

Monthly Report (00)

2020.07 Data Set

Saturday 15th August, 2020

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.

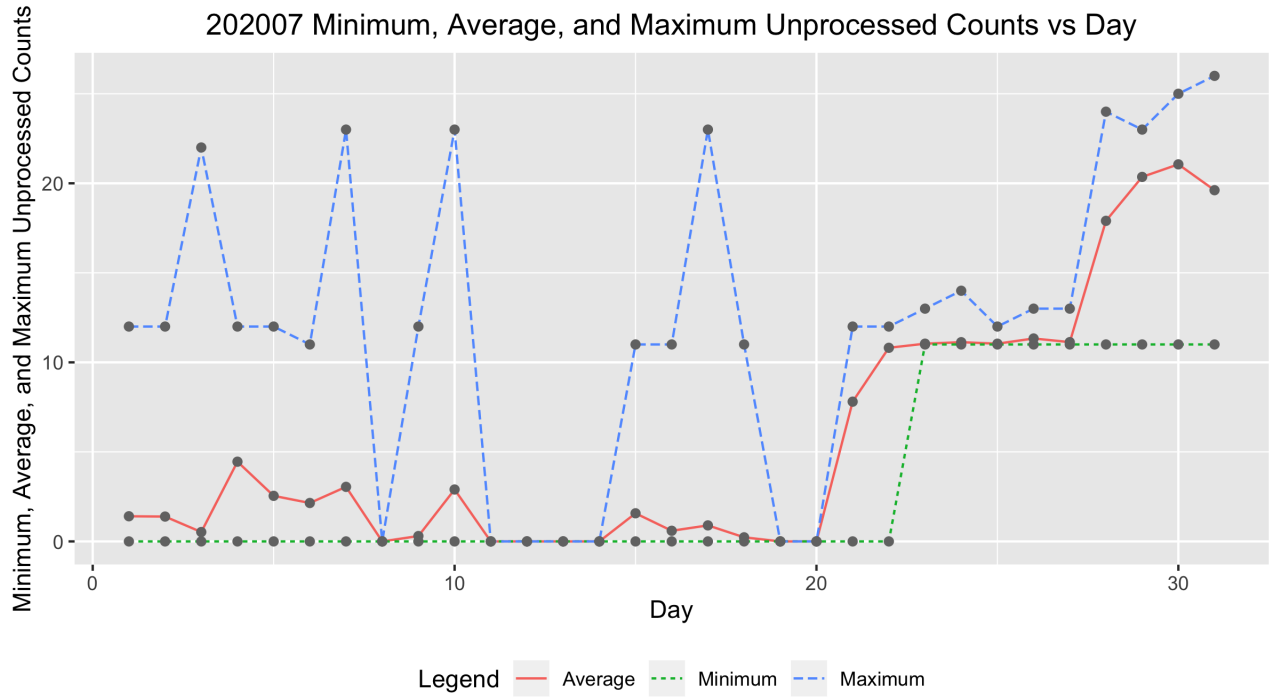


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202007 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	42.0000	0.0000	1.4048	12.0000
2.0000	49.0000	0.0000	1.3878	12.0000
3.0000	42.0000	0.0000	0.5238	22.0000
4.0000	42.0000	0.0000	4.4524	12.0000
5.0000	44.0000	0.0000	2.5455	12.0000
6.0000	41.0000	0.0000	2.1463	11.0000
7.0000	42.0000	0.0000	3.0476	23.0000
8.0000	38.0000	0.0000	0.0000	0.0000
9.0000	40.0000	0.0000	0.3000	12.0000
10.0000	40.0000	0.0000	2.9000	23.0000
11.0000	41.0000	0.0000	0.0000	0.0000
12.0000	49.0000	0.0000	0.0000	0.0000
13.0000	44.0000	0.0000	0.0000	0.0000
14.0000	38.0000	0.0000	0.0000	0.0000
15.0000	35.0000	0.0000	1.5714	11.0000
16.0000	37.0000	0.0000	0.5946	11.0000
17.0000	38.0000	0.0000	0.8947	23.0000
18.0000	48.0000	0.0000	0.2292	11.0000
19.0000	45.0000	0.0000	0.0000	0.0000
20.0000	50.0000	0.0000	0.0000	0.0000
21.0000	41.0000	0.0000	7.8049	12.0000
22.0000	43.0000	0.0000	10.8140	12.0000
23.0000	46.0000	11.0000	11.0435	13.0000
24.0000	47.0000	11.0000	11.1277	14.0000
25.0000	47.0000	11.0000	11.0426	12.0000
26.0000	48.0000	11.0000	11.3333	13.0000
27.0000	46.0000	11.0000	11.1304	13.0000
28.0000	52.0000	11.0000	17.9038	24.0000
29.0000	56.0000	11.0000	20.3571	23.0000
30.0000	51.0000	11.0000	21.0588	25.0000
31.0000	52.0000	11.0000	19.6154	26.0000

3 Error Tables

Data are for the month of July 2020. 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 25th through the 75th quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25th quartile, and 1.5 times the IQR above the 75th 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	2.4033	3.1377	0.5000	1.0000
2009.01	5.9004	5.2531	6.5477	1.3000	1.3000
2009.02	5.0564	4.4866	5.6263	0.7000	1.2000
2009.03	6.6805	6.4153	6.9457	0.3000	0.6000
2009.04	7.5329	7.2568	7.8090	0.4000	1.2000
2009.05	7.5821	7.2752	7.8891	1.6000	2.9000
2009.06	6.7143	6.3690	7.0596	3.2000	6.3000
2009.07	6.4076	6.1456	6.6697	3.6000	5.5000
2009.08	7.0352	6.7507	7.3197	0.0000	0.0000
2009.09	7.5250	7.2520	7.7980	4.5000	7.1000
2009.10	7.0295	6.6537	7.4053	4.5000	7.7000
2009.11	6.9901	6.7965	7.1837	3.3000	6.9000
2009.12	6.5074	6.3210	6.6939	10.4000	16.3000
2010.01	21.7881	19.2763	24.3000	13.3000	19.5000
2010.02	16.9429	14.6071	19.2787	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	18.5914	16.2549	20.9279	15.4000	24.0000
2010.04	20.7086	18.2358	23.1815	7.0000	10.4000
2010.05	24.6747	24.2354	25.1140	8.4000	8.7000
2010.06	20.5067	20.1656	20.8478	11.0000	13.6000
2010.07	21.4429	21.1314	21.7544	15.2000	16.1000
2010.08	22.7647	22.3909	23.1385	18.3000	19.6000
2010.09	25.2769	24.8599	25.6940	22.8000	25.2000
2010.10	23.8913	23.4784	24.3042	21.0000	23.5000
2010.11	24.3353	23.8930	24.7777	20.9000	21.6000
2010.12	21.7235	21.2846	22.1624	13.9000	14.5000
2011.01	77.4336	75.8276	79.0396	17.7000	18.7000
2011.02	65.5079	64.1085	66.9073	29.1000	29.6000
2011.03	69.9570	68.6181	71.2959	48.0000	55.8000
2011.04	78.7568	77.3414	80.1721	47.3000	54.4000
2011.05	79.4156	78.0720	80.7593	37.3000	41.5000
2011.06	65.9537	64.7977	67.1096	35.2000	37.0000
2011.07	68.2770	67.1083	69.4457	41.5000	43.8000
2011.08	73.3451	72.1647	74.5254	42.4000	50.5000
2011.09	80.0829	78.6966	81.4692	73.8000	78.0000
2011.10	75.6977	74.4233	76.9721	78.9000	88.0000
2011.11	76.8824	75.2777	78.4871	84.6000	96.7000
2011.12	67.5510	66.1593	68.9427	65.8000	73.0000
2012.01	83.0925	81.4558	84.7291	55.8000	58.2000
2012.02	69.1116	67.7041	70.5192	29.2000	33.1000
2012.03	74.4764	73.1562	75.7965	53.1000	64.1000
2012.04	82.6214	81.1761	84.0667	51.4000	55.2000
2012.05	84.9118	83.5118	86.3118	61.8000	69.0000
2012.06	69.8112	68.6251	70.9972	59.7000	64.5000
2012.07	72.6647	71.4728	73.8565	64.2000	51.3000
2012.08	75.2919	74.0833	76.5004	57.7000	63.1000
2012.09	82.7179	81.2826	84.1532	57.7000	61.5000
2012.10	79.0560	77.6093	80.5027	48.3000	53.3000
2012.11	80.2652	78.6533	81.8771	56.7000	61.4000
2012.12	70.7055	69.1703	72.2407	37.4000	40.8000
2013.01	92.3895	90.6225	94.1566	63.8000	62.9000
2013.02	76.9892	75.4384	78.5400	37.8000	38.0000
2013.03	80.3532	78.7183	81.9882	50.6000	57.9000
2013.04	90.0858	88.5009	91.6708	70.6000	72.4000
2013.05	90.4954	88.8839	92.1070	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	75.9280	74.5856	77.2703	51.0000	52.5000
2013.07	78.0482	76.7950	79.3015	57.0000	57.0000
2013.08	82.3992	81.0736	83.7247	60.0000	66.0000
2013.09	89.2471	87.6541	90.8400	34.6000	36.9000
2013.10	84.2442	82.6810	85.8075	74.5000	85.6000
2013.11	83.9938	82.1072	85.8803	73.9000	77.6000
2013.12	76.0893	74.4622	77.7164	77.8000	90.3000
2014.01	107.6309	105.3635	109.8983	77.4000	82.0000
2014.02	91.4842	89.6794	93.2891	93.9000	102.8000
2014.03	97.7201	95.9382	99.5019	80.9000	92.2000
2014.04	109.7173	107.7993	111.6352	76.9000	84.7000
2014.05	110.8985	109.0049	112.7921	72.3000	75.2000
2014.06	92.8577	91.2873	94.4281	67.2000	71.0000
2014.07	95.1377	93.5534	96.7219	72.5000	72.5000
2014.08	100.6066	99.0334	102.1798	71.2000	74.7000
2014.09	110.1005	108.1579	112.0431	83.2000	87.6000
2014.10	103.5931	101.6839	105.5023	59.5000	60.6000
2014.11	104.3651	102.1901	106.5400	65.8000	71.1000
2014.12	92.5771	90.4277	94.7265	75.8000	78.0000
2015.01	66.5365	65.2029	67.8701	65.9000	67.0000
2015.02	55.1872	53.9708	56.4036	42.4000	44.8000
2015.03	59.7223	58.6283	60.8163	38.0000	38.4000
2015.04	66.6235	65.4294	67.8176	49.0000	54.4000
2015.05	67.6533	66.5342	68.7725	56.3000	58.8000
2015.06	56.5182	55.4983	57.5382	50.2000	68.3000
2015.07	57.4275	56.4466	58.4083	47.9000	65.8000
2015.08	61.9388	60.8970	62.9805	39.5000	57.2000
2015.09	66.9185	65.7009	68.1361	49.2000	72.1000
2015.10	63.4664	62.2392	64.6936	39.3000	48.3000
2015.11	64.6279	63.2228	66.0330	39.6000	55.9000
2015.12	57.4014	56.1383	58.6644	36.4000	44.8000
2016.01	36.4426	35.6817	37.2036	33.7000	43.3000
2016.02	30.3542	29.7205	30.9878	38.3000	46.8000
2016.03	32.3197	31.6741	32.9653	30.5000	38.9000
2016.04	35.9613	35.2755	36.6472	26.6000	30.9000
2016.05	36.5915	35.9224	37.2606	33.7000	48.4000
2016.06	30.2455	29.7291	30.7618	13.1000	19.5000
2016.07	31.2729	30.7697	31.7762	21.2000	27.5000
2016.08	33.3898	32.8022	33.9773	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	36.9290	36.2546	37.6035	27.7000	37.1000
2016.10	34.6204	33.9525	35.2883	22.7000	31.7000
2016.11	34.8671	34.1377	35.5964	14.0000	22.2000
2016.12	31.3507	30.6797	32.0217	11.1000	20.0000
2017.01	19.8198	19.4024	20.2373	18.4000	26.2000
2017.02	16.5765	16.2121	16.9409	14.4000	20.6000
2017.03	17.8032	17.4638	18.1426	11.3000	15.5000
2017.04	20.0181	19.6646	20.3716	21.6000	33.2000
2017.05	20.0501	19.7038	20.3963	12.5000	18.1000
2017.06	16.5765	16.2998	16.8532	15.5000	19.3000
2017.07	17.2286	16.9543	17.5029	11.5000	16.3000
2017.08	18.3337	18.0143	18.6531	22.8000	35.7000
2017.09	20.6107	20.1780	21.0433	34.6000	42.9000
2017.10	18.8487	18.4656	19.2319	10.5000	11.0000
2017.11	18.8264	18.4322	19.2206	4.2000	5.6000
2017.12	16.8549	16.5997	17.1101	4.0000	4.6000
2018.01	5.4895	5.3715	5.6074	3.1000	6.3000
2018.02	4.5599	4.4480	4.6718	6.8000	11.8000
2018.03	4.8099	4.7145	4.9053	1.1000	1.2000
2018.04	5.3648	5.2568	5.4727	4.7000	7.5000
2018.05	5.4596	5.3562	5.5630	8.4000	14.0000
2018.06	4.5184	4.4389	4.5979	10.2000	13.6000
2018.07	4.6962	4.6438	4.7486	0.5000	1.7000
2018.08	4.9416	4.8569	5.0262	5.9000	9.5000
2018.09	5.3496	5.2504	5.4488	1.6000	2.9000
2018.10	5.1521	5.0526	5.2516	2.5000	5.6000
2018.11	5.1804	5.0746	5.2862	3.1000	4.2000
2018.12	4.7331	4.6418	4.8244	1.6000	2.3000
2019.01	3.6348	3.5668	3.7028	5.4000	2.3000
2019.02	3.0834	3.0235	3.1433	0.1000	1.2000
2019.03	3.2137	3.1593	3.2681	6.1000	12.1000
2019.04	3.6050	3.5377	3.6723	6.2000	9.3000
2019.05	3.5506	3.4890	3.6123	7.0000	11.9000
2019.06	2.9412	2.8916	2.9908	0.7000	1.5000
2019.07	3.0677	3.0218	3.1137	0.4000	2.2000
2019.08	3.2826	3.2338	3.3314	0.3000	0.8000
2019.09	3.6256	3.5682	3.6831	0.5000	1.0000
2019.10	3.3863	3.3281	3.4445	0.2000	0.5000
2019.11	3.4653	3.3986	3.5320	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	3.0709	3.0099	3.1319	0.8000	1.0000
2020.01	3.6541	3.5823	3.7259	4.0000	5.3000
2020.02	3.0614	3.0002	3.1226	0.1000	0.0000
2020.03	3.2290	3.1693	3.2888	1.2000	1.5000
2020.04	3.6650	3.6058	3.7241	3.0000	5.1000
2020.05	3.6469	3.5894	3.7045	0.1000	0.4000
2020.06	3.0404	2.9933	3.0875	3.9000	6.4000
2020.07	3.1244	3.0776	3.1712	4.2000	7.7000

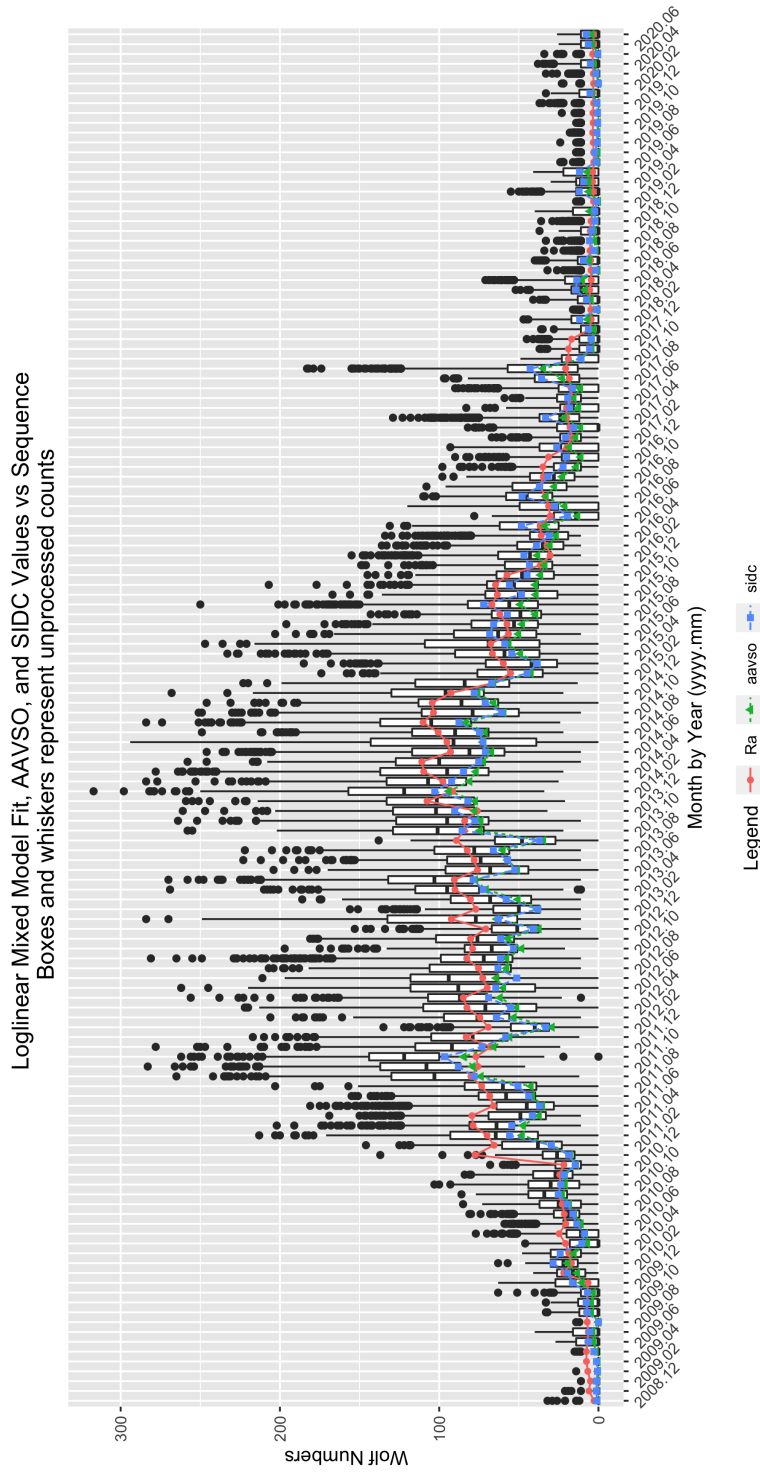


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202007 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4710	0.3060	4.8070	0.0000
seeF	-0.2177	0.0058	-37.8293	0.0000
seeG	-0.1165	0.0050	-23.2484	0.0000
seeM	-0.2009	0.0237	-8.4658	0.0000
seeP	-0.3227	0.0082	-39.1629	0.0000
sidc1	0.1394	0.0682	2.0433	0.0410
year2009	0.6371	0.3068	2.0764	0.0379
year2010	1.8465	0.3047	6.0598	0.0000
year2011	2.9647	0.3046	9.7326	0.0000
year2012	3.0015	0.3046	9.8536	0.0000
year2013	3.0973	0.3046	10.1683	0.0000
year2014	3.2943	0.3046	10.8149	0.0000
year2015	2.8094	0.3046	9.2228	0.0000
year2016	2.1926	0.3046	7.1974	0.0000
year2017	1.5873	0.3047	5.2096	0.0000
year2018	0.2900	0.3050	0.9508	0.3417
year2019	-0.1353	0.3052	-0.4433	0.6575
year2020	-0.1163	0.3056	-0.3807	0.7034
mon2	-0.1734	0.0091	-19.1197	0.0000
mon3	-0.1151	0.0085	-13.5856	0.0000
mon4	-0.0098	0.0082	-1.2028	0.2290
mon5	-0.0051	0.0080	-0.6337	0.5263
mon6	-0.1929	0.0084	-22.9508	0.0000
mon7	-0.1670	0.0082	-20.4400	0.0000
mon8	-0.1029	0.0080	-12.8211	0.0000
mon9	-0.0048	0.0081	-0.5921	0.5538
mon10	-0.0594	0.0083	-7.1643	0.0000
mon11	-0.0376	0.0087	-4.3470	0.0000
mon12	-0.1474	0.0088	-16.7028	0.0000

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: 202007 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:129365	Min. :0.0000
1st Qu.:2013	1st Qu.: 4.000	1st Qu.: 8.00	Class :character	1st Qu.:0.0000
Median :2015	Median : 7.000	Median :16.00	Mode :character	Median :0.0000
Mean :2015	Mean : 6.544	Mean :15.73		Mean :0.2579
3rd Qu.:2018	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2020	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202007 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.00	Min. : 0.00	Min. : 0.00	Length:129365	Length:129365
1st Qu.: 0.00	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.00	Median : 8.00	Median : 31.00	Mode :character	Mode :character
Mean : 2.81	Mean : 16.68	Mean : 44.78		
3rd Qu.: 5.00	3rd Qu.: 25.00	3rd Qu.: 73.00		
Max. :19.00	Max. :204.00	Max. :317.00		

Table 6: 202007 Summary of Sunspot Numbers

inst	filter	unit
Length:129365	Length:129365	Length:129365
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202007 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 50.00	1st Qu.: 4.00	1st Qu.: 33.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 90.27	Mean : 29.82	Mean : 882.5	Mean : 184.6
3rd Qu.: 104.00	3rd Qu.: 23.00	3rd Qu.:1200.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

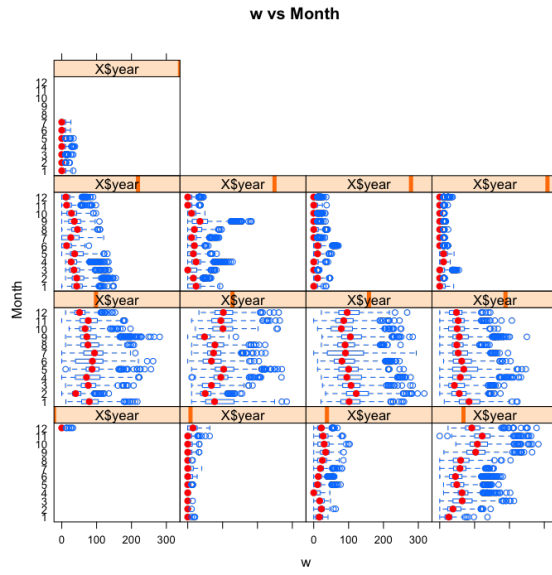
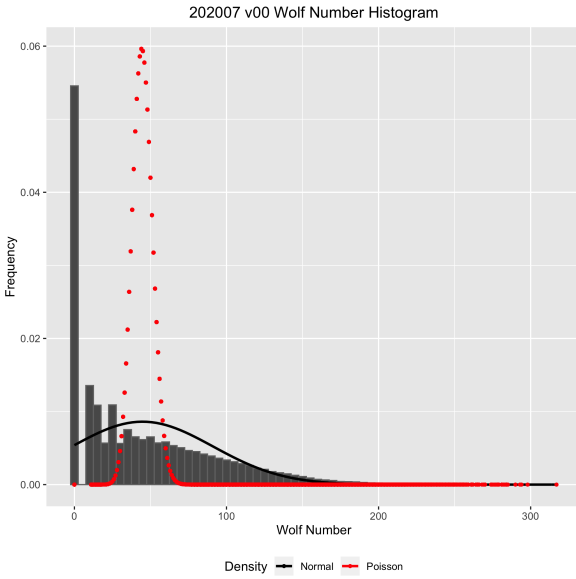


Figure 3: Box plots of raw Wolf number (w) by observer rank.

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

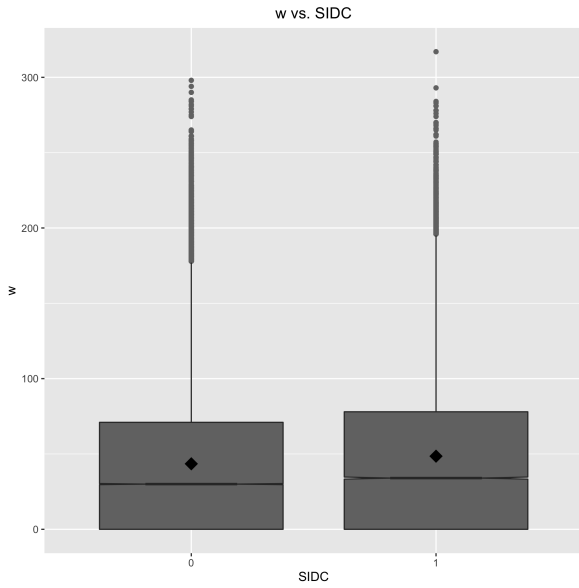
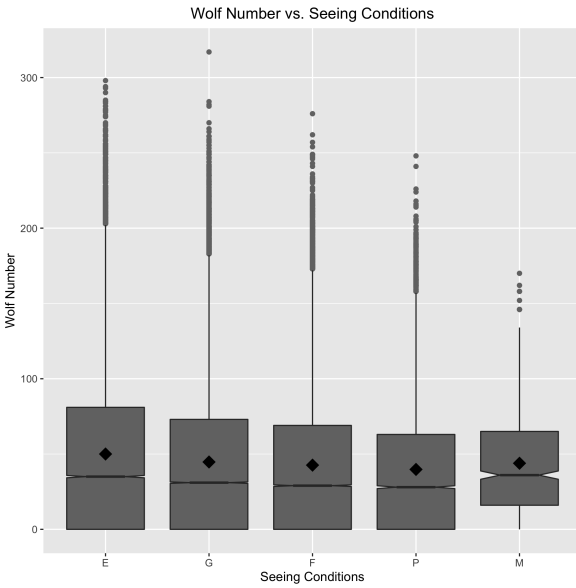


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

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

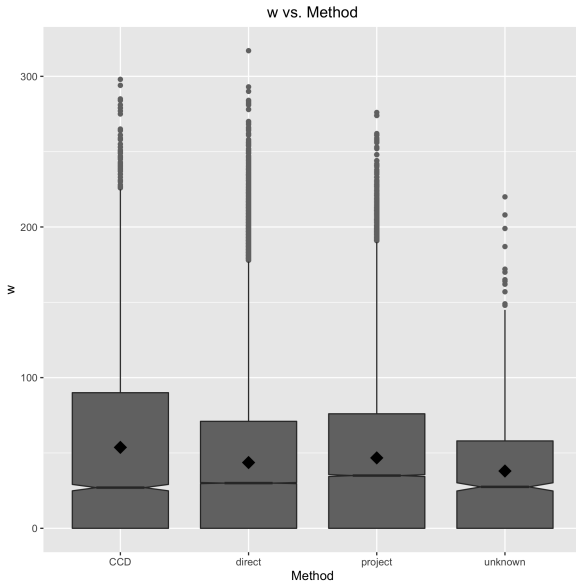


Figure 7: Box plots of raw Wolf number (w) by observer rank.

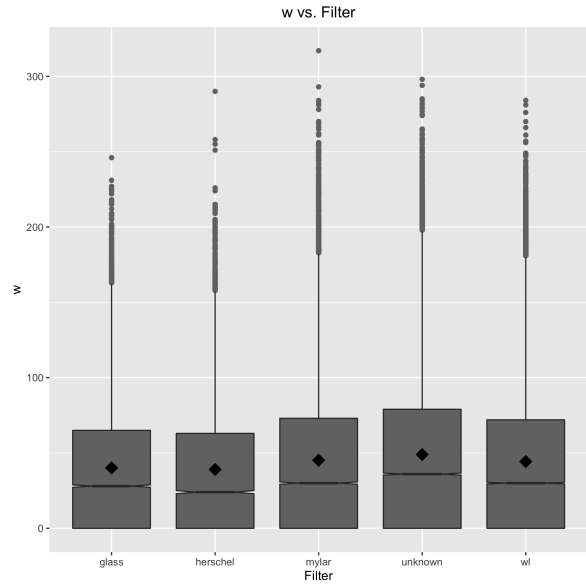


Figure 8: Box plots of raw Wolf number (w) by month and year.

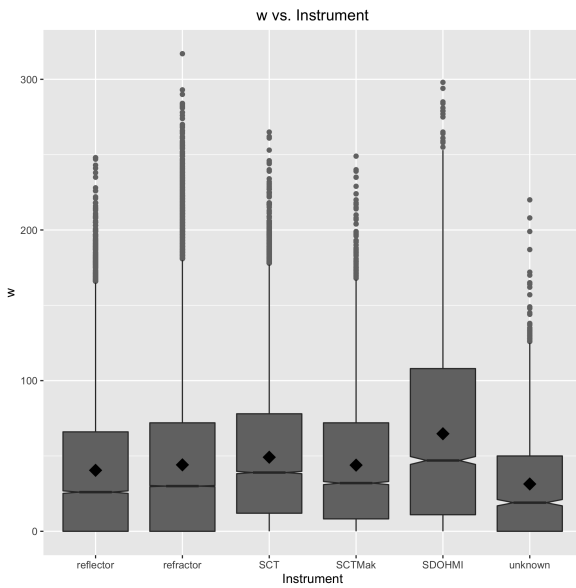


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

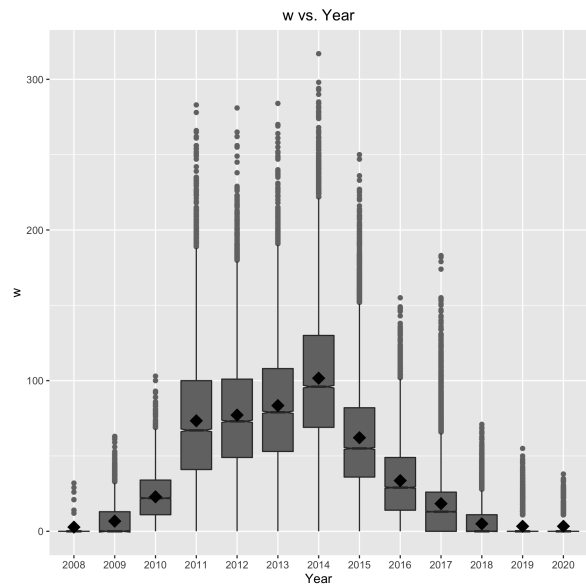


Figure 10: Box plots of raw Wolf number (w) by organization.

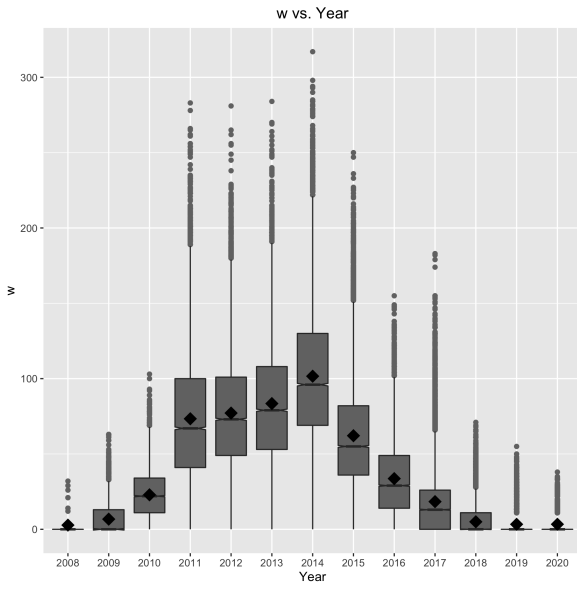


Figure 11: Box plots of raw Wolf number (w) by year.

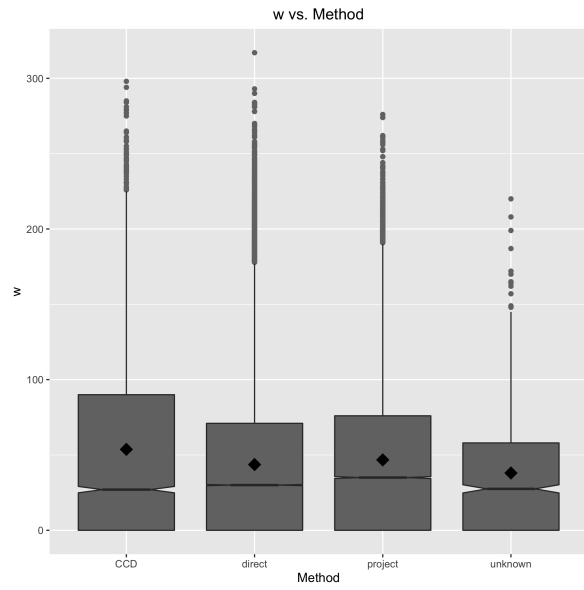


Figure 12: Box plots of raw Wolf number (w) by observing method.