Monthly Report (00)

2022.02 Data Set

Monday 14th March, 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.

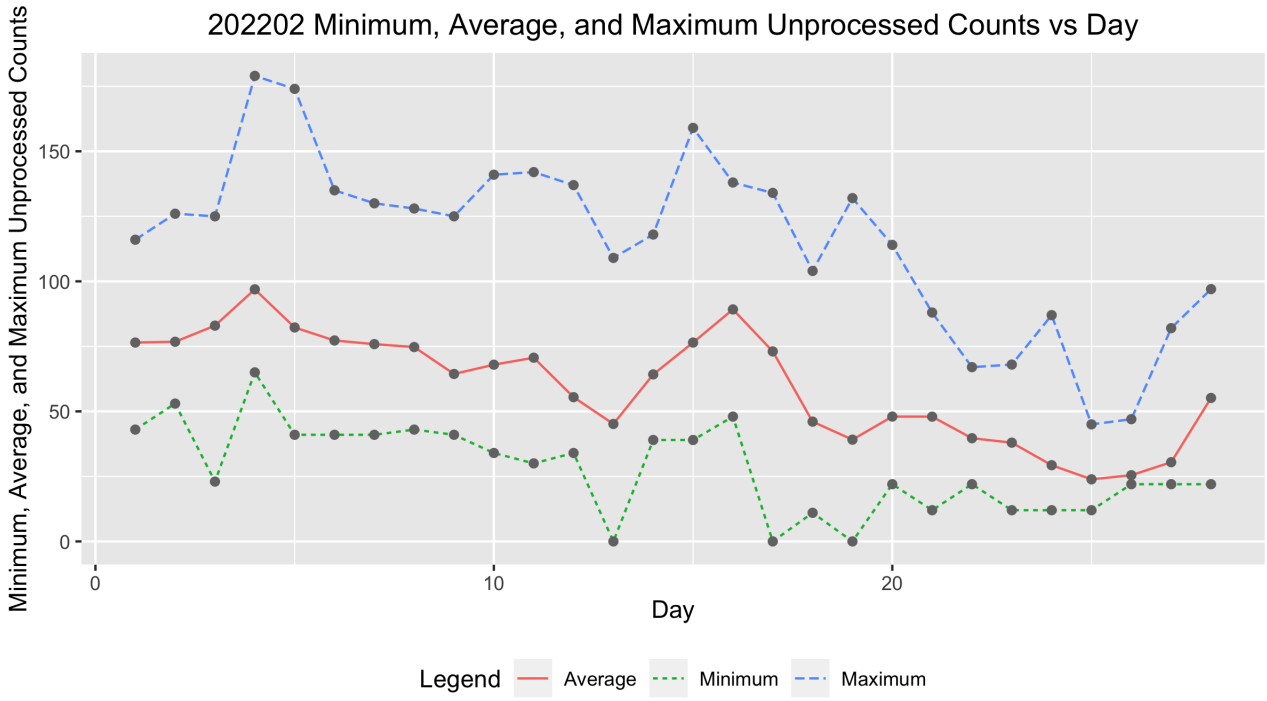

Figure 1: Raw average sunspot count by day of the month.

Table 1: 202202 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	35.0000	43.0000	76.4571	116.0000
2.0000	30.0000	53.0000	76.7667	126.0000
3.0000	29.0000	23.0000	82.9655	125.0000
4.0000	25.0000	65.0000	96.9200	179.0000
5.0000	50.0000	41.0000	82.2600	174.0000
6.0000	43.0000	41.0000	77.2558	135.0000
7.0000	35.0000	41.0000	75.8571	130.0000
8.0000	41.0000	43.0000	74.7317	128.0000
9.0000	49.0000	41.0000	64.3878	125.0000
10.0000	39.0000	34.0000	67.9487	141.0000
11.0000	44.0000	30.0000	70.6364	142.0000
12.0000	39.0000	34.0000	55.4615	137.0000
13.0000	38.0000	0.0000	45.1579	109.0000
14.0000	37.0000	39.0000	64.2162	118.0000
15.0000	45.0000	39.0000	76.4667	159.0000
16.0000	29.0000	48.0000	89.2069	138.0000
17.0000	36.0000	0.0000	73.0556	134.0000
18.0000	35.0000	11.0000	46.0571	104.0000
19.0000	40.0000	0.0000	39.1250	132.0000
20.0000	42.0000	22.0000	48.0000	114.0000
21.0000	31.0000	12.0000	47.9677	88.0000
22.0000	31.0000	22.0000	39.6774	67.0000
23.0000	33.0000	12.0000	37.9697	68.0000
24.0000	33.0000	12.0000	29.3030	87.0000
25.0000	33.0000	12.0000	23.8788	45.0000
26.0000	41.0000	22.0000	25.4634	47.0000
27.0000	44.0000	22.0000	30.4545	82.0000
28.0000	42.0000	22.0000	55.1667	97.0000

3 Error Tables

Data are for the month of February 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	2.4167	3.1243	0.5000	1.0000
2009.01	5.3120	4.7510	5.8729	1.3000	1.3000
2009.02	4.7161	4.2043	5.2279	0.7000	1.2000
2009.03	6.1533	5.9220	6.3847	0.3000	0.6000
2009.04	7.0419	6.7983	7.2855	0.4000	1.2000
2009.05	7.0351	6.7655	7.3047	1.6000	2.9000
2009.06	6.3649	6.0490	6.6808	3.2000	6.3000
2009.07	6.1449	5.9032	6.3865	3.6000	5.5000
2009.08	6.6416	6.3891	6.8942	0.0000	0.0000
2009.09	7.3742	7.1201	7.6283	4.5000	7.1000
2009.10	6.8724	6.5185	7.2263	4.5000	7.7000
2009.11	7.0981	6.9039	7.2922	3.3000	6.9000
2009.12	6.9943	6.7964	7.1922	10.4000	16.3000
2010.01	20.1430	17.9058	22.3803	13.3000	19.5000
2010.02	16.2310	14.0808	18.3813	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	17.7722	15.6203	19.9240	15.4000	24.0000
2010.04	20.0536	17.7472	22.3601	7.0000	10.4000
2010.05	23.6060	23.1901	24.0220	8.4000	8.7000
2010.06	20.0282	19.6929	20.3634	11.0000	13.6000
2010.07	21.1770	20.8672	21.4868	15.2000	16.1000
2010.08	22.1222	21.7570	22.4874	18.3000	19.6000
2010.09	25.5010	25.0804	25.9216	22.8000	25.2000
2010.10	24.0690	23.6518	24.4861	21.0000	23.5000
2010.11	25.3653	24.9060	25.8246	20.9000	21.6000
2010.12	24.0392	23.5585	24.5199	13.9000	14.5000
2011.01	72.2741	70.8054	73.7429	17.7000	18.7000
2011.02	63.3463	62.0217	64.6709	29.1000	29.6000
2011.03	67.3362	66.0522	68.6203	48.0000	55.8000
2011.04	76.9485	75.5533	78.3437	47.3000	54.4000
2011.05	77.0470	75.7482	78.3457	37.3000	41.5000
2011.06	65.3449	64.2008	66.4891	35.2000	37.0000
2011.07	68.3385	67.1725	69.5044	41.5000	43.8000
2011.08	72.2206	71.0591	73.3821	42.4000	50.5000
2011.09	81.9080	80.4873	83.3288	73.8000	78.0000
2011.10	77.3810	76.0773	78.6848	78.9000	88.0000
2011.11	81.2914	79.6044	82.9784	84.6000	96.7000
2011.12	75.7228	74.1728	77.2728	65.8000	73.0000
2012.01	77.6876	76.1586	79.2167	55.8000	58.2000
2012.02	66.9062	65.5425	68.2698	29.2000	33.1000
2012.03	71.8405	70.5664	73.1146	53.1000	64.1000
2012.04	80.7522	79.3248	82.1796	51.4000	55.2000
2012.05	82.4494	81.0818	83.8170	61.8000	69.0000
2012.06	69.2972	68.1165	70.4780	59.7000	64.5000
2012.07	72.9491	71.7491	74.1491	64.2000	51.3000
2012.08	74.2682	73.0683	75.4682	57.7000	63.1000
2012.09	84.7717	83.2964	86.2471	57.7000	61.5000
2012.10	80.8809	79.3965	82.3652	48.3000	53.3000
2012.11	85.0565	83.3407	86.7723	56.7000	61.4000
2012.12	79.4011	77.6725	81.1296	37.4000	40.8000
2013.01	86.3152	84.6571	87.9732	63.8000	62.9000
2013.02	74.4568	72.9514	75.9622	37.8000	38.0000
2013.03	77.4354	75.8495	79.0212	50.6000	57.9000
2013.04	88.0730	86.5123	89.6336	70.6000	72.4000
2013.05	87.8570	86.2781	89.4359	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	75.3414	73.9992	76.6837	51.0000	52.5000
2013.07	78.2872	77.0186	79.5559	57.0000	57.0000
2013.08	81.3475	80.0281	82.6668	60.0000	66.0000
2013.09	91.4185	89.7766	93.0603	34.6000	36.9000
2013.10	86.2408	84.6308	87.8508	74.5000	85.6000
2013.11	89.0712	87.0554	91.0871	73.9000	77.6000
2013.12	85.4864	83.6497	87.3231	77.8000	90.3000
2014.01	100.7096	98.5782	102.8409	77.4000	82.0000
2014.02	88.6737	86.9129	90.4345	93.9000	102.8000
2014.03	94.3445	92.6128	96.0761	80.9000	92.2000
2014.04	107.4613	105.5675	109.3550	76.9000	84.7000
2014.05	107.8115	105.9630	109.6600	72.3000	75.2000
2014.06	92.2583	90.6901	93.8264	67.2000	71.0000
2014.07	95.5832	93.9784	97.1881	72.5000	72.5000
2014.08	99.4386	97.8770	101.0002	71.2000	74.7000
2014.09	113.0094	111.0042	115.0145	83.2000	87.6000
2014.10	106.1627	104.1979	108.1276	59.5000	60.6000
2014.11	110.8679	108.5525	113.1832	65.8000	71.1000
2014.12	104.0204	101.6023	106.4385	75.8000	78.0000
2015.01	62.1631	60.9161	63.4101	65.9000	67.0000
2015.02	53.4764	52.2929	54.6600	42.4000	44.8000
2015.03	57.6593	56.6019	58.7166	38.0000	38.4000
2015.04	65.2571	64.0871	66.4272	49.0000	54.4000
2015.05	65.6906	64.6016	66.7795	56.3000	58.8000
2015.06	56.0805	55.0734	57.0875	50.2000	68.3000
2015.07	57.5897	56.6126	58.5668	47.9000	65.8000
2015.08	61.0673	60.0460	62.0886	39.5000	57.2000
2015.09	68.6067	67.3623	69.8510	49.2000	72.1000
2015.10	64.8967	63.6446	66.1488	39.3000	48.3000
2015.11	68.4184	66.9264	69.9103	39.6000	55.9000
2015.12	64.3709	62.9396	65.8022	36.4000	44.8000
2016.01	34.0273	33.3178	34.7368	33.7000	43.3000
2016.02	29.3495	28.7373	29.9618	38.3000	46.8000
2016.03	31.1426	30.5205	31.7646	30.5000	38.9000
2016.04	35.1642	34.4939	35.8345	26.6000	30.9000
2016.05	35.5027	34.8547	36.1506	33.7000	48.4000
2016.06	29.9686	29.4575	30.4797	13.1000	19.5000
2016.07	31.3309	30.8285	31.8332	21.2000	27.5000
2016.08	32.8850	32.3073	33.4626	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	37.8248	37.1347	38.5149	27.7000	37.1000
2016.10	35.4287	34.7464	36.1109	22.7000	31.7000
2016.11	36.9390	36.1670	37.7110	14.0000	22.2000
2016.12	35.2022	34.4464	35.9580	11.1000	20.0000
2017.01	18.3887	18.0007	18.7767	18.4000	26.2000
2017.02	15.9229	15.5727	16.2731	14.4000	20.6000
2017.03	17.0389	16.7140	17.3639	11.3000	15.5000
2017.04	19.4184	19.0758	19.7610	21.6000	33.2000
2017.05	19.3108	18.9771	19.6445	12.5000	18.1000
2017.06	16.2954	16.0222	16.5687	15.5000	19.3000
2017.07	17.1205	16.8452	17.3958	11.5000	16.3000
2017.08	17.9213	17.6068	18.2359	22.8000	35.7000
2017.09	20.9381	20.4968	21.3794	34.6000	42.9000
2017.10	19.1068	18.7125	19.5011	10.5000	11.0000
2017.11	19.7751	19.3551	20.1951	4.2000	5.6000
2017.12	18.7396	18.4526	19.0267	4.0000	4.6000
2018.01	5.1461	5.0357	5.2565	3.1000	6.3000
2018.02	4.4143	4.3062	4.5224	6.8000	11.8000
2018.03	4.6413	4.5471	4.7355	1.1000	1.2000
2018.04	5.2360	5.1301	5.3419	4.7000	7.5000
2018.05	5.2873	5.1874	5.3872	8.4000	14.0000
2018.06	4.4755	4.3963	4.5547	10.2000	13.6000
2018.07	4.7009	4.6473	4.7545	0.5000	1.7000
2018.08	4.8670	4.7832	4.9507	5.9000	9.5000
2018.09	5.4836	5.3803	5.5870	1.6000	2.9000
2018.10	5.2685	5.1644	5.3726	2.5000	5.6000
2018.11	5.4730	5.3583	5.5877	3.1000	4.2000
2018.12	5.2945	5.1905	5.3986	1.6000	2.3000
2019.01	3.3925	3.3273	3.4577	5.4000	2.3000
2019.02	2.9766	2.9179	3.0354	0.1000	1.2000
2019.03	3.0917	3.0386	3.1448	6.1000	12.1000
2019.04	3.5215	3.4547	3.5883	6.2000	9.3000
2019.05	3.4456	3.3852	3.5059	7.0000	11.9000
2019.06	2.9267	2.8771	2.9762	0.7000	1.5000
2019.07	3.0759	3.0298	3.1220	0.4000	2.2000
2019.08	3.2343	3.1860	3.2827	0.3000	0.8000
2019.09	3.7223	3.6634	3.7811	0.5000	1.0000
2019.10	3.4705	3.4107	3.5303	0.2000	0.5000
2019.11	3.6801	3.6089	3.7512	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	3.4651	3.3963	3.5339	0.8000	1.0000
2020.01	7.5112	7.3625	7.6600	4.0000	5.3000
2020.02	6.5037	6.3720	6.6354	0.1000	0.0000
2020.03	6.8254	6.6965	6.9544	1.2000	1.5000
2020.04	7.8171	7.6870	7.9471	3.0000	5.1000
2020.05	7.7226	7.6002	7.8450	0.1000	0.4000
2020.06	6.6027	6.5006	6.7048	3.9000	6.4000
2020.07	6.8385	6.7379	6.9392	4.2000	7.7000
2020.08	7.0745	6.9760	7.1731	5.3000	7.8000
2020.09	8.1234	7.9930	8.2538	0.4000	0.9000
2020.10	7.7635	7.6355	7.8915	9.9000	13.6000
2020.11	8.1885	8.0570	8.3199	21.2000	33.1000
2020.12	7.7506	7.6141	7.8871	15.4000	19.8000
2021.01	26.1206	25.6595	26.5817	7.0000	15.8000
2021.02	22.9927	22.5833	23.4022	5.8000	10.7000
2021.03	24.3263	23.9406	24.7120	11.0000	17.2000
2021.04	27.7558	27.3380	28.1736	18.5000	28.8000
2021.05	27.7205	27.3343	28.1066	15.9000	22.9000
2021.06	23.7406	23.3947	24.0866	19.9000	24.1000
2021.07	24.5429	24.1668	24.9189	23.8000	35.6000
2021.08	26.0659	25.6728	26.4589	15.7000	19.5000
2021.09	29.8570	29.3919	30.3221	39.1000	52.5000
2021.10	28.7927	28.3129	29.2724	27.1000	37.0000
2021.11	30.9321	30.4147	31.4496	27.2000	35.1000
2021.12	30.1484	29.5980	30.6987	50.6000	69.0000
2022.01	60.2634	59.2407	61.2860	43.9000	62.0000
2022.02	52.9585	52.0304	53.8866	48.8000	60.5000

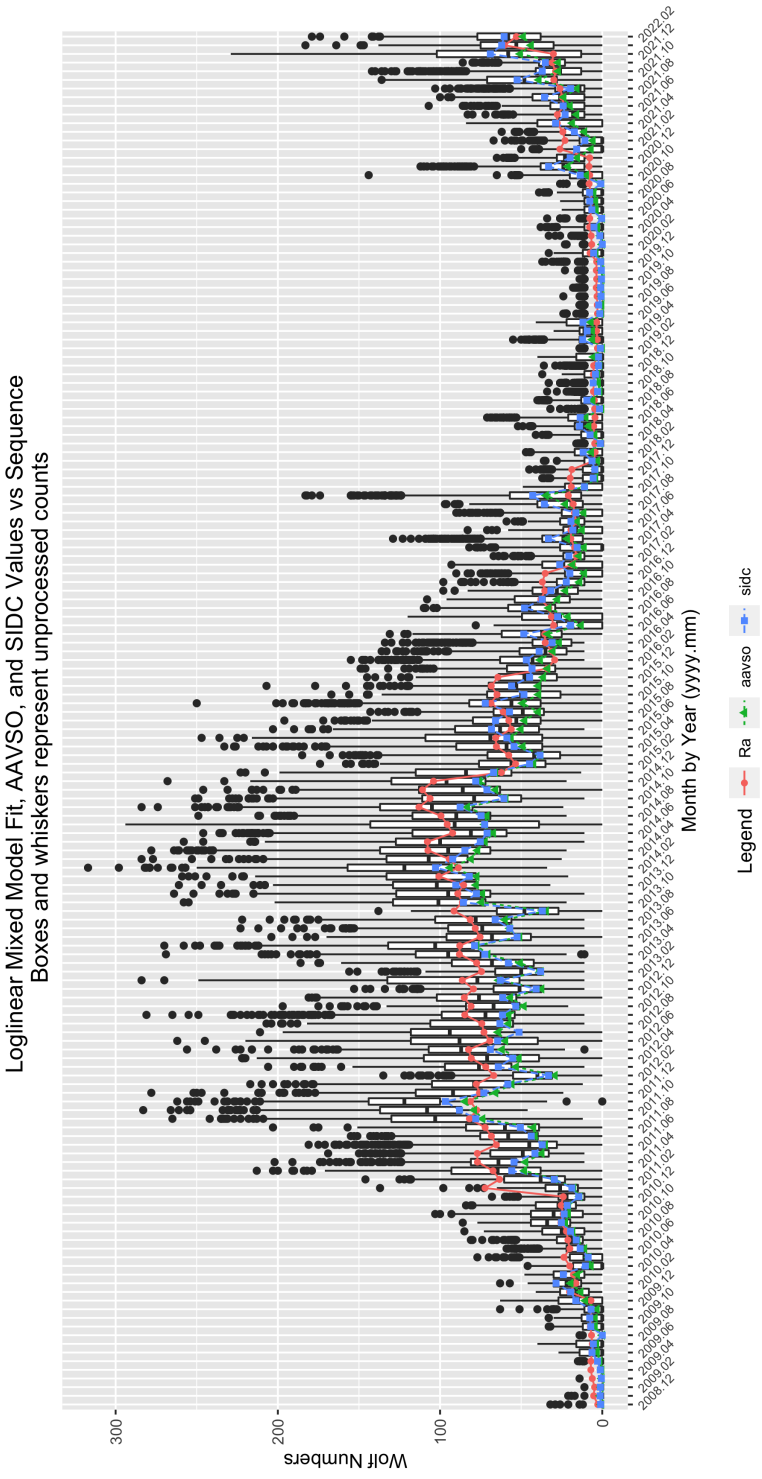

Figure 2: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202202 Parameter Estimates

	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	1.3170	0.3150	4.1813	0.0000
seeF	-0.2254	0.0057	-39.7956	0.0000
seeG	-0.1226	0.0050	-24.7689	0.0000
seeM	-0.1954	0.0244	-8.0236	0.0000
seeP	-0.3261	0.0081	-40.3748	0.0000
sidc1	0.0665	0.0190	3.5077	0.0005
year2009	0.7140	0.3163	2.2575	0.0240
year2010	1.9522	0.3141	6.2156	0.0000
year2011	3.0855	0.3140	9.8272	0.0000
year2012	3.1247	0.3140	9.9521	0.0000
year2013	3.2208	0.3140	10.2582	0.0000
year2014	3.4189	0.3140	10.8893	0.0000
year2015	2.9335	0.3140	9.3430	0.0000
year2016	2.3168	0.3140	7.3779	0.0000
year2017	1.7051	0.3141	5.4294	0.0000
year2018	0.4226	0.3143	1.3444	0.1788
year2019	-0.0007	0.3146	-0.0023	0.9981
year2020	0.8041	0.3142	2.5590	0.0105
year2021	2.0727	0.3140	6.6001	0.0000
year2022	2.8204	0.3143	8.9742	0.0000
mon2	-0.1386	0.0086	-16.1824	0.0000
mon3	-0.0840	0.0085	-9.8972	0.0000
mon4	0.0349	0.0082	4.2761	0.0000
mon5	0.0321	0.0080	4.0016	0.0001
mon6	-0.1340	0.0084	-16.0032	0.0000
mon7	-0.0973	0.0081	-11.9718	0.0000
mon8	-0.0496	0.0080	-6.2020	0.0000
mon9	0.0871	0.0080	10.9304	0.0000
mon10	0.0315	0.0082	3.8542	0.0001
mon11	0.0886	0.0084	10.4960	0.0000
mon12	0.0372	0.0085	4.3800	0.0000

Table 4: 202202 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:152135	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 : 6.592	Mean :15.71		Mean :0.2486
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: 202202 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:152135	Length:152135
1st Qu.: 0.000	1st Qu.: 0.0	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 7.0	Median : 27.00	Mode :character	Mode :character
Mean : 2.659	Mean : 15.4	Mean : 41.99		
3rd Qu.: 4.000	3rd Qu.: 23.0	3rd Qu.: 67.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 202202 Summary of Sunspot Numbers

inst	filter	unit
Length:152135	Length:152135	Length:152135
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202202 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.: 35.0	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 900.0	Median : 57.5
Mean : 91.61	Mean : 34.89	Mean : 889.1	Mean : 181.4
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

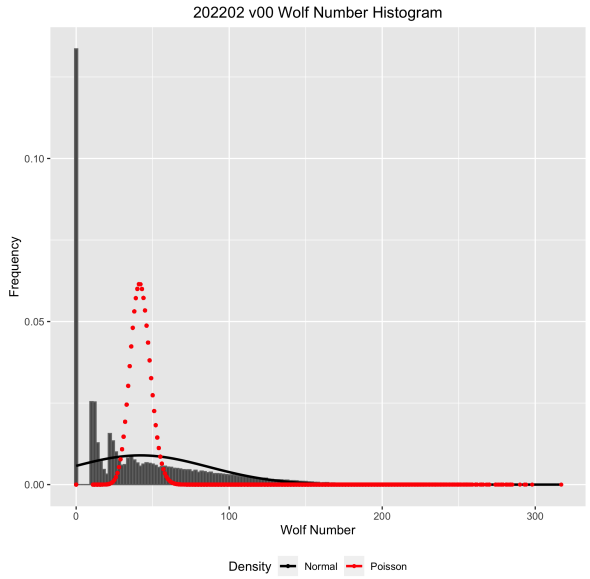

Figure 3: Box plots of raw Wolf number (w) by observer rank.

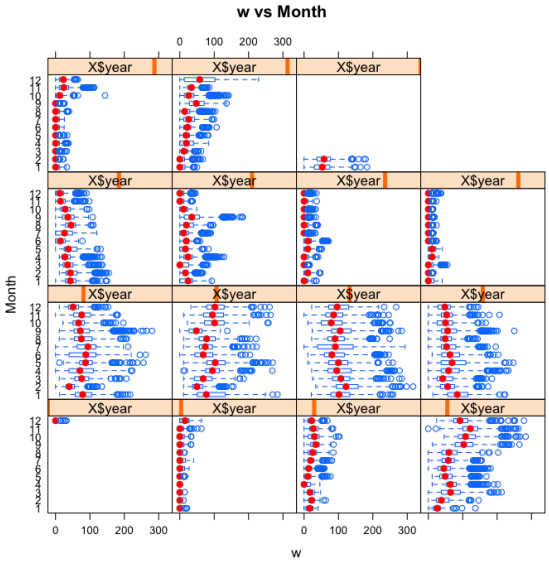

Figure 4: Box plots of raw Wolf number (w) by month and year.

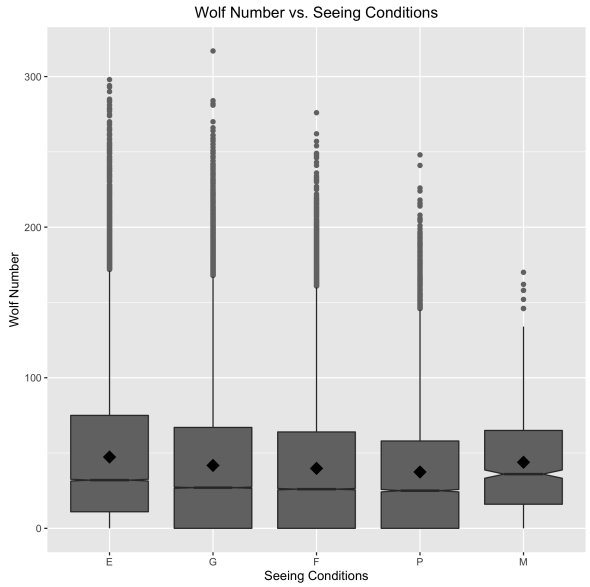

Figure 5: Box plots of raw Wolf number (w) by seeing condition.

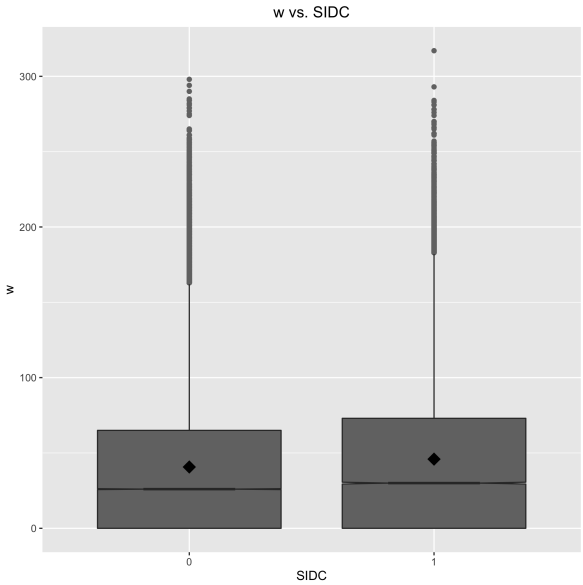

Figure 6: Box plots of raw Wolf number (w) by organization.

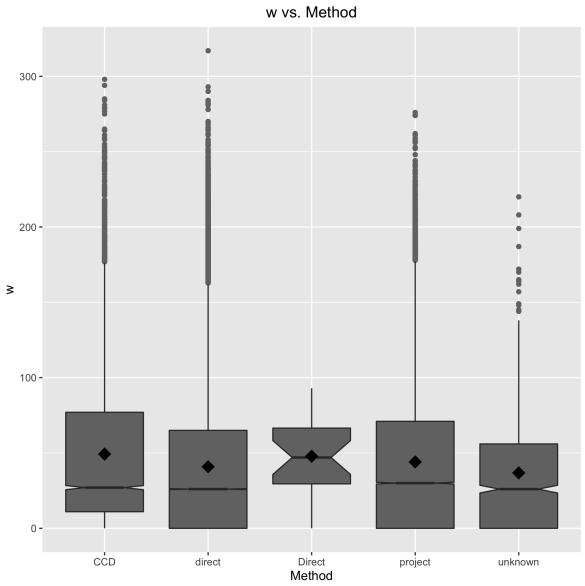

Figure 7: Box plots of raw Wolf number (w) by observer rank.

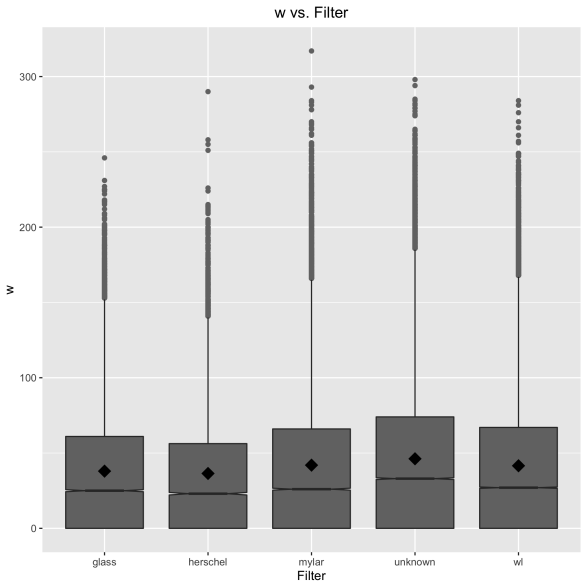

Figure 8: Box plots of raw Wolf number (w) by month and year.

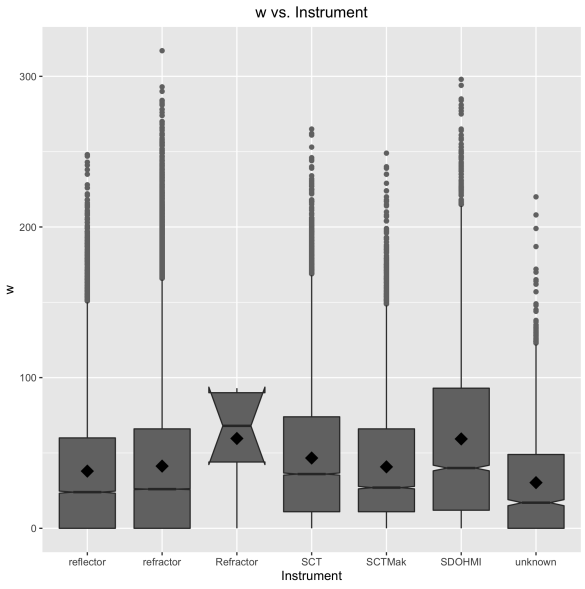

Figure 9: Box plots of raw Wolf number (w) by seeing condition.

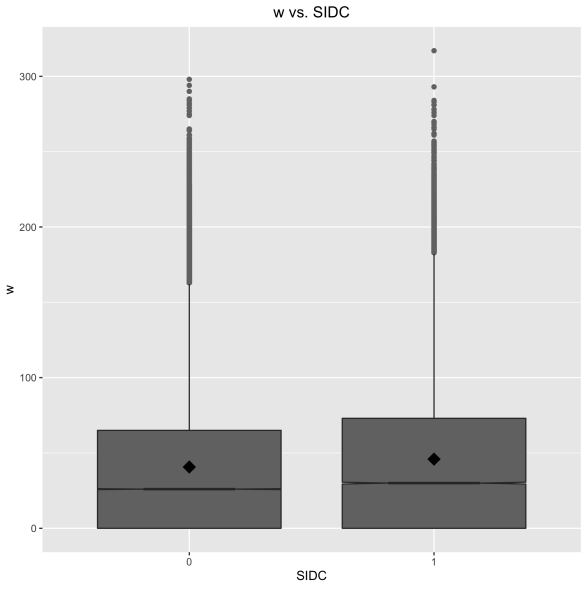

Figure 10: Box plots of raw Wolf number (w) by organization.

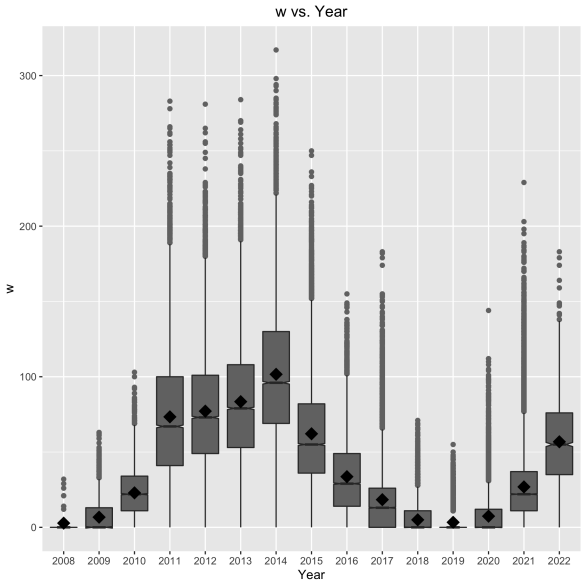

Figure 11: Box plots of raw Wolf number (w) by year.

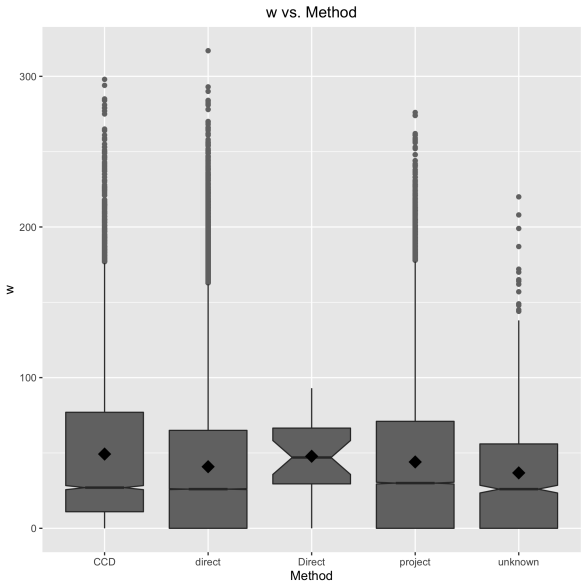

Figure 12: Box plots of raw Wolf number (w) by observing method.