Monthly Report (00)

2022.05 Data Set

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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.

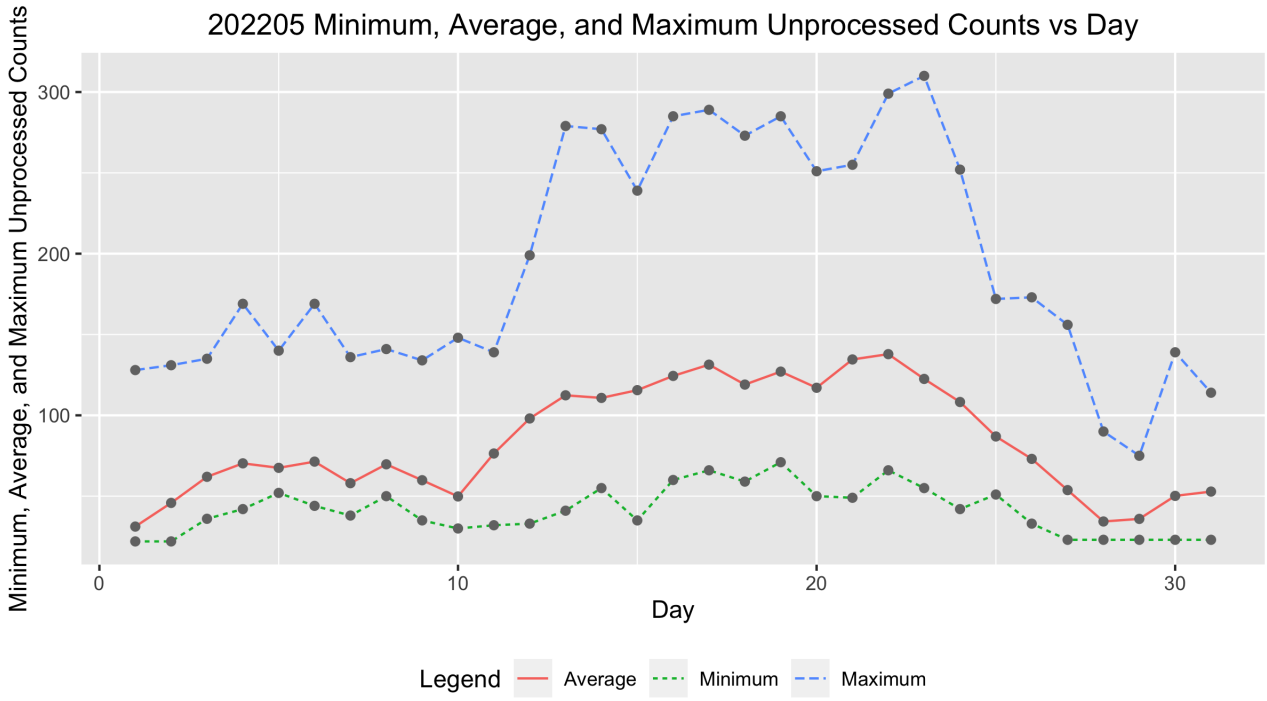

Figure 1: Raw average sunspot count by day of the month.

Table 1: 202205 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	39.0000	22.0000	31.1795	128.0000
2.0000	33.0000	22.0000	45.8182	131.0000
3.0000	34.0000	36.0000	61.9706	135.0000
4.0000	34.0000	42.0000	70.2941	169.0000
5.0000	43.0000	52.0000	67.5116	140.0000
6.0000	36.0000	44.0000	71.3611	169.0000
7.0000	44.0000	38.0000	58.0227	136.0000
8.0000	47.0000	50.0000	69.7021	141.0000
9.0000	44.0000	35.0000	59.8636	134.0000
10.0000	50.0000	30.0000	49.8200	148.0000
11.0000	44.0000	32.0000	76.3864	139.0000
12.0000	46.0000	33.0000	98.0652	199.0000
13.0000	47.0000	41.0000	112.3830	279.0000
14.0000	49.0000	55.0000	110.7755	277.0000
15.0000	47.0000	35.0000	115.5745	239.0000
16.0000	45.0000	60.0000	124.3778	285.0000
17.0000	45.0000	66.0000	131.3556	289.0000
18.0000	43.0000	59.0000	119.0233	273.0000
19.0000	40.0000	71.0000	127.0500	285.0000
20.0000	39.0000	50.0000	117.0513	251.0000
21.0000	46.0000	49.0000	134.5652	255.0000
22.0000	41.0000	66.0000	137.8537	299.0000
23.0000	38.0000	55.0000	122.5263	310.0000
24.0000	32.0000	42.0000	108.2500	252.0000
25.0000	38.0000	51.0000	86.9211	172.0000
26.0000	38.0000	33.0000	73.0526	173.0000
27.0000	35.0000	23.0000	53.7429	156.0000
28.0000	46.0000	23.0000	34.3261	90.0000
29.0000	45.0000	23.0000	35.9333	75.0000
30.0000	47.0000	23.0000	50.1702	139.0000
31.0000	37.0000	23.0000	52.8378	114.0000

3 Error Tables

Data are for the month of May 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^{th} through the 75^{th} quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25^{th} quartile, and 1.5 times the IQR above the 75^{th} 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	2.4194	3.1216	0.5000	1.0000
2009.01	5.2180	4.6712	5.7649	1.3000	1.3000
2009.02	4.6383	4.1386	5.1379	0.7000	1.2000
2009.03	6.1979	5.9664	6.4294	0.3000	0.6000
2009.04	6.9944	6.7552	7.2336	0.4000	1.2000
2009.05	7.1845	6.9114	7.4576	1.6000	2.9000
2009.06	6.3593	6.0466	6.6719	3.2000	6.3000
2009.07	6.1432	5.9027	6.3836	3.6000	5.5000
2009.08	6.6454	6.3962	6.8947	0.0000	0.0000
2009.09	7.3700	7.1185	7.6215	4.5000	7.1000
2009.10	6.8688	6.5170	7.2206	4.5000	7.7000
2009.11	7.1023	6.9082	7.2965	3.3000	6.9000
2009.12	7.0004	6.8022	7.1986	10.4000	16.3000
2010.01	19.7624	17.5854	21.9393	13.3000	19.5000
2010.02	15.9367	13.8434	18.0300	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	17.9350	15.7800	20.0900	15.4000	24.0000
2010.04	19.9396	17.6640	22.2152	7.0000	10.4000
2010.05	24.0270	23.6018	24.4522	8.4000	8.7000
2010.06	19.9629	19.6261	20.2997	11.0000	13.6000
2010.07	21.1168	20.8049	21.4287	15.2000	16.1000
2010.08	22.0578	21.6897	22.4259	18.3000	19.6000
2010.09	25.4294	25.0058	25.8530	22.8000	25.2000
2010.10	24.0132	23.5924	24.4340	21.0000	23.5000
2010.11	25.3013	24.8399	25.7627	20.9000	21.6000
2010.12	24.0217	23.5401	24.5033	13.9000	14.5000
2011.01	70.9481	69.5039	72.3923	17.7000	18.7000
2011.02	62.2078	60.9019	63.5138	29.1000	29.6000
2011.03	67.8770	66.5761	69.1780	48.0000	55.8000
2011.04	76.5212	75.1147	77.9277	47.3000	54.4000
2011.05	78.6647	77.3244	80.0050	37.3000	41.5000
2011.06	65.3203	64.1688	66.4717	35.2000	37.0000
2011.07	68.2888	67.1202	69.4575	41.5000	43.8000
2011.08	72.1530	70.9869	73.3191	42.4000	50.5000
2011.09	81.9061	80.4766	83.3356	73.8000	78.0000
2011.10	77.3845	76.0730	78.6960	78.9000	88.0000
2011.11	81.3574	79.6686	83.0462	84.6000	96.7000
2011.12	75.8168	74.2630	77.3706	65.8000	73.0000
2012.01	76.2269	74.7227	77.7311	55.8000	58.2000
2012.02	65.7075	64.3629	67.0522	29.2000	33.1000
2012.03	72.4272	71.1398	73.7147	53.1000	64.1000
2012.04	80.2453	78.8169	81.6737	51.4000	55.2000
2012.05	84.2099	82.8046	85.6151	61.8000	69.0000
2012.06	69.2926	68.1078	70.4773	59.7000	64.5000
2012.07	72.9466	71.7415	74.1517	64.2000	51.3000
2012.08	74.2327	73.0266	75.4389	57.7000	63.1000
2012.09	84.7734	83.2940	86.2528	57.7000	61.5000
2012.10	80.9000	79.4103	82.3897	48.3000	53.3000
2012.11	85.2005	83.4792	86.9218	56.7000	61.4000
2012.12	79.5214	77.7882	81.2546	37.4000	40.8000
2013.01	84.6953	83.0654	86.3252	63.8000	62.9000
2013.02	73.1257	71.6424	74.6089	37.8000	38.0000
2013.03	78.0851	76.4823	79.6880	50.6000	57.9000
2013.04	87.5295	85.9719	89.0871	70.6000	72.4000
2013.05	89.7310	88.1117	91.3504	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	75.3345	73.9852	76.6838	51.0000	52.5000
2013.07	78.3197	77.0425	79.5970	57.0000	57.0000
2013.08	81.3603	80.0334	82.6872	60.0000	66.0000
2013.09	91.4425	89.7942	93.0907	34.6000	36.9000
2013.10	86.2582	84.6428	87.8736	74.5000	85.6000
2013.11	89.2675	87.2384	91.2967	73.9000	77.6000
2013.12	85.6409	83.7990	87.4828	77.8000	90.3000
2014.01	98.8313	96.7359	100.9268	77.4000	82.0000
2014.02	87.1037	85.3659	88.8414	93.9000	102.8000
2014.03	95.1241	93.3723	96.8758	80.9000	92.2000
2014.04	106.7933	104.9020	108.6845	76.9000	84.7000
2014.05	110.1187	108.2236	112.0137	72.3000	75.2000
2014.06	92.2858	90.7084	93.8632	67.2000	71.0000
2014.07	95.6185	94.0037	97.2333	72.5000	72.5000
2014.08	99.4457	97.8776	101.0138	71.2000	74.7000
2014.09	113.0386	111.0241	115.0530	83.2000	87.6000
2014.10	106.1743	104.2041	108.1444	59.5000	60.6000
2014.11	111.0628	108.7350	113.3906	65.8000	71.1000
2014.12	104.1311	101.7077	106.5546	75.8000	78.0000
2015.01	61.0077	59.7820	62.2333	65.9000	67.0000
2015.02	52.5457	51.3759	53.7154	42.4000	44.8000
2015.03	58.1598	57.0886	59.2310	38.0000	38.4000
2015.04	64.9092	63.7380	66.0805	49.0000	54.4000
2015.05	67.1084	65.9899	68.2268	56.3000	58.8000
2015.06	56.0707	55.0619	57.0794	50.2000	68.3000
2015.07	57.5664	56.5892	58.5436	47.9000	65.8000
2015.08	61.0394	60.0182	62.0605	39.5000	57.2000
2015.09	68.5996	67.3544	69.8448	49.2000	72.1000
2015.10	64.8714	63.6185	66.1243	39.3000	48.3000
2015.11	68.4945	66.9985	69.9904	39.6000	55.9000
2015.12	64.4770	63.0421	65.9119	36.4000	44.8000
2016.01	33.4049	32.7073	34.1026	33.7000	43.3000
2016.02	28.8347	28.2322	29.4372	38.3000	46.8000
2016.03	31.4143	30.7856	32.0429	30.5000	38.9000
2016.04	34.9461	34.2785	35.6137	26.6000	30.9000
2016.05	36.2517	35.5891	36.9142	33.7000	48.4000
2016.06	29.9664	29.4546	30.4782	13.1000	19.5000
2016.07	31.3442	30.8411	31.8473	21.2000	27.5000
2016.08	32.8801	32.3022	33.4580	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	37.8271	37.1363	38.5179	27.7000	37.1000
2016.10	35.4359	34.7529	36.1188	22.7000	31.7000
2016.11	37.0054	36.2309	37.7798	14.0000	22.2000
2016.12	35.2767	34.5181	36.0354	11.1000	20.0000
2017.01	18.0485	17.6669	18.4301	18.4000	26.2000
2017.02	15.6442	15.2994	15.9889	14.4000	20.6000
2017.03	17.1853	16.8570	17.5136	11.3000	15.5000
2017.04	19.2964	18.9554	19.6374	21.6000	33.2000
2017.05	19.7298	19.3884	20.0713	12.5000	18.1000
2017.06	16.2910	16.0184	16.5636	15.5000	19.3000
2017.07	17.1179	16.8427	17.3931	11.5000	16.3000
2017.08	17.9084	17.5945	18.2222	22.8000	35.7000
2017.09	20.9300	20.4913	21.3687	34.6000	42.9000
2017.10	19.0961	18.7022	19.4900	10.5000	11.0000
2017.11	19.8039	19.3828	20.2250	4.2000	5.6000
2017.12	18.7742	18.4865	19.0619	4.0000	4.6000
2018.01	5.0542	4.9459	5.1624	3.1000	6.3000
2018.02	4.3360	4.2304	4.4416	6.8000	11.8000
2018.03	4.6832	4.5881	4.7784	1.1000	1.2000
2018.04	5.2015	5.0969	5.3061	4.7000	7.5000
2018.05	5.3992	5.2979	5.5006	8.4000	14.0000
2018.06	4.4735	4.3945	4.5526	10.2000	13.6000
2018.07	4.7007	4.6471	4.7542	0.5000	1.7000
2018.08	4.8640	4.7803	4.9476	5.9000	9.5000
2018.09	5.4812	5.3780	5.5845	1.6000	2.9000
2018.10	5.2680	5.1638	5.3721	2.5000	5.6000
2018.11	5.4806	5.3655	5.5956	3.1000	4.2000
2018.12	5.3022	5.1979	5.4064	1.6000	2.3000
2019.01	3.3299	3.2659	3.3939	5.4000	2.3000
2019.02	2.9225	2.8649	2.9802	0.1000	1.2000
2019.03	3.1179	3.0644	3.1713	6.1000	12.1000
2019.04	3.5007	3.4344	3.5670	6.2000	9.3000
2019.05	3.5194	3.4578	3.5810	7.0000	11.9000
2019.06	2.9281	2.8784	2.9778	0.7000	1.5000
2019.07	3.0756	3.0296	3.1217	0.4000	2.2000
2019.08	3.2329	3.1846	3.2812	0.3000	0.8000
2019.09	3.7227	3.6638	3.7815	0.5000	1.0000
2019.10	3.4713	3.4115	3.5311	0.2000	0.5000
2019.11	3.6888	3.6174	3.7602	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	3.4733	3.4044	3.5422	0.8000	1.0000
2020.01	7.3737	7.2280	7.5195	4.0000	5.3000
2020.02	6.3950	6.2655	6.5245	0.1000	0.0000
2020.03	6.8899	6.7599	7.0199	1.2000	1.5000
2020.04	7.7753	7.6458	7.9047	3.0000	5.1000
2020.05	7.8941	7.7692	8.0190	0.1000	0.4000
2020.06	6.6062	6.5041	6.7083	3.9000	6.4000
2020.07	6.8395	6.7384	6.9405	4.2000	7.7000
2020.08	7.0758	6.9769	7.1748	5.3000	7.8000
2020.09	8.1239	7.9930	8.2548	0.4000	0.9000
2020.10	7.7615	7.6329	7.8900	9.9000	13.6000
2020.11	8.1848	8.0527	8.3170	21.2000	33.1000
2020.12	7.7384	7.6001	7.8767	15.4000	19.8000
2021.01	25.7666	25.3081	26.2250	7.0000	15.8000
2021.02	22.6991	22.2925	23.1058	5.8000	10.7000
2021.03	24.6550	24.2624	25.0476	11.0000	17.2000
2021.04	27.7723	27.3437	28.2008	18.5000	28.8000
2021.05	28.4939	28.0875	28.9003	15.9000	22.9000
2021.06	23.7986	23.4514	24.1458	19.9000	24.1000
2021.07	24.5808	24.2029	24.9586	23.8000	35.6000
2021.08	26.2252	25.8228	26.6276	15.7000	19.5000
2021.09	29.8717	29.4059	30.3376	39.1000	52.5000
2021.10	28.8089	28.3300	29.2878	27.1000	37.0000
2021.11	30.3797	29.8899	30.8695	27.2000	35.1000
2021.12	29.5273	29.0027	30.0519	50.6000	69.0000
2022.01	67.0418	65.9286	68.1549	43.9000	62.0000
2022.02	58.9124	57.9010	59.9238	48.8000	60.5000
2022.03	64.5384	63.4423	65.6345	58.4000	80.6000
2022.04	70.5838	69.5226	71.6450	59.1000	83.9000
2022.05	74.4589	73.3129	75.6050	72.5000	0.4000

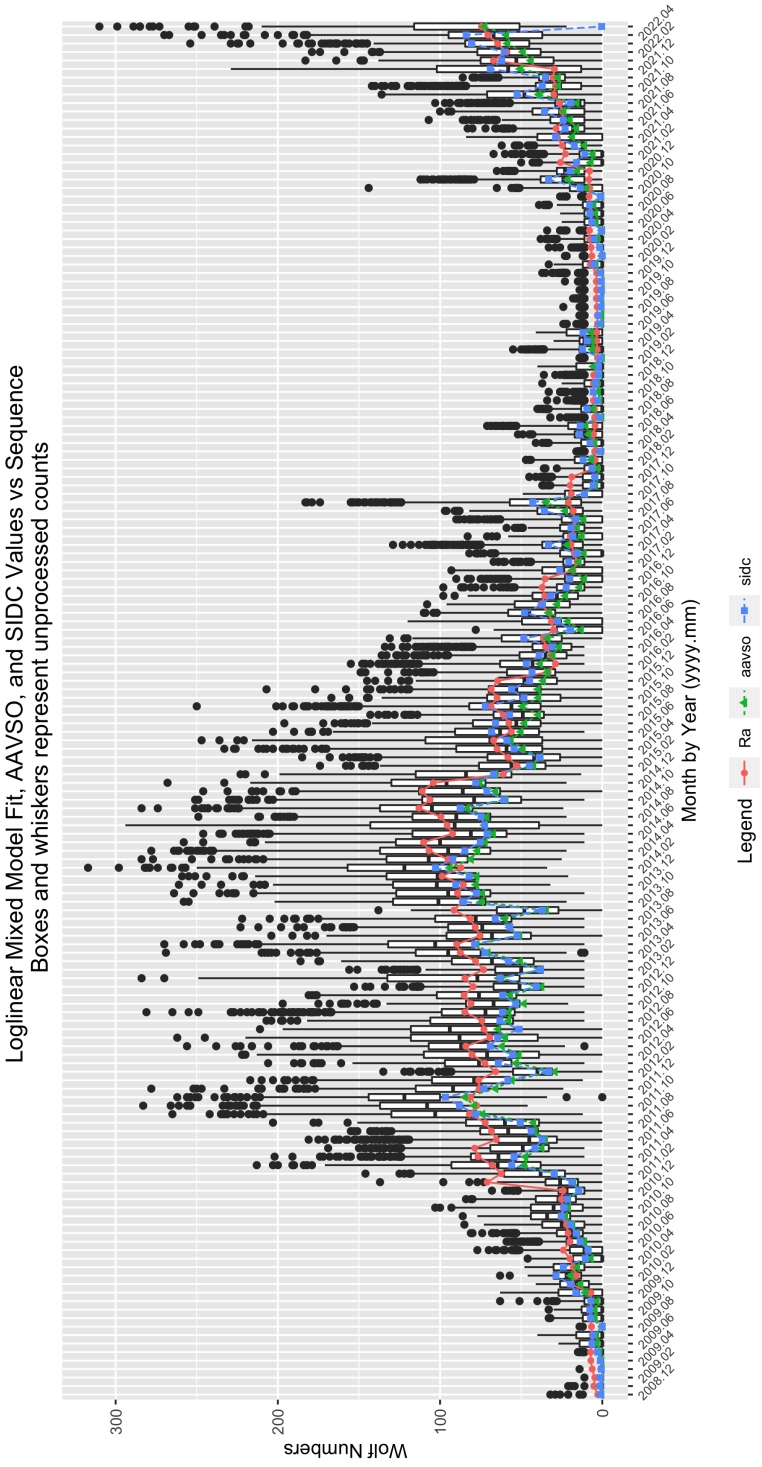

Figure 2: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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 contribution to both institutions tend to differ from those observers contributing only to the AAVSO.

5 Supporting Information

Table 3: 202205 Parameter Estimates

	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	1.2719	0.3154	4.0329	0.0001
seeF	-0.2252	0.0056	-40.4882	0.0000
seeG	-0.1207	0.0049	-24.8461	0.0000
seeM	-0.1940	0.0244	-7.9610	0.0000
seeP	-0.3240	0.0080	-40.7280	0.0000
sidc1	0.0495	0.0162	3.0473	0.0023
year2009	0.7164	0.3168	2.2616	0.0237
year2010	1.9534	0.3146	6.2096	0.0000
year2011	3.0900	0.3145	9.8259	0.0000
year2012	3.1296	0.3145	9.9519	0.0000
year2013	3.2257	0.3145	10.2579	0.0000
year2014	3.4238	0.3145	10.8878	0.0000
year2015	2.9392	0.3145	9.3462	0.0000
year2016	2.3229	0.3145	7.3857	0.0000
year2017	1.7113	0.3145	5.4405	0.0000
year2018	0.4302	0.3148	1.3664	0.1718
year2019	0.0081	0.3150	0.0257	0.9795
year2020	0.8137	0.3147	2.5857	0.0097
year2021	2.0909	0.3145	6.6477	0.0000
year2022	2.9840	0.3146	9.4861	0.0000
mon2	-0.1378	0.0086	-16.0653	0.0000
mon3	-0.0566	0.0080	-7.0559	0.0000
mon4	0.0476	0.0077	6.1582	0.0000
mon5	0.0722	0.0076	9.5323	0.0000
mon6	-0.1149	0.0083	-13.8962	0.0000
mon7	-0.0783	0.0080	-9.7530	0.0000
mon8	-0.0309	0.0079	-3.9117	0.0001
mon9	0.1062	0.0079	13.5022	0.0000
mon10	0.0506	0.0081	6.2684	0.0000
mon11	0.1092	0.0083	13.0901	0.0000
mon12	0.0581	0.0084	6.9069	0.0000

Table 4: 202205 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:155764	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 :0.2476
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: 202205 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:155764	Length:155764
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 7.00	Median : 28.00	Mode :character	Mode :character
Mean : 2.708	Mean : 15.65	Mean : 42.73		
3rd Qu.: 4.000	3rd Qu.: 23.00	3rd Qu.: 68.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202205 Summary of Sunspot Numbers

inst	filter	unit
Length:155764	Length:155764	Length:155764
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202205 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.: 5.00	1st Qu.: 36.0	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 900.0	Median : 57.5
Mean : 91.81	Mean : 35.54	Mean : 889.4	Mean : 181.0
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

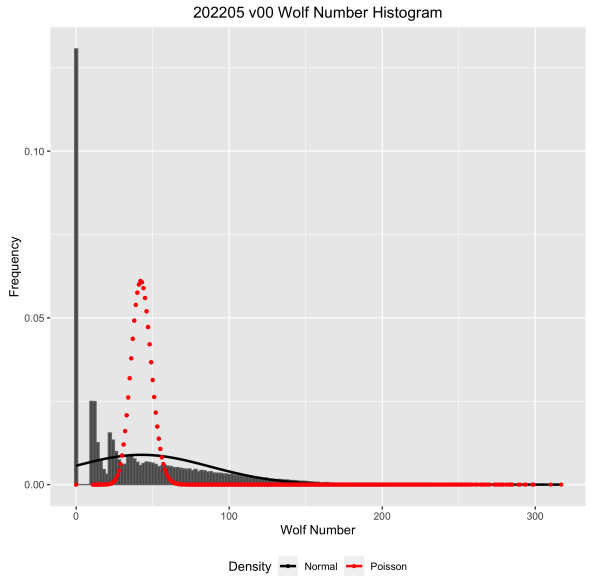

Figure 3: Box plots of raw Wolf number (w) by observer rank.

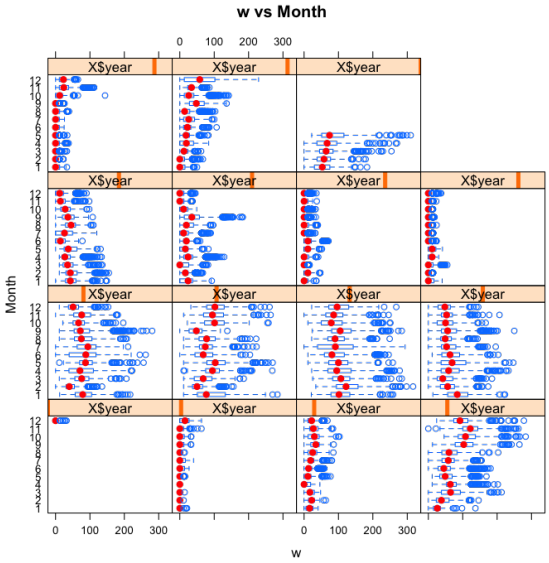

Figure 4: Box plots of raw Wolf number (w) by month and year.

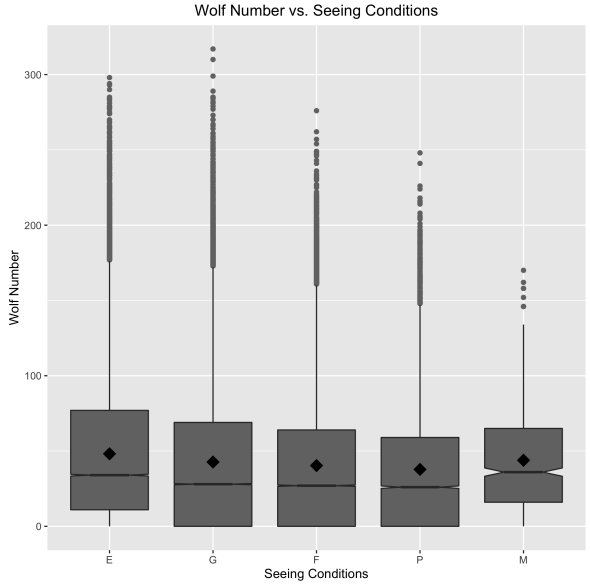

Figure 5: Box plots of raw Wolf number (w) by seeing condition.

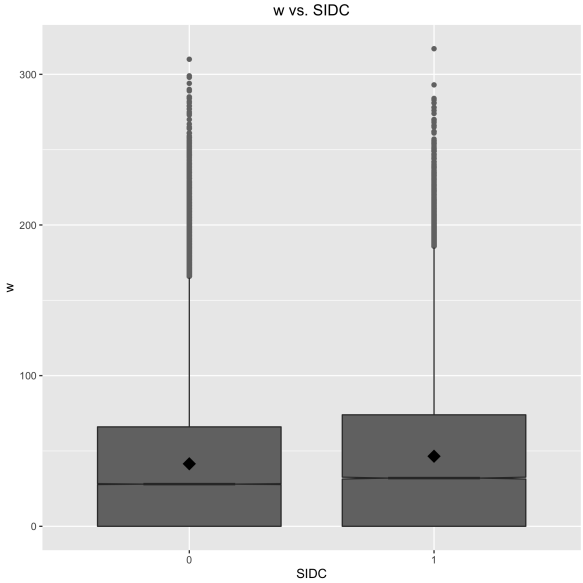

Figure 6: Box plots of raw Wolf number (w) by organization.

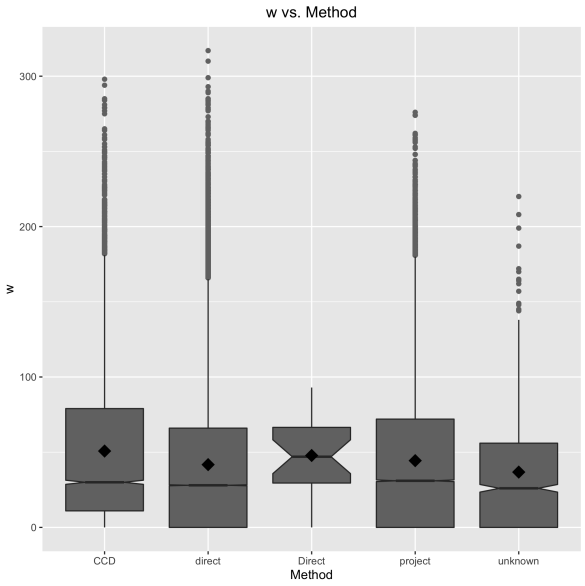

Figure 7: Box plots of raw Wolf number (w) by observer rank.

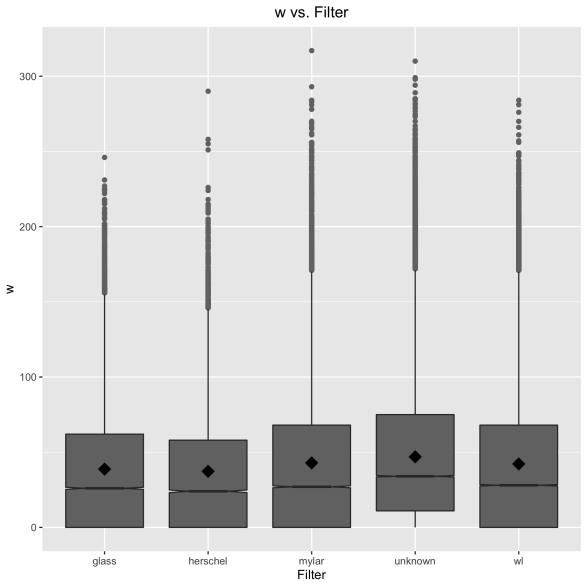

Figure 8: Box plots of raw Wolf number (w) by month and year.

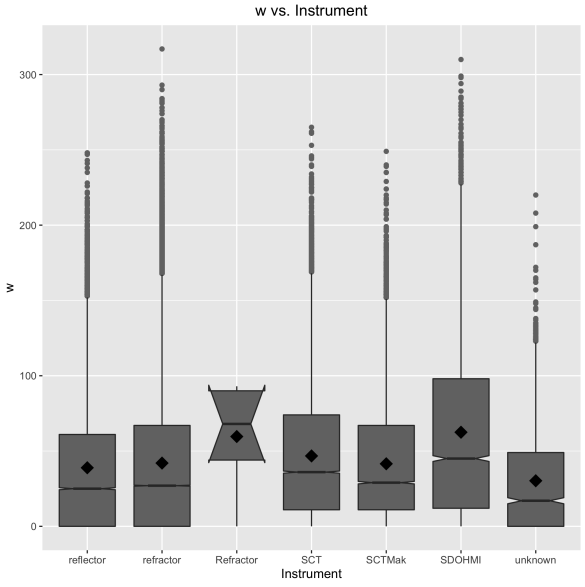

Figure 9: Box plots of raw Wolf number (w) by seeing condition.

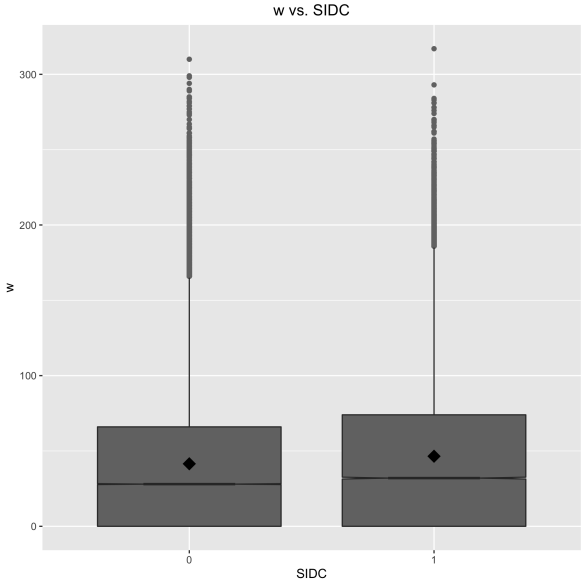

Figure 10: Box plots of raw Wolf number (w) by organization.

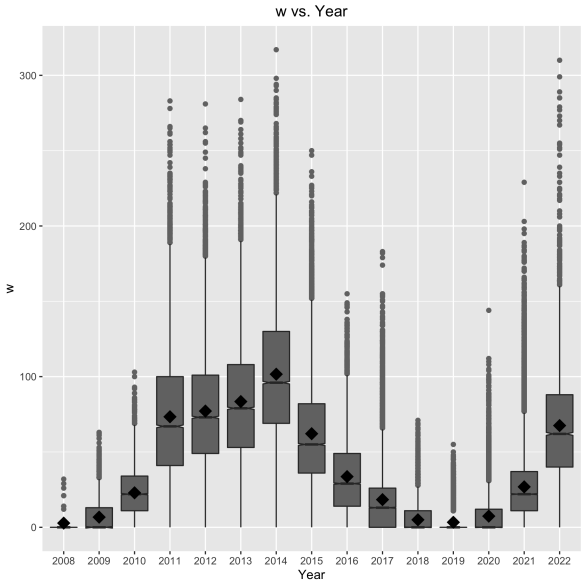

Figure 11: Box plots of raw Wolf number (w) by year.

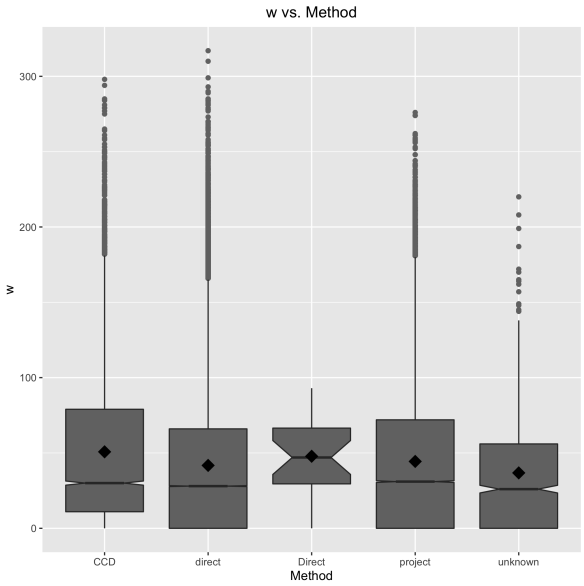

Figure 12: Box plots of raw Wolf number (w) by observing method.