

Monthly Report (00)

2020.09 Data Set

Monday 12th October, 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.

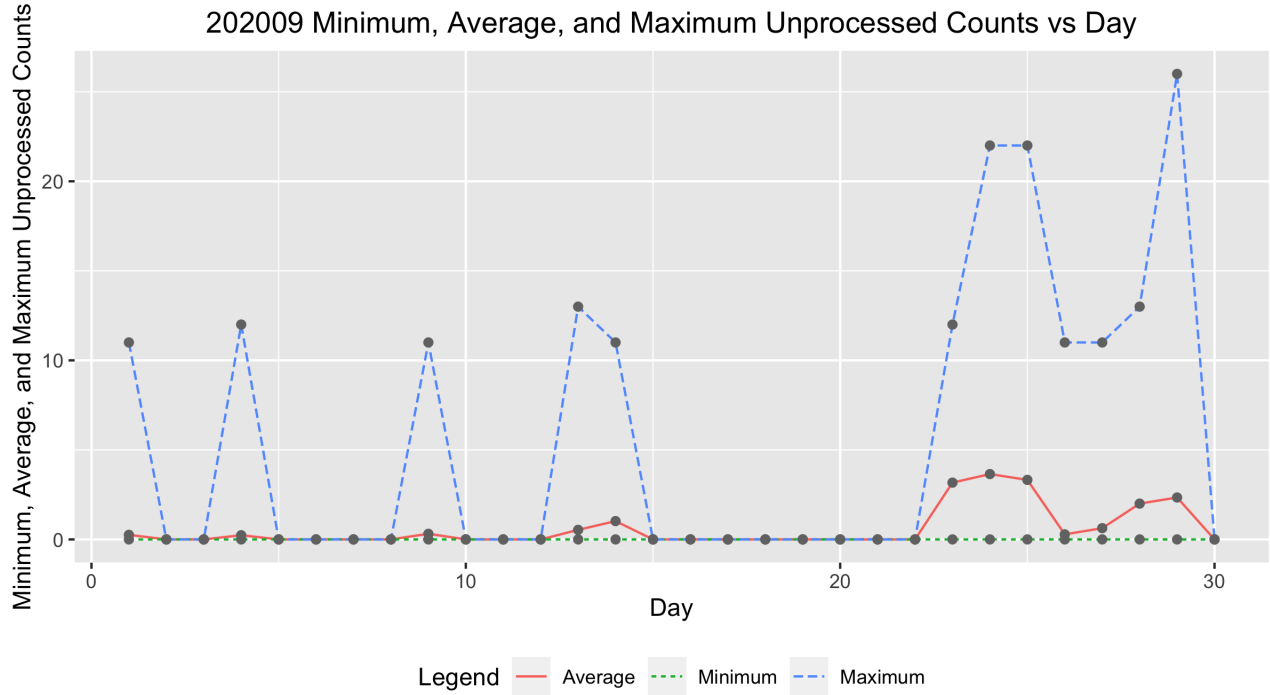


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202009 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	43.0000	0.0000	0.2558	11.0000
2.0000	49.0000	0.0000	0.0000	0.0000
3.0000	46.0000	0.0000	0.0000	0.0000
4.0000	51.0000	0.0000	0.2353	12.0000
5.0000	50.0000	0.0000	0.0000	0.0000
6.0000	53.0000	0.0000	0.0000	0.0000
7.0000	44.0000	0.0000	0.0000	0.0000
8.0000	43.0000	0.0000	0.0000	0.0000
9.0000	35.0000	0.0000	0.3143	11.0000
10.0000	40.0000	0.0000	0.0000	0.0000
11.0000	45.0000	0.0000	0.0000	0.0000
12.0000	43.0000	0.0000	0.0000	0.0000
13.0000	45.0000	0.0000	0.5333	13.0000
14.0000	43.0000	0.0000	1.0233	11.0000
15.0000	51.0000	0.0000	0.0000	0.0000
16.0000	44.0000	0.0000	0.0000	0.0000
17.0000	40.0000	0.0000	0.0000	0.0000
18.0000	42.0000	0.0000	0.0000	0.0000
19.0000	45.0000	0.0000	0.0000	0.0000
20.0000	45.0000	0.0000	0.0000	0.0000
21.0000	43.0000	0.0000	0.0000	0.0000
22.0000	41.0000	0.0000	0.0000	0.0000
23.0000	35.0000	0.0000	3.1714	12.0000
24.0000	37.0000	0.0000	3.6486	22.0000
25.0000	37.0000	0.0000	3.3243	22.0000
26.0000	39.0000	0.0000	0.2821	11.0000
27.0000	35.0000	0.0000	0.6286	11.0000
28.0000	37.0000	0.0000	2.0000	13.0000
29.0000	41.0000	0.0000	2.3415	26.0000
30.0000	46.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of September 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	2.4026	3.1384	0.5000	1.0000
2009.01	5.8981	5.2498	6.5465	1.3000	1.3000
2009.02	5.0547	4.4839	5.6256	0.7000	1.2000
2009.03	6.6807	6.4159	6.9454	0.3000	0.6000
2009.04	7.5327	7.2571	7.8084	0.4000	1.2000
2009.05	7.5820	7.2757	7.8883	1.6000	2.9000
2009.06	6.7141	6.3692	7.0590	3.2000	6.3000
2009.07	6.4079	6.1462	6.6696	3.6000	5.5000
2009.08	7.0938	6.8077	7.3799	0.0000	0.0000
2009.09	7.4728	7.2021	7.7434	4.5000	7.1000
2009.10	7.0307	6.6553	7.4060	4.5000	7.7000
2009.11	6.9899	6.7960	7.1837	3.3000	6.9000
2009.12	6.5068	6.3202	6.6934	10.4000	16.3000
2010.01	21.7858	19.2695	24.3022	13.3000	19.5000
2010.02	16.9364	14.5966	19.2761	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	18.5854	16.2453	20.9255	15.4000	24.0000
2010.04	20.7011	18.2246	23.1777	7.0000	10.4000
2010.05	24.6670	24.2272	25.1068	8.4000	8.7000
2010.06	20.5031	20.1619	20.8443	11.0000	13.6000
2010.07	21.4407	21.1291	21.7524	15.2000	16.1000
2010.08	22.9512	22.5742	23.3283	18.3000	19.6000
2010.09	25.0985	24.6845	25.5126	22.8000	25.2000
2010.10	23.8923	23.4793	24.3053	21.0000	23.5000
2010.11	24.3355	23.8930	24.7779	20.9000	21.6000
2010.12	21.7248	21.2856	22.1639	13.9000	14.5000
2011.01	77.4168	75.8111	79.0225	17.7000	18.7000
2011.02	65.4902	64.0906	66.8898	29.1000	29.6000
2011.03	69.9437	68.6052	71.2823	48.0000	55.8000
2011.04	78.7425	77.3278	80.1572	47.3000	54.4000
2011.05	79.3973	78.0539	80.7408	37.3000	41.5000
2011.06	65.9408	64.7849	67.0967	35.2000	37.0000
2011.07	68.2654	67.0965	69.4342	41.5000	43.8000
2011.08	73.9367	72.7465	75.1268	42.4000	50.5000
2011.09	79.5246	78.1469	80.9023	73.8000	78.0000
2011.10	75.6979	74.4236	76.9723	78.9000	88.0000
2011.11	76.8782	75.2738	78.4826	84.6000	96.7000
2011.12	67.5509	66.1596	68.9423	65.8000	73.0000
2012.01	83.0764	81.4396	84.7131	55.8000	58.2000
2012.02	69.0954	67.6879	70.5029	29.2000	33.1000
2012.03	74.4619	73.1419	75.7819	53.1000	64.1000
2012.04	82.6034	81.1581	84.0487	51.4000	55.2000
2012.05	84.8970	83.4974	86.2967	61.8000	69.0000
2012.06	69.7964	68.6104	70.9823	59.7000	64.5000
2012.07	72.6537	71.4620	73.8455	64.2000	51.3000
2012.08	75.8991	74.6805	77.1176	57.7000	63.1000
2012.09	82.1252	80.7000	83.5504	57.7000	61.5000
2012.10	79.0535	77.6069	80.5002	48.3000	53.3000
2012.11	80.2640	78.6518	81.8762	56.7000	61.4000
2012.12	70.7055	69.1700	72.2409	37.4000	40.8000
2013.01	92.3682	90.6011	94.1353	63.8000	62.9000
2013.02	76.9719	75.4212	78.5226	37.8000	38.0000
2013.03	80.3351	78.7001	81.9701	50.6000	57.9000
2013.04	90.0621	88.4772	91.6471	70.6000	72.4000
2013.05	90.4728	88.8614	92.0841	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	75.9117	74.5696	77.2538	51.0000	52.5000
2013.07	78.0306	76.7775	79.2836	57.0000	57.0000
2013.08	83.0707	81.7343	84.4070	60.0000	66.0000
2013.09	88.6080	87.0264	90.1896	34.6000	36.9000
2013.10	84.2457	82.6823	85.8091	74.5000	85.6000
2013.11	83.9946	82.1080	85.8813	73.9000	77.6000
2013.12	76.0909	74.4637	77.7182	77.8000	90.3000
2014.01	107.6043	105.3371	109.8715	77.4000	82.0000
2014.02	91.4620	89.6575	93.2666	93.9000	102.8000
2014.03	97.6964	95.9149	99.4780	80.9000	92.2000
2014.04	109.6863	107.7687	111.6040	76.9000	84.7000
2014.05	110.8652	108.9721	112.7583	72.3000	75.2000
2014.06	92.8336	91.2637	94.4036	67.2000	71.0000
2014.07	95.1142	93.5301	96.6982	72.5000	72.5000
2014.08	101.4251	99.8393	103.0109	71.2000	74.7000
2014.09	109.3153	107.3868	111.2438	83.2000	87.6000
2014.10	103.5901	101.6809	105.4992	59.5000	60.6000
2014.11	104.3612	102.1861	106.5362	65.8000	71.1000
2014.12	92.5768	90.4274	94.7262	75.8000	78.0000
2015.01	66.5183	65.1851	67.8516	65.9000	67.0000
2015.02	55.1800	53.9639	56.3960	42.4000	44.8000
2015.03	59.7126	58.6191	60.8062	38.0000	38.4000
2015.04	66.6136	65.4202	67.8070	49.0000	54.4000
2015.05	67.6456	66.5272	68.7640	56.3000	58.8000
2015.06	56.5087	55.4892	57.5281	50.2000	68.3000
2015.07	57.4209	56.4405	58.4014	47.9000	65.8000
2015.08	62.4407	61.3908	63.4906	39.5000	57.2000
2015.09	66.4444	65.2356	67.6533	49.2000	72.1000
2015.10	63.4692	62.2422	64.6961	39.3000	48.3000
2015.11	64.6281	63.2234	66.0329	39.6000	55.9000
2015.12	57.4012	56.1381	58.6644	36.4000	44.8000
2016.01	36.4343	35.6736	37.1949	33.7000	43.3000
2016.02	30.3475	29.7140	30.9809	38.3000	46.8000
2016.03	32.3134	31.6681	32.9588	30.5000	38.9000
2016.04	35.9541	35.2686	36.6397	26.6000	30.9000
2016.05	36.5840	35.9153	37.2526	33.7000	48.4000
2016.06	30.2378	29.7217	30.7539	13.1000	19.5000
2016.07	31.2659	30.7630	31.7688	21.2000	27.5000
2016.08	33.6630	33.0711	34.2548	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	36.6687	35.9996	37.3379	27.7000	37.1000
2016.10	34.6214	33.9539	35.2890	22.7000	31.7000
2016.11	34.8703	34.1414	35.5993	14.0000	22.2000
2016.12	31.3484	30.6777	32.0192	11.1000	20.0000
2017.01	19.8188	19.4015	20.2360	18.4000	26.2000
2017.02	16.5757	16.2115	16.9399	14.4000	20.6000
2017.03	17.8018	17.4625	18.1411	11.3000	15.5000
2017.04	20.0158	19.6625	20.3691	21.6000	33.2000
2017.05	20.0501	19.7041	20.3961	12.5000	18.1000
2017.06	16.5742	16.2976	16.8508	15.5000	19.3000
2017.07	17.2258	16.9516	17.5000	11.5000	16.3000
2017.08	18.4834	18.1614	18.8055	22.8000	35.7000
2017.09	20.4672	20.0367	20.8977	34.6000	42.9000
2017.10	18.8496	18.4661	19.2331	10.5000	11.0000
2017.11	18.8281	18.4338	19.2225	4.2000	5.6000
2017.12	16.8561	16.6008	17.1114	4.0000	4.6000
2018.01	5.4896	5.3714	5.6078	3.1000	6.3000
2018.02	4.5591	4.4468	4.6713	6.8000	11.8000
2018.03	4.8084	4.7130	4.9037	1.1000	1.2000
2018.04	5.3631	5.2549	5.4714	4.7000	7.5000
2018.05	5.4559	5.3524	5.5595	8.4000	14.0000
2018.06	4.5177	4.4382	4.5971	10.2000	13.6000
2018.07	4.6958	4.6433	4.7482	0.5000	1.7000
2018.08	4.9820	4.8966	5.0675	5.9000	9.5000
2018.09	5.3109	5.2123	5.4095	1.6000	2.9000
2018.10	5.1538	5.0542	5.2535	2.5000	5.6000
2018.11	5.1819	5.0762	5.2877	3.1000	4.2000
2018.12	4.7329	4.6418	4.8241	1.6000	2.3000
2019.01	3.6371	3.5691	3.7052	5.4000	2.3000
2019.02	3.0829	3.0229	3.1428	0.1000	1.2000
2019.03	3.2138	3.1593	3.2683	6.1000	12.1000
2019.04	3.6056	3.5381	3.6731	6.2000	9.3000
2019.05	3.5521	3.4903	3.6139	7.0000	11.9000
2019.06	2.9408	2.8911	2.9905	0.7000	1.5000
2019.07	3.0678	3.0218	3.1139	0.4000	2.2000
2019.08	3.3086	3.2591	3.3580	0.3000	0.8000
2019.09	3.5976	3.5404	3.6549	0.5000	1.0000
2019.10	3.3835	3.3247	3.4422	0.2000	0.5000
2019.11	3.4660	3.3989	3.5331	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	3.0691	3.0079	3.1302	0.8000	1.0000
2020.01	3.7482	3.6740	3.8225	4.0000	5.3000
2020.02	3.1370	3.0737	3.2003	0.1000	0.0000
2020.03	3.3110	3.2491	3.3728	1.2000	1.5000
2020.04	3.7587	3.6976	3.8198	3.0000	5.1000
2020.05	3.7402	3.6809	3.7994	0.1000	0.4000
2020.06	3.1186	3.0700	3.1672	3.9000	6.4000
2020.07	3.1961	3.1479	3.2442	4.2000	7.7000
2020.08	3.3868	3.3396	3.4340	5.3000	7.8000
2020.09	3.6705	3.6118	3.7293	0.4000	0.9000

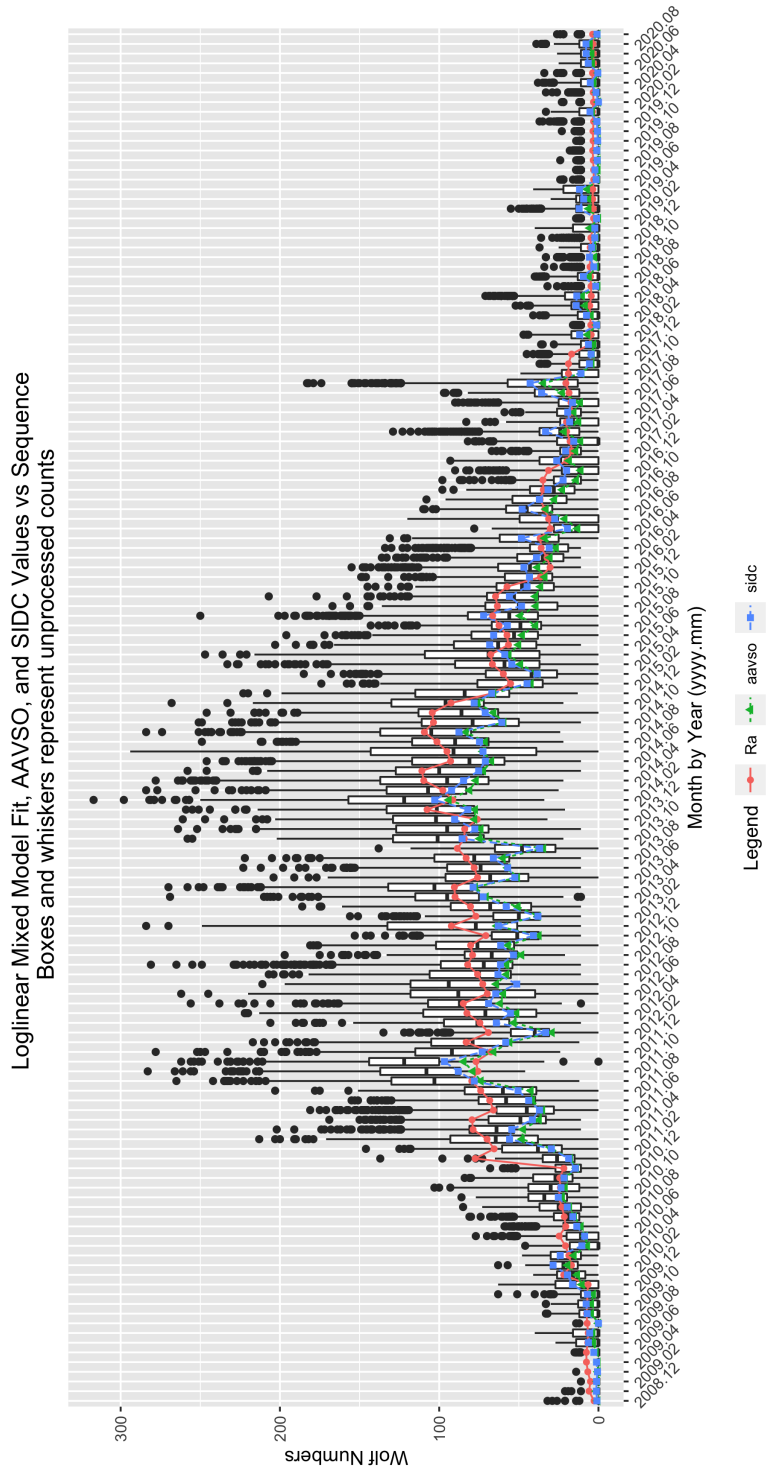


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202009 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4622	0.3049	4.7949	0.0000
seeF	-0.2180	0.0057	-38.0430	0.0000
seeG	-0.1170	0.0050	-23.4510	0.0000
seeM	-0.2016	0.0236	-8.5245	0.0000
seeP	-0.3226	0.0082	-39.3309	0.0000
sidc1	0.1457	0.0680	2.1417	0.0322
year2009	0.6369	0.3058	2.0829	0.0373
year2010	1.8463	0.3037	6.0805	0.0000
year2011	2.9645	0.3036	9.7659	0.0000
year2012	3.0012	0.3035	9.8872	0.0000
year2013	3.0971	0.3035	10.2029	0.0000
year2014	3.2939	0.3035	10.8516	0.0000
year2015	2.8091	0.3036	9.2541	0.0000
year2016	2.1923	0.3036	7.2214	0.0000
year2017	1.5871	0.3036	5.2271	0.0000
year2018	0.2900	0.3039	0.9541	0.3401
year2019	-0.1355	0.3041	-0.4456	0.6559
year2020	-0.0905	0.3043	-0.2975	0.7661
mon2	-0.1735	0.0090	-19.1895	0.0000
mon3	-0.1151	0.0084	-13.6325	0.0000
mon4	-0.0099	0.0081	-1.2122	0.2255
mon5	-0.0051	0.0080	-0.6415	0.5212
mon6	-0.1930	0.0084	-23.0330	0.0000
mon7	-0.1670	0.0081	-20.5117	0.0000
mon8	-0.0946	0.0080	-11.8731	0.0000
mon9	-0.0118	0.0080	-1.4645	0.1431
mon10	-0.0592	0.0083	-7.1695	0.0000
mon11	-0.0375	0.0086	-4.3460	0.0000
mon12	-0.1472	0.0088	-16.7415	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: 202009 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:132022	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 : 6.583	Mean :15.73		Mean :0.2573
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: 202009 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:132022	Length:132022
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 : 2.759	Mean : 16.36	Mean : 43.95		
3rd Qu.: 5.000	3rd Qu.: 25.00	3rd Qu.: 72.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202009 Summary of Sunspot Numbers

inst	filter	unit
Length:132022	Length:132022	Length:132022
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202009 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.: 32.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 900.0	Median : 57.5
Mean : 89.62	Mean : 30.44	Mean : 874.5	Mean : 184.1
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

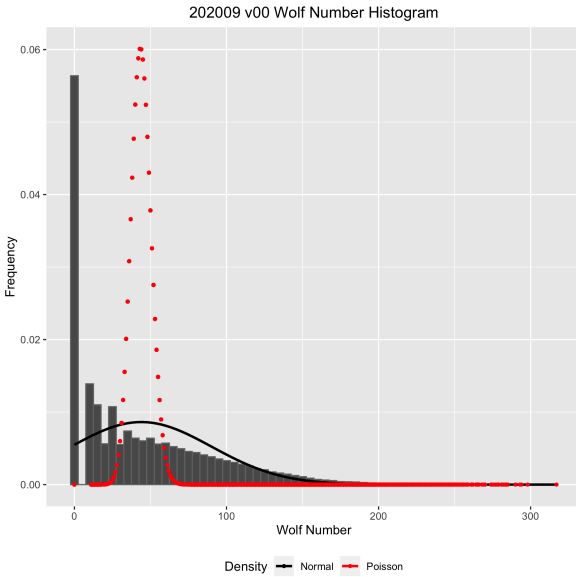


Figure 3: Box plots of raw Wolf number (w) by observer rank.

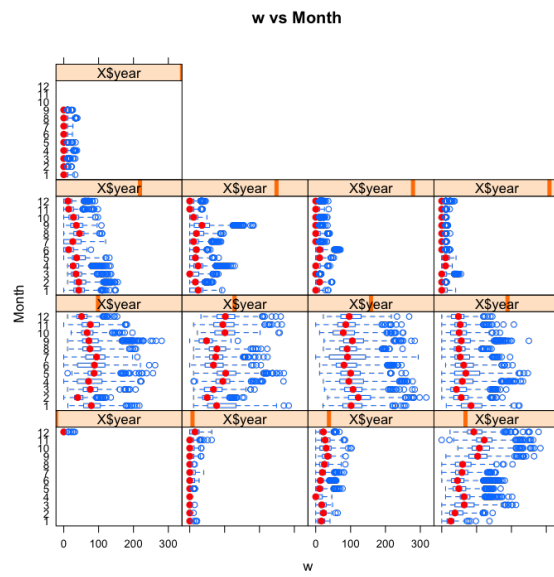


Figure 4: Box plots of raw Wolf number (w) by month and year.

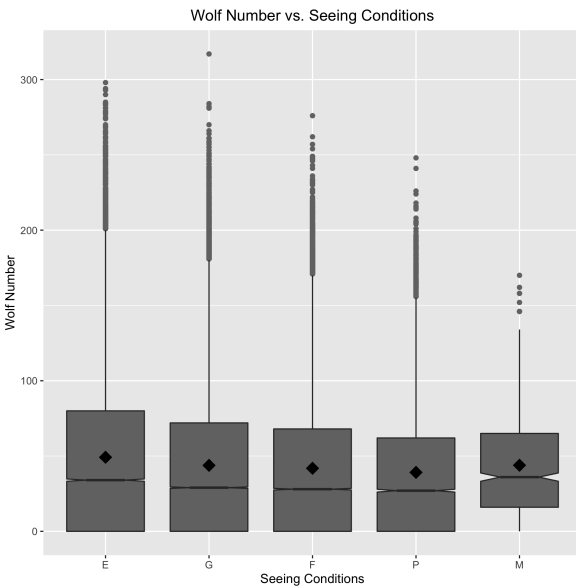


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

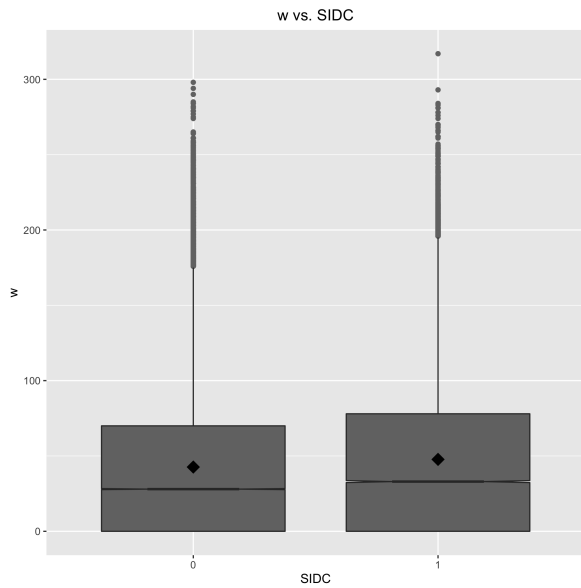


Figure 6: Box plots of raw Wolf number (w) by organization.

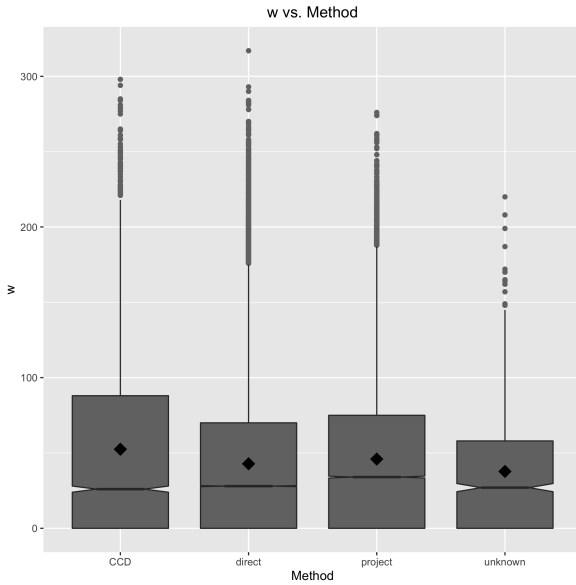


Figure 7: Box plots of raw Wolf number (w) by observer rank.

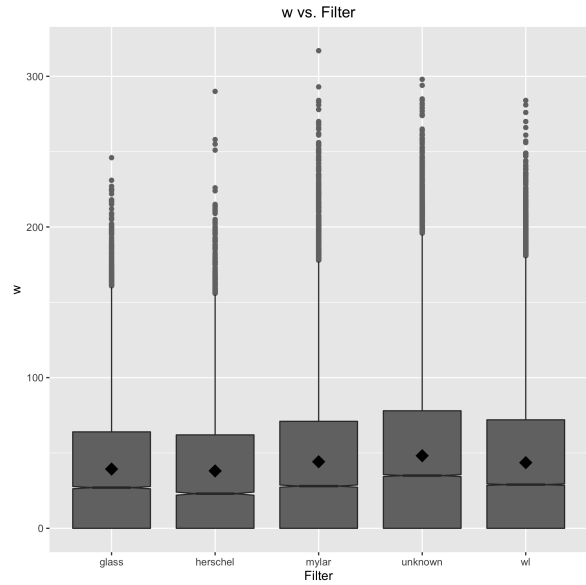


Figure 8: Box plots of raw Wolf number (w) by month and year.

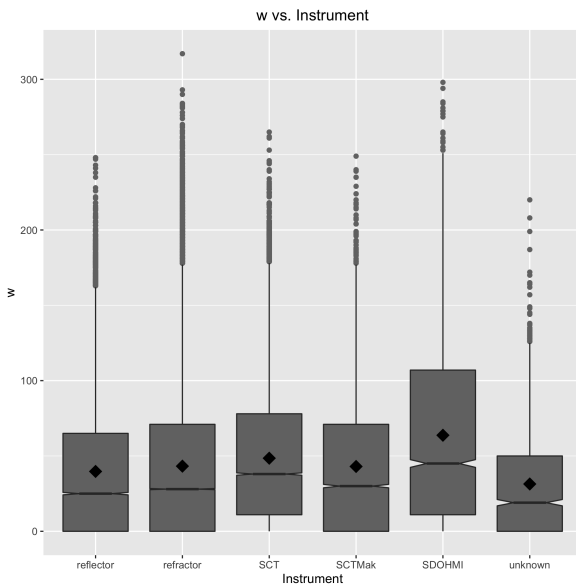


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

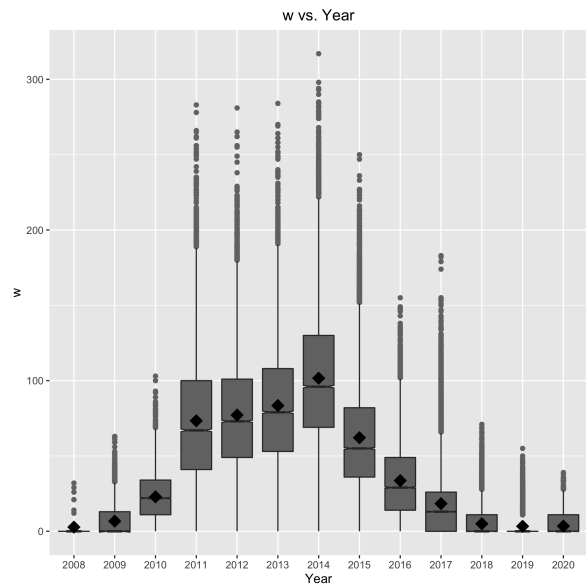


Figure 10: Box plots of raw Wolf number (w) by organization.

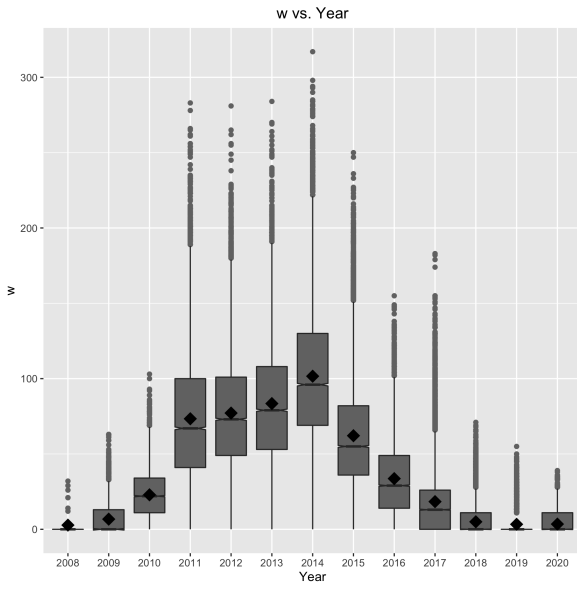


Figure 11: Box plots of raw Wolf number (w) by year.

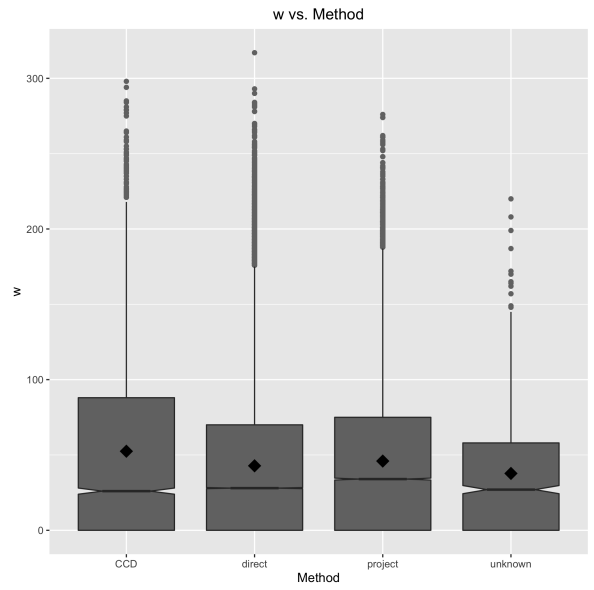


Figure 12: Box plots of raw Wolf number (w) by observing method.