318	37.1415	38.5220	27.7000	37.1000
2016.10	35.4259	34.7437	36.1082	22.7000	31.7000
2016.11	36.9111	36.1396	37.6826	14.0000	22.2000
2016.12	35.1718	34.4166	35.9270	11.1000	20.0000
2017.01	18.6848	18.2906	19.0789	18.4000	26.2000
2017.02	15.6218	15.2783	15.9653	14.4000	20.6000
2017.03	17.0427	16.7176	17.3677	11.3000	15.5000
2017.04	19.4229	19.0803	19.7655	21.6000	33.2000
2017.05	19.3129	18.9791	19.6467	12.5000	18.1000
2017.06	16.2995	16.0259	16.5731	15.5000	19.3000
2017.07	17.1237	16.8483	17.3992	11.5000	16.3000
2017.08	17.9262	17.6111	18.2413	22.8000	35.7000
2017.09	20.9487	20.5040	21.3935	34.6000	42.9000
2017.10	19.1074	18.7124	19.5024	10.5000	11.0000
2017.11	19.7585	19.3387	20.1782	4.2000	5.6000
2017.12	18.7165	18.4296	19.0035	4.0000	4.6000
2018.01	5.2282	5.1159	5.3405	3.1000	6.3000
2018.02	4.3318	4.2255	4.4380	6.8000	11.8000
2018.03	4.6424	4.5483	4.7366	1.1000	1.2000
2018.04	5.2371	5.1309	5.3434	4.7000	7.5000
2018.05	5.2881	5.1880	5.3881	8.4000	14.0000
2018.06	4.4763	4.3970	4.5555	10.2000	13.6000
2018.07	4.7016	4.6479	4.7552	0.5000	1.7000
2018.08	4.8679	4.7841	4.9517	5.9000	9.5000
2018.09	5.4843	5.3808	5.5877	1.6000	2.9000
2018.10	5.2688	5.1647	5.3728	2.5000	5.6000
2018.11	5.4703	5.3558	5.5848	3.1000	4.2000
2018.12	5.2905	5.1865	5.3945	1.6000	2.3000
2019.01	3.4456	3.3794	3.5118	5.4000	2.3000
2019.02	2.9202	2.8626	2.9778	0.1000	1.2000
2019.03	3.0918	3.0386	3.1450	6.1000	12.1000
2019.04	3.5219	3.4549	3.5888	6.2000	9.3000
2019.05	3.4455	3.3852	3.5058	7.0000	11.9000
2019.06	2.9273	2.8779	2.9768	0.7000	1.5000
2019.07	3.0766	3.0305	3.1227	0.4000	2.2000
2019.08	3.2347	3.1864	3.2829	0.3000	0.8000
2019.09	3.7231	3.6643	3.7819	0.5000	1.0000
2019.10	3.4702	3.4105	3.5298	0.2000	0.5000
2019.11	3.6764	3.6055	3.7473	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	3.4628	3.3940	3.5316	0.8000	1.0000
2020.01	7.6299	7.4785	7.7812	4.0000	5.3000
2020.02	6.3766	6.2475	6.5056	0.1000	0.0000
2020.03	6.8254	6.6965	6.9542	1.2000	1.5000
2020.04	7.8172	7.6873	7.9471	3.0000	5.1000
2020.05	7.7239	7.6016	7.8461	0.1000	0.4000
2020.06	6.6020	6.4999	6.7041	3.9000	6.4000
2020.07	6.8390	6.7384	6.9395	4.2000	7.7000
2020.08	7.0756	6.9774	7.1738	5.3000	7.8000
2020.09	8.1220	7.9916	8.2524	0.4000	0.9000
2020.10	7.7652	7.6374	7.8929	9.9000	13.6000
2020.11	8.1909	8.0599	8.3218	21.2000	33.1000
2020.12	7.7530	7.6173	7.8887	15.4000	19.8000
2021.01	26.4606	25.9956	26.9257	7.0000	15.8000
2021.02	22.4854	22.0860	22.8848	5.8000	10.7000
2021.03	24.2591	23.8755	24.6426	11.0000	17.2000
2021.04	27.6794	27.2649	28.0939	18.5000	28.8000
2021.05	27.6521	27.2697	28.0346	15.9000	22.9000
2021.06	23.6752	23.3316	24.0187	19.9000	24.1000
2021.07	24.4846	24.1104	24.8588	23.8000	35.6000
2021.08	25.9899	25.5987	26.3810	15.7000	19.5000
2021.09	29.8121	29.3459	30.2782	39.1000	52.5000
2021.10	28.8593	28.3687	29.3499	27.1000	37.0000
2021.11	31.2367	30.6896	31.7839	27.2000	35.1000
2021.12	30.5143	29.9240	31.1047	50.6000	69.0000
2022.01	54.3754	53.3932	55.3577	43.9000	62.0000

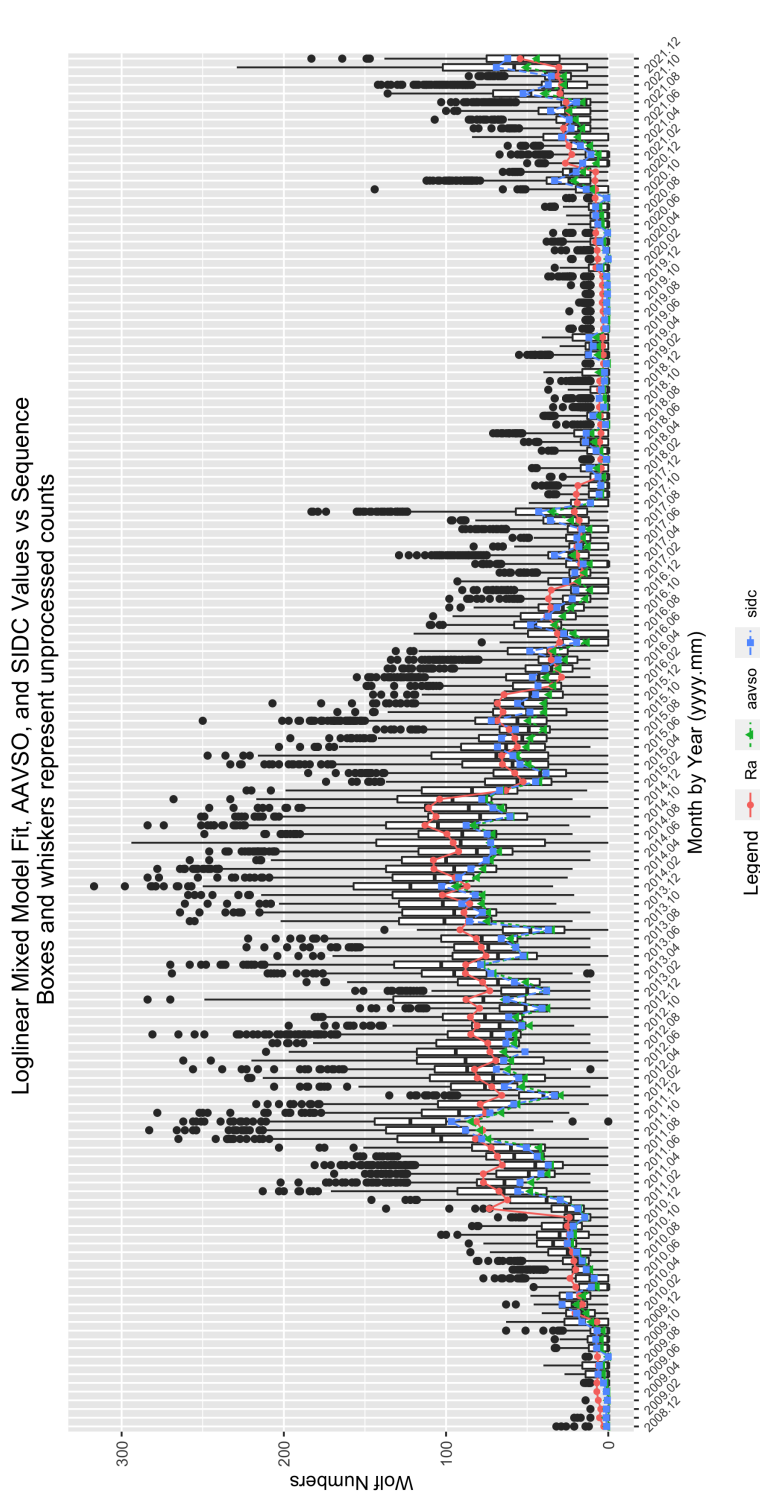


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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.

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 3: 202201 Parameter Estimates

	Estimate	Std. Error	t-value	Pr(> t )
(Intercept)	1.3488	0.3153	4.2775	0.0000
seeF	-0.2262	0.0057	-39.7322	0.0000
seeG	-0.1238	0.0050	-24.8835	0.0000
seeM	-0.1967	0.0244	-8.0700	0.0000
seeP	-0.3267	0.0081	-40.2324	0.0000
sidc1	0.0625	0.0199	3.1463	0.0017
year2009	0.7131	0.3165	2.2528	0.0243
year2010	1.9514	0.3144	6.2076	0.0000
year2011	3.0844	0.3143	9.8152	0.0000
year2012	3.1236	0.3142	9.9400	0.0000
year2013	3.2197	0.3142	10.2457	0.0000
year2014	3.4179	0.3142	10.8765	0.0000
year2015	2.9321	0.3143	9.3304	0.0000
year2016	2.3155	0.3143	7.3674	0.0000
year2017	1.7037	0.3143	5.4203	0.0000
year2018	0.4210	0.3146	1.3381	0.1809
year2019	-0.0025	0.3148	-0.0080	0.9936
year2020	0.8021	0.3145	2.5504	0.0108
year2021	2.0661	0.3143	6.5734	0.0000
year2022	2.6775	0.3148	8.5054	0.0000
mon2	-0.1738	0.0092	-18.8002	0.0000
mon3	-0.0999	0.0086	-11.6130	0.0000
mon4	0.0190	0.0083	2.3004	0.0214
mon5	0.0162	0.0081	1.9884	0.0468
mon6	-0.1499	0.0085	-17.6658	0.0000
mon7	-0.1133	0.0082	-13.7350	0.0000
mon8	-0.0656	0.0081	-8.0742	0.0000
mon9	0.0711	0.0081	8.7888	0.0000
mon10	0.0153	0.0083	1.8405	0.0657
mon11	0.0718	0.0086	8.3875	0.0000
mon12	0.0204	0.0086	2.3625	0.0182

Table 4: 202201 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:151086	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 : 6.624	Mean :15.72		Mean :0.2488
3rd Qu.:2019	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:0.0000
Max. :2022	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202201 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:151086	Length:151086
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 : 2.649	Mean : 15.37	Mean : 41.86		
3rd Qu.: 4.000	3rd Qu.: 22.00	3rd Qu.: 67.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202201 Summary of Sunspot Numbers

inst	filter	unit
Length:151086	Length:151086	Length:151086
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202201 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.: 5.00	1st Qu.: 35	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 900	Median : 57.5
Mean : 91.53	Mean : 34.66	Mean : 889	Mean : 181.5
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

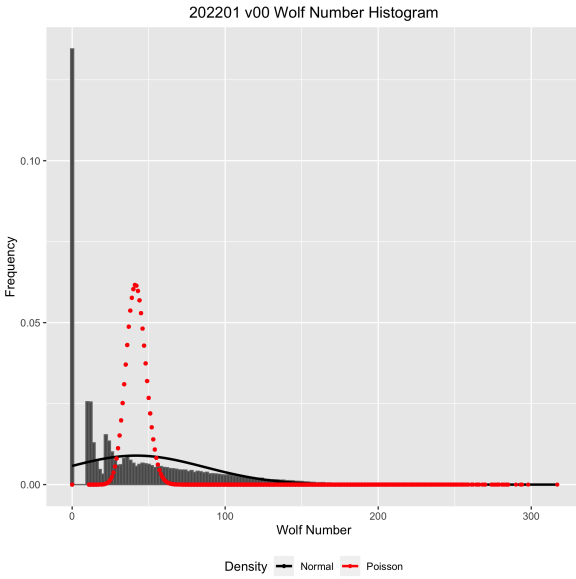


Figure 3: Box plots of raw Wolf number ( $w$ ) by observer rank.

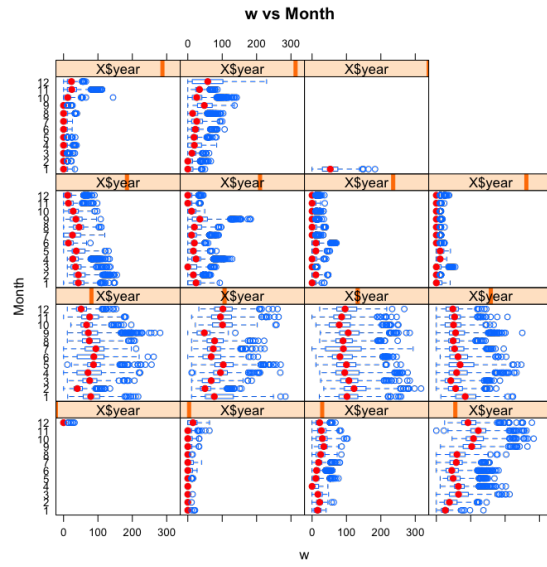


Figure 4: Box plots of raw Wolf number ( $w$ ) by month and year.

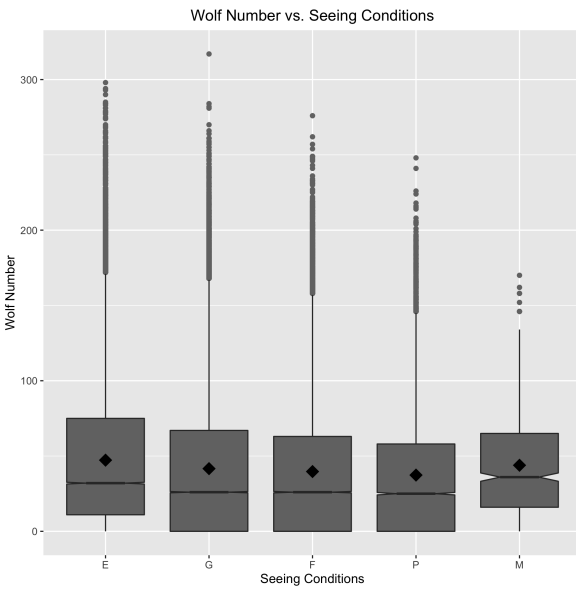


Figure 5: Box plots of raw Wolf number ( $w$ ) by seeing condition.

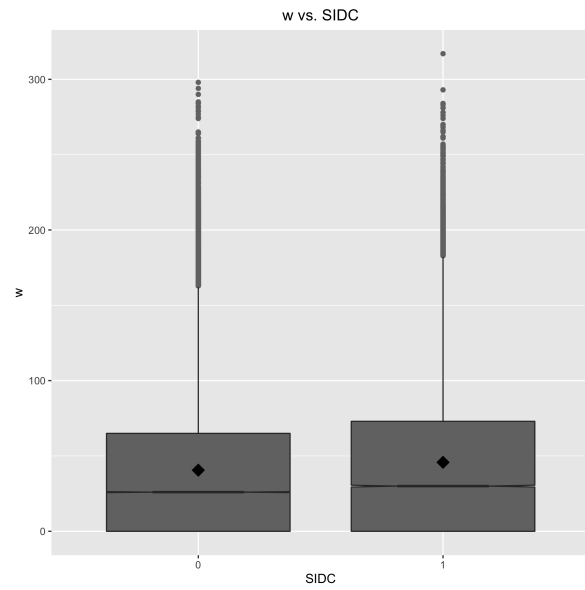


Figure 6: Box plots of raw Wolf number ( $w$ ) by organization.

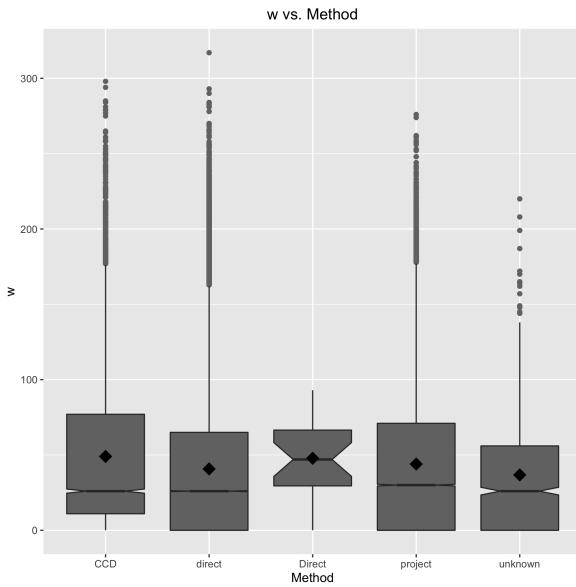


Figure 7: Box plots of raw Wolf number ( $w$ ) by observer rank.

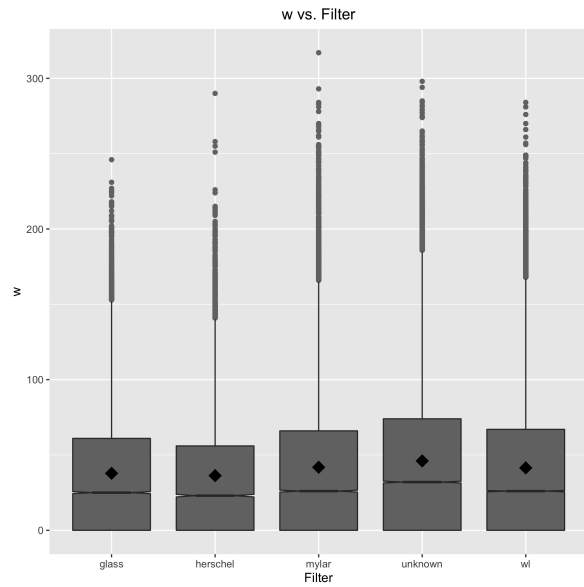


Figure 8: Box plots of raw Wolf number ( $w$ ) by month and year.

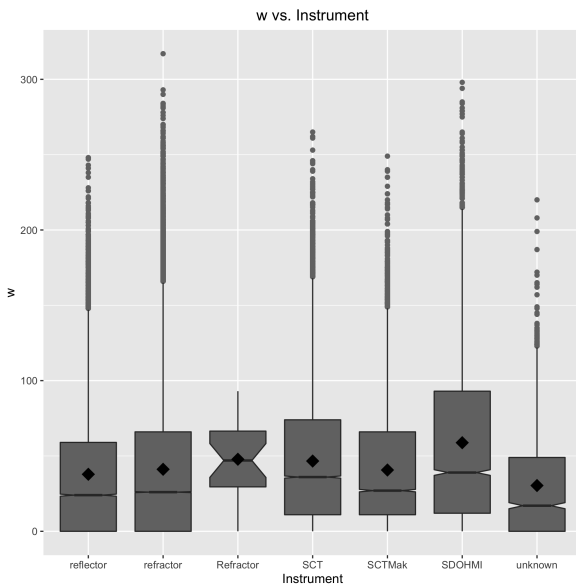


Figure 9: Box plots of raw Wolf number ( $w$ ) by seeing condition.

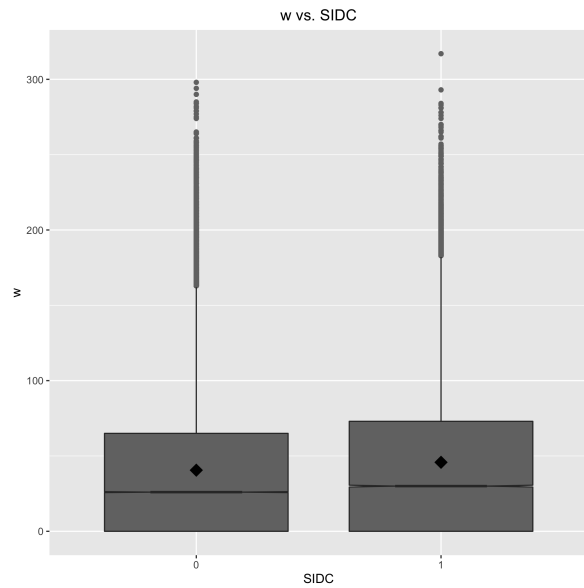


Figure 10: Box plots of raw Wolf number ( $w$ ) by organization.



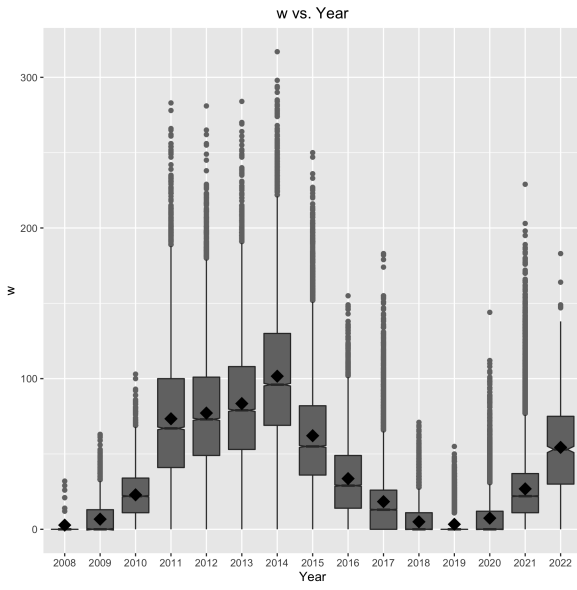


Figure 11: Box plots of raw Wolf number (w) by year.

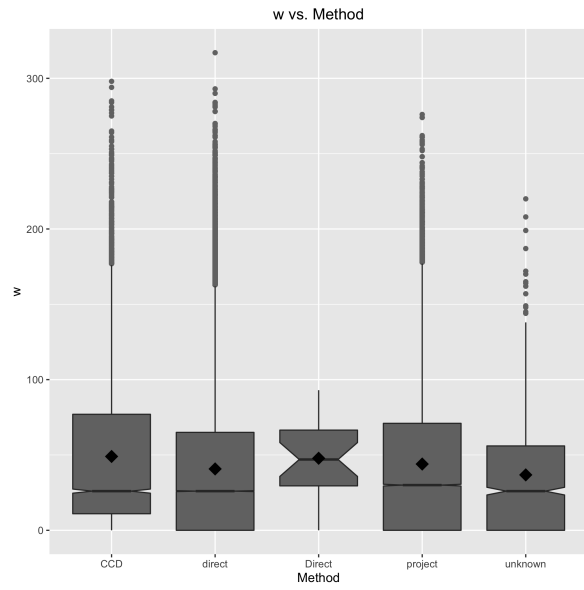


Figure 12: Box plots of raw Wolf number (w) by observing method.