Monthly Report (00)

2022.06 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.

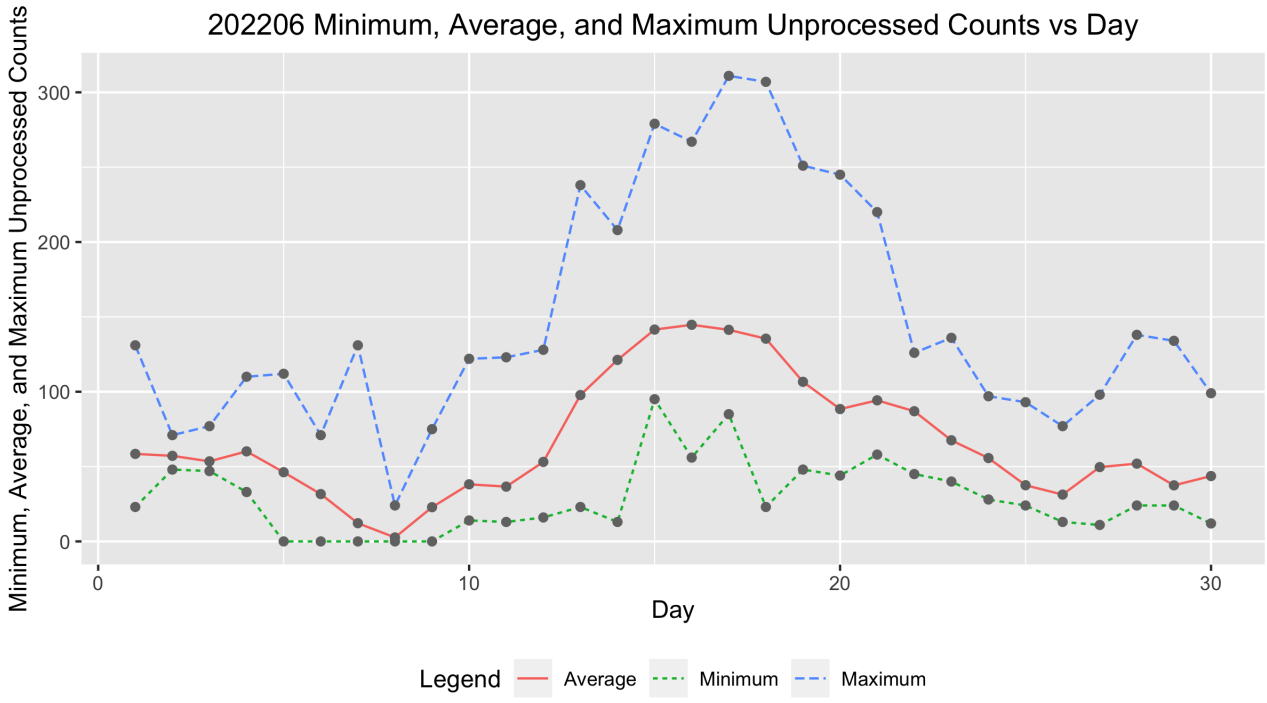

Figure 1: Raw average sunspot count by day of the month.

Table 1: 202206 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	42.0000	23.0000	58.4762	131.0000
2.0000	43.0000	48.0000	57.1628	71.0000
3.0000	47.0000	47.0000	53.4894	77.0000
4.0000	47.0000	33.0000	60.1489	110.0000
5.0000	43.0000	0.0000	46.2326	112.0000
6.0000	40.0000	0.0000	31.6250	71.0000
7.0000	39.0000	0.0000	12.1795	131.0000
8.0000	41.0000	0.0000	2.6341	24.0000
9.0000	50.0000	0.0000	22.8600	75.0000
10.0000	45.0000	14.0000	38.1556	122.0000
11.0000	43.0000	13.0000	36.6047	123.0000
12.0000	45.0000	16.0000	53.1111	128.0000
13.0000	49.0000	23.0000	97.7755	238.0000
14.0000	46.0000	13.0000	121.2609	208.0000
15.0000	48.0000	95.0000	141.5208	279.0000
16.0000	45.0000	56.0000	144.7111	267.0000
17.0000	48.0000	85.0000	141.3542	311.0000
18.0000	43.0000	23.0000	135.4419	307.0000
19.0000	52.0000	48.0000	106.6154	251.0000
20.0000	42.0000	44.0000	88.4286	245.0000
21.0000	40.0000	58.0000	94.2500	220.0000
22.0000	38.0000	45.0000	86.9737	126.0000
23.0000	38.0000	40.0000	67.5526	136.0000
24.0000	38.0000	28.0000	55.6842	97.0000
25.0000	40.0000	24.0000	37.5250	93.0000
26.0000	45.0000	13.0000	31.2889	77.0000
27.0000	47.0000	11.0000	49.6596	98.0000
28.0000	50.0000	24.0000	51.9600	138.0000
29.0000	49.0000	24.0000	37.4490	134.0000
30.0000	47.0000	12.0000	43.6596	99.0000

3 Error Tables

Data are for the month of June 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	2.4202	3.1208	0.5000	1.0000
2009.01	5.2062	4.6619	5.7506	1.3000	1.3000
2009.02	4.6283	4.1308	5.1257	0.7000	1.2000
2009.03	6.1824	5.9518	6.4130	0.3000	0.6000
2009.04	6.9761	6.7380	7.2141	0.4000	1.2000
2009.05	7.1655	6.8937	7.4373	1.6000	2.9000
2009.06	6.4438	6.1272	6.7604	3.2000	6.3000
2009.07	6.1438	5.9034	6.3842	3.6000	5.5000
2009.08	6.6468	6.3985	6.8951	0.0000	0.0000
2009.09	7.3702	7.1191	7.6212	4.5000	7.1000
2009.10	6.8697	6.5180	7.2214	4.5000	7.7000
2009.11	7.1018	6.9078	7.2958	3.3000	6.9000
2009.12	7.0008	6.8025	7.1991	10.4000	16.3000
2010.01	19.7038	17.5386	21.8691	13.3000	19.5000
2010.02	15.8901	13.8085	17.9718	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	17.8928	15.7482	20.0375	15.4000	24.0000
2010.04	19.8870	17.6231	22.1510	7.0000	10.4000
2010.05	23.9309	23.5070	24.3548	8.4000	8.7000
2010.06	20.2022	19.8605	20.5438	11.0000	13.6000
2010.07	21.0949	20.7825	21.4074	15.2000	16.1000
2010.08	22.0365	21.6677	22.4053	18.3000	19.6000
2010.09	25.4015	24.9773	25.8256	22.8000	25.2000
2010.10	23.9923	23.5705	24.4141	21.0000	23.5000
2010.11	25.2750	24.8137	25.7363	20.9000	21.6000
2010.12	24.0045	23.5231	24.4859	13.9000	14.5000
2011.01	70.7295	69.2885	72.1705	17.7000	18.7000
2011.02	62.0167	60.7130	63.3205	29.1000	29.6000
2011.03	67.7023	66.4029	69.0016	48.0000	55.8000
2011.04	76.3298	74.9220	77.7377	47.3000	54.4000
2011.05	78.4465	77.1074	79.7856	37.3000	41.5000
2011.06	66.1689	65.0006	67.3371	35.2000	37.0000
2011.07	68.2683	67.0993	69.4374	41.5000	43.8000
2011.08	72.1213	70.9542	73.2883	42.4000	50.5000
2011.09	81.8961	80.4643	83.3279	73.8000	78.0000
2011.10	77.3815	76.0681	78.6948	78.9000	88.0000
2011.11	81.3521	79.6636	83.0407	84.6000	96.7000
2011.12	75.8329	74.2780	77.3878	65.8000	73.0000
2012.01	76.0051	74.5036	77.5066	55.8000	58.2000
2012.02	65.5159	64.1736	66.8582	29.2000	33.1000
2012.03	72.2439	70.9590	73.5288	53.1000	64.1000
2012.04	80.0242	78.5969	81.4516	51.4000	55.2000
2012.05	83.9805	82.5769	85.3842	61.8000	69.0000
2012.06	70.2013	69.0005	71.4022	59.7000	64.5000
2012.07	72.9454	71.7391	74.1516	64.2000	51.3000
2012.08	74.2272	73.0195	75.4350	57.7000	63.1000
2012.09	84.7743	83.2937	86.2549	57.7000	61.5000
2012.10	80.9158	79.4244	82.4072	48.3000	53.3000
2012.11	85.2309	83.5087	86.9531	56.7000	61.4000
2012.12	79.5420	77.8076	81.2764	37.4000	40.8000
2013.01	84.4358	82.8099	86.0617	63.8000	62.9000
2013.02	72.9062	71.4263	74.3861	37.8000	38.0000
2013.03	77.8812	76.2813	79.4810	50.6000	57.9000
2013.04	87.2911	85.7359	88.8462	70.6000	72.4000
2013.05	89.4851	87.8681	91.1021	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	76.3238	74.9551	77.6924	51.0000	52.5000
2013.07	78.3180	77.0388	79.5972	57.0000	57.0000
2013.08	81.3632	80.0344	82.6919	60.0000	66.0000
2013.09	91.4373	89.7878	93.0869	34.6000	36.9000
2013.10	86.2669	84.6499	87.8839	74.5000	85.6000
2013.11	89.3012	87.2693	91.3331	73.9000	77.6000
2013.12	85.6707	83.8279	87.5134	77.8000	90.3000
2014.01	98.5357	96.4452	100.6261	77.4000	82.0000
2014.02	86.8553	85.1205	88.5902	93.9000	102.8000
2014.03	94.8867	93.1376	96.6359	80.9000	92.2000
2014.04	106.5095	104.6205	108.3984	76.9000	84.7000
2014.05	109.8159	107.9238	111.7081	72.3000	75.2000
2014.06	93.5066	91.9057	95.1075	67.2000	71.0000
2014.07	95.6190	94.0016	97.2363	72.5000	72.5000
2014.08	99.4511	97.8809	101.0212	71.2000	74.7000
2014.09	113.0519	111.0347	115.0691	83.2000	87.6000
2014.10	106.1876	104.2160	108.1593	59.5000	60.6000
2014.11	111.0974	108.7664	113.4284	65.8000	71.1000
2014.12	104.1524	101.7284	106.5764	75.8000	78.0000
2015.01	60.8323	59.6095	62.0551	65.9000	67.0000
2015.02	52.4018	51.2332	53.5705	42.4000	44.8000
2015.03	58.0185	56.9487	59.0883	38.0000	38.4000
2015.04	64.7555	63.5850	65.9260	49.0000	54.4000
2015.05	66.9295	65.8125	68.0466	56.3000	58.8000
2015.06	56.8125	55.7900	57.8350	50.2000	68.3000
2015.07	57.5637	56.5868	58.5406	47.9000	65.8000
2015.08	61.0399	60.0186	62.0611	39.5000	57.2000
2015.09	68.5970	67.3517	69.8423	49.2000	72.1000
2015.10	64.8667	63.6136	66.1197	39.3000	48.3000
2015.11	68.5022	67.0057	69.9988	39.6000	55.9000
2015.12	64.4960	63.0609	65.9311	36.4000	44.8000
2016.01	33.3044	32.6087	34.0000	33.7000	43.3000
2016.02	28.7471	28.1464	29.3479	38.3000	46.8000
2016.03	31.3362	30.7090	31.9634	30.5000	38.9000
2016.04	34.8457	34.1799	35.5115	26.6000	30.9000
2016.05	36.1450	35.4842	36.8058	33.7000	48.4000
2016.06	30.3612	29.8427	30.8796	13.1000	19.5000
2016.07	31.3476	30.8446	31.8506	21.2000	27.5000
2016.08	32.8754	32.2977	33.4532	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	37.8210	37.1305	38.5116	27.7000	37.1000
2016.10	35.4364	34.7537	36.1191	22.7000	31.7000
2016.11	37.0087	36.2342	37.7832	14.0000	22.2000
2016.12	35.2902	34.5311	36.0492	11.1000	20.0000
2017.01	17.9942	17.6138	18.3746	18.4000	26.2000
2017.02	15.5989	15.2550	15.9427	14.4000	20.6000
2017.03	17.1430	16.8154	17.4705	11.3000	15.5000
2017.04	19.2424	18.9024	19.5825	21.6000	33.2000
2017.05	19.6737	19.3332	20.0143	12.5000	18.1000
2017.06	16.5025	16.2267	16.7782	15.5000	19.3000
2017.07	17.1145	16.8397	17.3894	11.5000	16.3000
2017.08	17.9014	17.5879	18.2149	22.8000	35.7000
2017.09	20.9269	20.4884	21.3654	34.6000	42.9000
2017.10	19.0930	18.6994	19.4866	10.5000	11.0000
2017.11	19.8042	19.3833	20.2252	4.2000	5.6000
2017.12	18.7818	18.4940	19.0696	4.0000	4.6000
2018.01	5.0385	4.9306	5.1464	3.1000	6.3000
2018.02	4.3230	4.2177	4.4282	6.8000	11.8000
2018.03	4.6715	4.5765	4.7664	1.1000	1.2000
2018.04	5.1871	5.0828	5.2913	4.7000	7.5000
2018.05	5.3817	5.2807	5.4828	8.4000	14.0000
2018.06	4.5313	4.4512	4.6114	10.2000	13.6000
2018.07	4.7014	4.6478	4.7549	0.5000	1.7000
2018.08	4.8640	4.7803	4.9476	5.9000	9.5000
2018.09	5.4808	5.3777	5.5840	1.6000	2.9000
2018.10	5.2680	5.1638	5.3721	2.5000	5.6000
2018.11	5.4814	5.3663	5.5966	3.1000	4.2000
2018.12	5.3038	5.1997	5.4080	1.6000	2.3000
2019.01	3.3197	3.2559	3.3834	5.4000	2.3000
2019.02	2.9127	2.8552	2.9701	0.1000	1.2000
2019.03	3.1097	3.0564	3.1630	6.1000	12.1000
2019.04	3.4914	3.4254	3.5574	6.2000	9.3000
2019.05	3.5101	3.4487	3.5714	7.0000	11.9000
2019.06	2.9679	2.9177	3.0181	0.7000	1.5000
2019.07	3.0766	3.0307	3.1226	0.4000	2.2000
2019.08	3.2331	3.1849	3.2814	0.3000	0.8000
2019.09	3.7226	3.6640	3.7813	0.5000	1.0000
2019.10	3.4709	3.4113	3.5306	0.2000	0.5000
2019.11	3.6892	3.6179	3.7606	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	3.4744	3.4055	3.5432	0.8000	1.0000
2020.01	7.3504	7.2054	7.4954	4.0000	5.3000
2020.02	6.3743	6.2454	6.5032	0.1000	0.0000
2020.03	6.8727	6.7432	7.0022	1.2000	1.5000
2020.04	7.7562	7.6277	7.8848	3.0000	5.1000
2020.05	7.8721	7.7480	7.9963	0.1000	0.4000
2020.06	6.6940	6.5909	6.7971	3.9000	6.4000
2020.07	6.8405	6.7397	6.9413	4.2000	7.7000
2020.08	7.0769	6.9782	7.1756	5.3000	7.8000
2020.09	8.1250	7.9943	8.2556	0.4000	0.9000
2020.10	7.7611	7.6328	7.8895	9.9000	13.6000
2020.11	8.1873	8.0554	8.3192	21.2000	33.1000
2020.12	7.7348	7.5963	7.8732	15.4000	19.8000
2021.01	25.6740	25.2166	26.1314	7.0000	15.8000
2021.02	22.6269	22.2220	23.0319	5.8000	10.7000
2021.03	24.5832	24.1915	24.9750	11.0000	17.2000
2021.04	27.7111	27.2818	28.1403	18.5000	28.8000
2021.05	28.4480	28.0421	28.8539	15.9000	22.9000
2021.06	24.1368	23.7850	24.4886	19.9000	24.1000
2021.07	24.6160	24.2343	24.9978	23.8000	35.6000
2021.08	26.2718	25.8632	26.6804	15.7000	19.5000
2021.09	29.9013	29.4270	30.3756	39.1000	52.5000
2021.10	28.7979	28.3172	29.2786	27.1000	37.0000
2021.11	30.3117	29.8258	30.7976	27.2000	35.1000
2021.12	29.4225	28.8995	29.9455	50.6000	69.0000
2022.01	68.1437	67.0157	69.2717	43.9000	62.0000
2022.02	59.9029	58.8758	60.9299	48.8000	60.5000
2022.03	65.6531	64.5408	66.7653	58.4000	80.6000
2022.04	71.7410	70.6653	72.8166	59.1000	83.9000
2022.05	75.7703	74.5895	76.9512	72.5000	0.4000
2022.06	62.6072	61.6462	63.5681	58.9000	0.4000

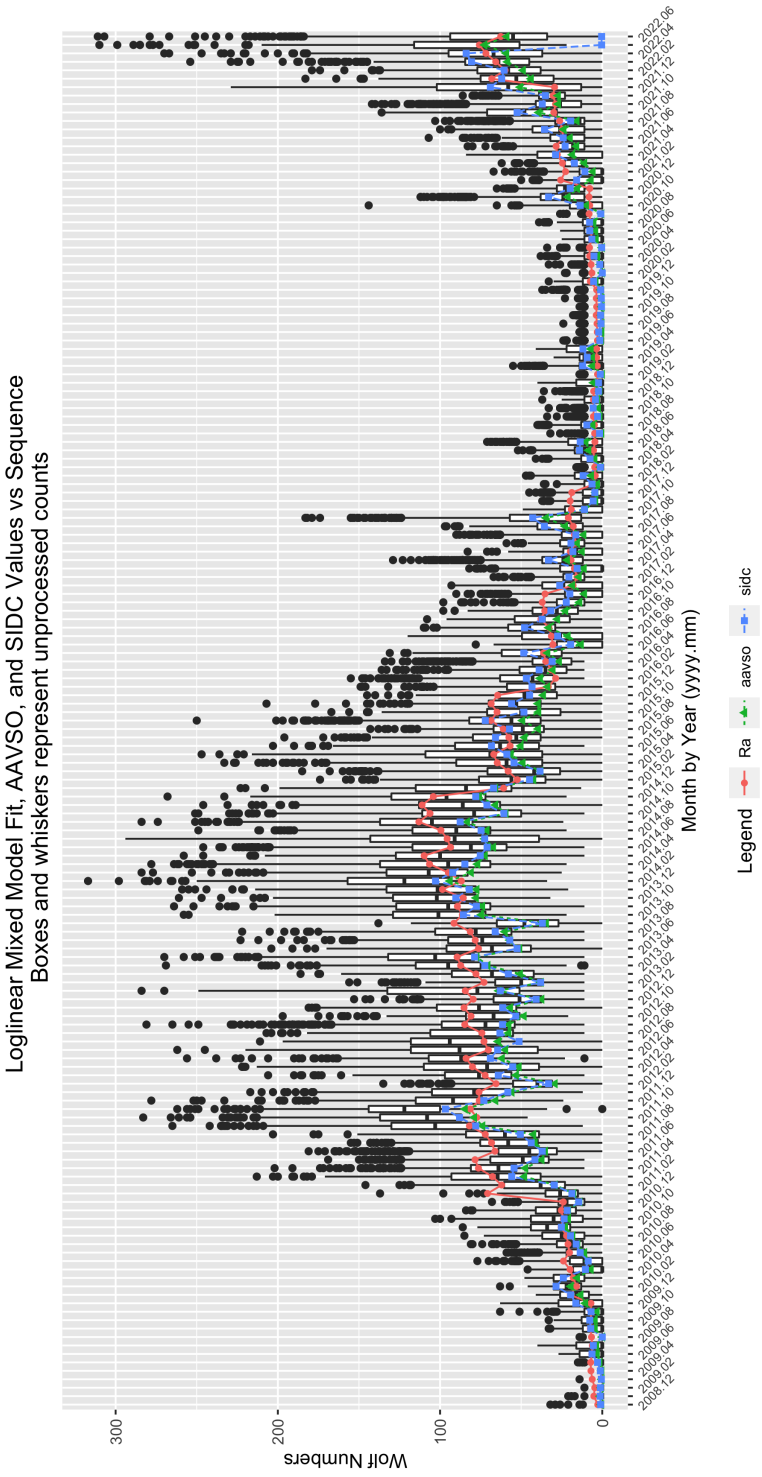

Figure 2: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202206 Parameter Estimates

	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	1.2678	0.3163	4.0081	0.0001
seeF	-0.2258	0.0055	-40.7827	0.0000
seeG	-0.1214	0.0048	-25.1030	0.0000
seeM	-0.1940	0.0244	-7.9389	0.0000
seeP	-0.3251	0.0079	-40.9803	0.0000
sidc1	0.0452	0.0157	2.8729	0.0041
year2009	0.7174	0.3177	2.2581	0.0239
year2010	1.9537	0.3155	6.1923	0.0000
year2011	3.0915	0.3154	9.8017	0.0000
year2012	3.1313	0.3154	9.9281	0.0000
year2013	3.2273	0.3154	10.2328	0.0000
year2014	3.4254	0.3154	10.8608	0.0000
year2015	2.9408	0.3154	9.3239	0.0000
year2016	2.3245	0.3154	7.3691	0.0000
year2017	1.7130	0.3155	5.4299	0.0000
year2018	0.4321	0.3158	1.3683	0.1712
year2019	0.0100	0.3160	0.0317	0.9747
year2020	0.8155	0.3156	2.5837	0.0098
year2021	2.0933	0.3155	6.6358	0.0000
year2022	3.0095	0.3155	9.5395	0.0000
mon2	-0.1378	0.0086	-16.0124	0.0000
mon3	-0.0562	0.0080	-6.9794	0.0000
mon4	0.0478	0.0077	6.1695	0.0000
mon5	0.0723	0.0076	9.5240	0.0000
mon6	-0.0988	0.0079	-12.4859	0.0000
mon7	-0.0754	0.0080	-9.3784	0.0000
mon8	-0.0280	0.0079	-3.5450	0.0004
mon9	0.1091	0.0079	13.8535	0.0000
mon10	0.0537	0.0081	6.6386	0.0000
mon11	0.1125	0.0084	13.4580	0.0000
mon12	0.0614	0.0084	7.2948	0.0000

Table 4: 202206 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:157094	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 : 6.528	Mean :15.72		Mean :0.2472
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: 202206 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:157094	Length:157094
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 8.00	Median : 29.00	Mode :character	Mode :character
Mean : 2.723	Mean : 15.72	Mean : 42.94		
3rd Qu.: 4.000	3rd Qu.: 23.00	3rd Qu.: 68.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202206 Summary of Sunspot Numbers

inst	filter	unit
Length:157094	Length:157094	Length:157094
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202206 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 : 91.94	Mean : 35.74	Mean : 889.4	Mean : 180.8
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

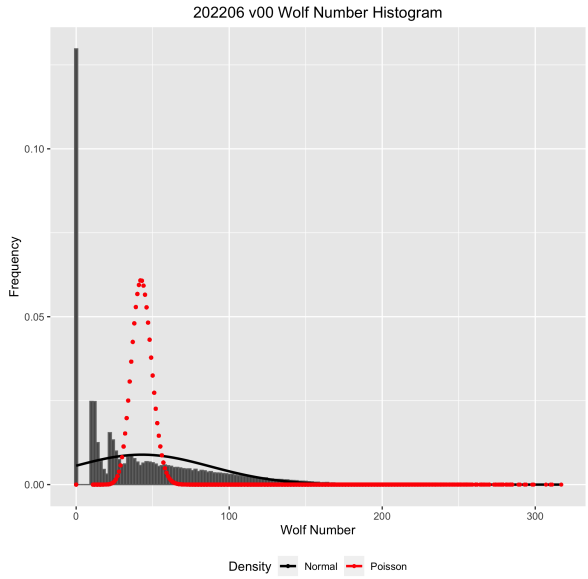

Figure 3: Box plots of raw Wolf number (w) by observer rank.

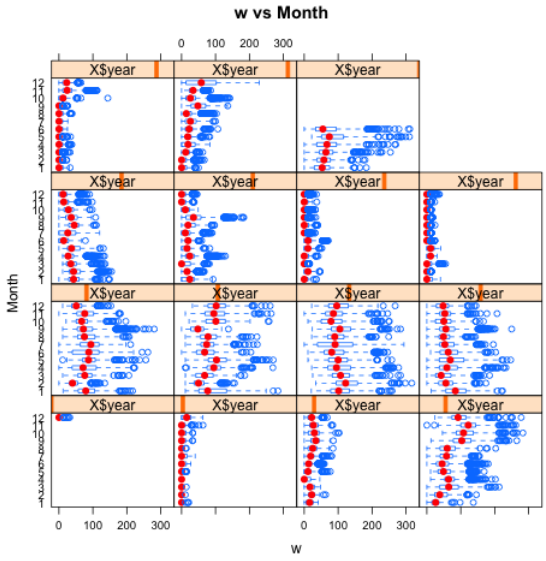

Figure 4: Box plots of raw Wolf number (w) by month and year.

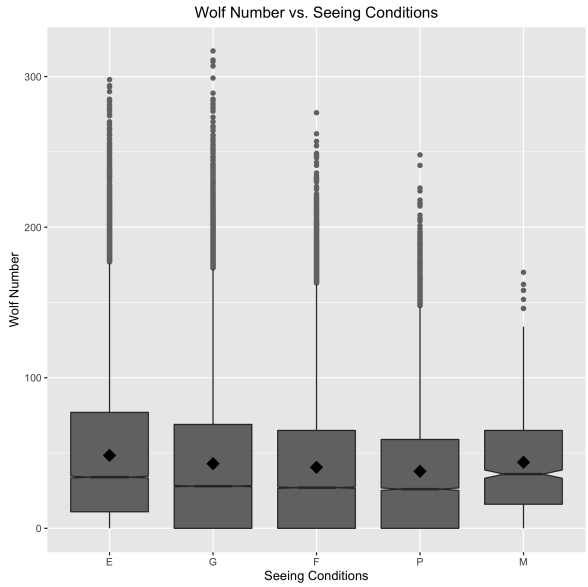

Figure 5: Box plots of raw Wolf number (w) by seeing condition.

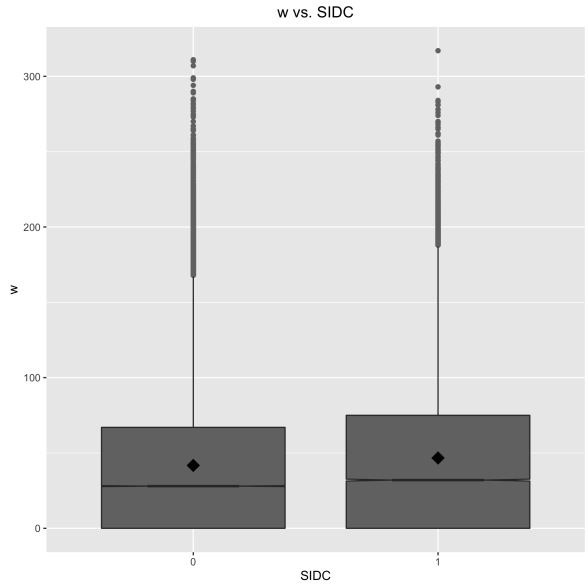

Figure 6: Box plots of raw Wolf number (w) by organization.

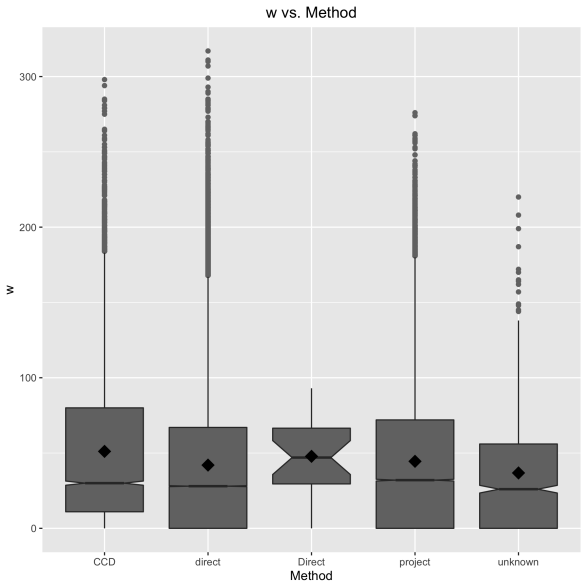

Figure 7: Box plots of raw Wolf number (w) by observer rank.

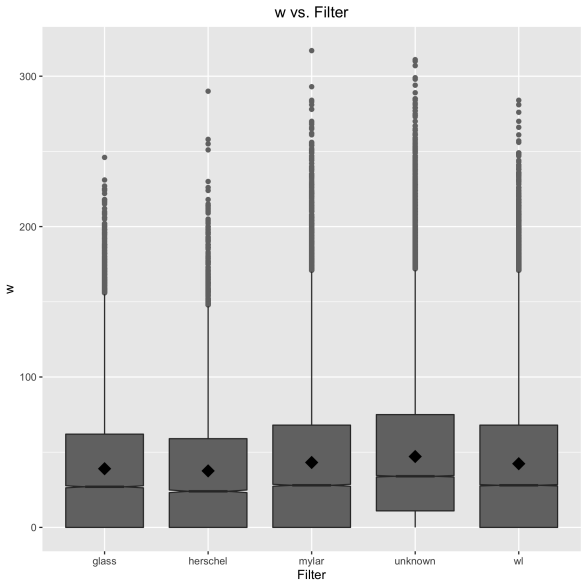

Figure 8: Box plots of raw Wolf number (w) by month and year.

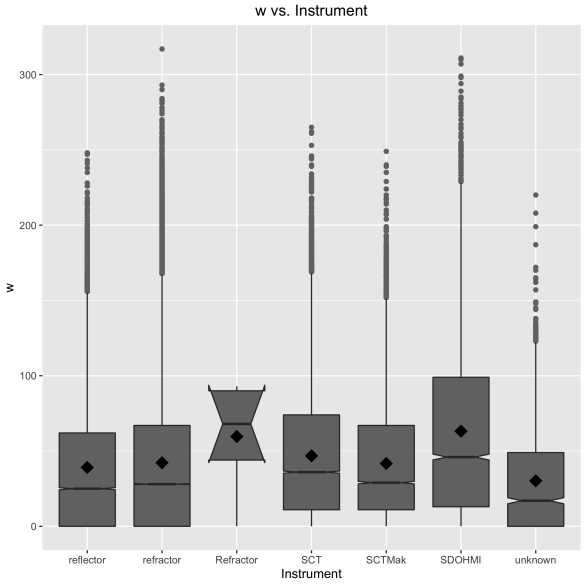

Figure 9: Box plots of raw Wolf number (w) by seeing condition.

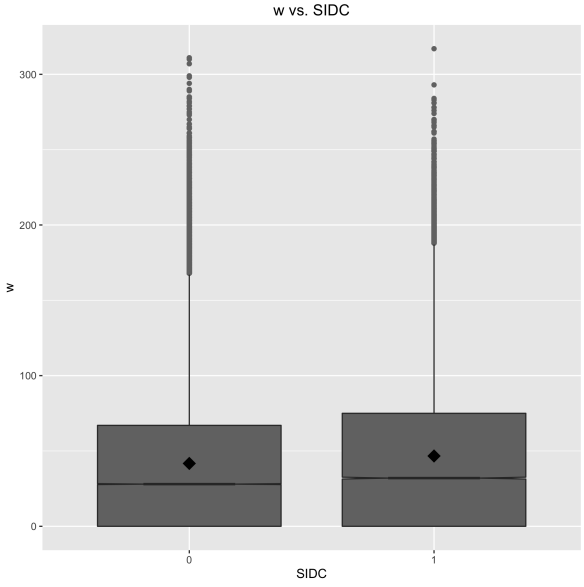

Figure 10: Box plots of raw Wolf number (w) by organization.

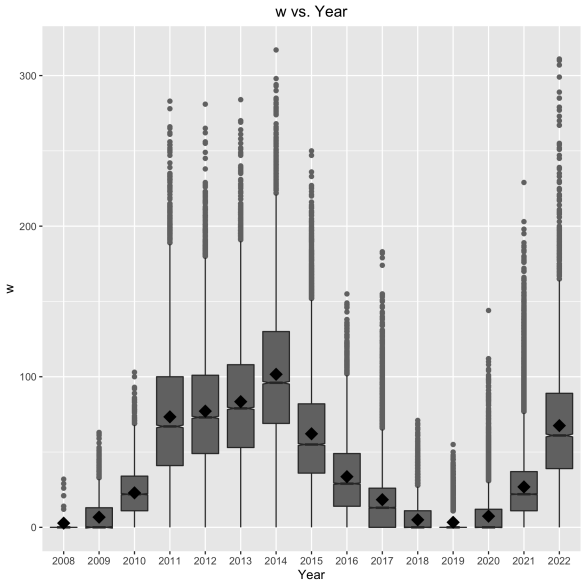

Figure 11: Box plots of raw Wolf number (w) by year.

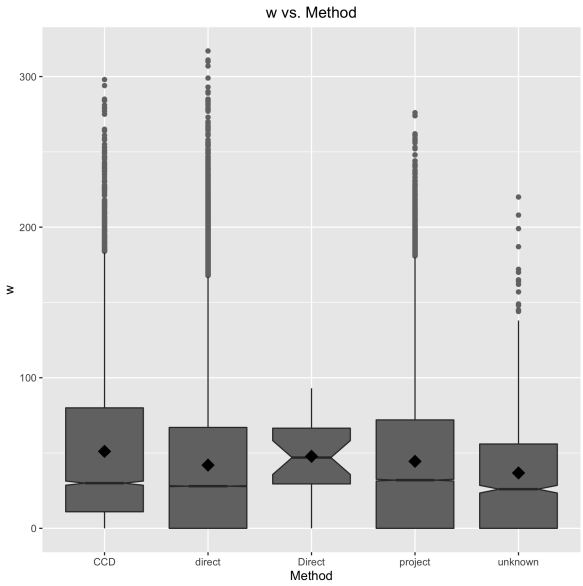

Figure 12: Box plots of raw Wolf number (w) by observing method.