

Monthly Report (00)
2020.08 Data Set

Tuesday 15th September, 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.

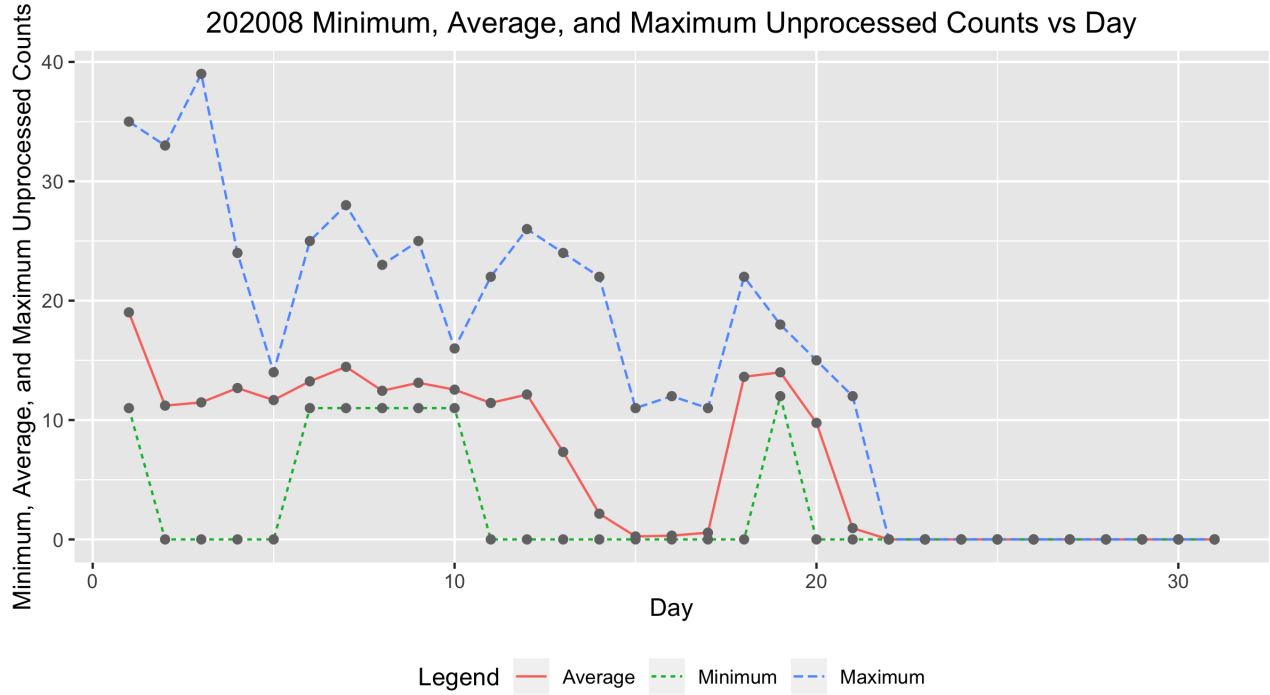


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202008 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	47.0000	11.0000	19.0213	35.0000
2.0000	43.0000	0.0000	11.2093	33.0000
3.0000	46.0000	0.0000	11.4783	39.0000
4.0000	47.0000	0.0000	12.6809	24.0000
5.0000	55.0000	0.0000	11.6727	14.0000
6.0000	49.0000	11.0000	13.2449	25.0000
7.0000	48.0000	11.0000	14.4583	28.0000
8.0000	42.0000	11.0000	12.4524	23.0000
9.0000	49.0000	11.0000	13.1224	25.0000
10.0000	44.0000	11.0000	12.5455	16.0000
11.0000	44.0000	0.0000	11.4318	22.0000
12.0000	43.0000	0.0000	12.1395	26.0000
13.0000	46.0000	0.0000	7.3261	24.0000
14.0000	46.0000	0.0000	2.1522	22.0000
15.0000	44.0000	0.0000	0.2500	11.0000
16.0000	38.0000	0.0000	0.3158	12.0000
17.0000	39.0000	0.0000	0.5641	11.0000
18.0000	45.0000	0.0000	13.6222	22.0000
19.0000	44.0000	12.0000	14.0000	18.0000
20.0000	42.0000	0.0000	9.7619	15.0000
21.0000	38.0000	0.0000	0.9474	12.0000
22.0000	45.0000	0.0000	0.0000	0.0000
23.0000	44.0000	0.0000	0.0000	0.0000
24.0000	45.0000	0.0000	0.0000	0.0000
25.0000	45.0000	0.0000	0.0000	0.0000
26.0000	39.0000	0.0000	0.0000	0.0000
27.0000	40.0000	0.0000	0.0000	0.0000
28.0000	41.0000	0.0000	0.0000	0.0000
29.0000	39.0000	0.0000	0.0000	0.0000
30.0000	47.0000	0.0000	0.0000	0.0000
31.0000	45.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of August 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	2.4043	3.1367	0.5000	1.0000
2009.01	5.8968	5.2517	6.5419	1.3000	1.3000
2009.02	5.0527	4.4848	5.6206	0.7000	1.2000
2009.03	6.6724	6.4079	6.9370	0.3000	0.6000
2009.04	7.5227	7.2473	7.7981	0.4000	1.2000
2009.05	7.5722	7.2661	7.8783	1.6000	2.9000
2009.06	6.7056	6.3610	7.0501	3.2000	6.3000
2009.07	6.3999	6.1384	6.6614	3.6000	5.5000
2009.08	7.0852	6.7993	7.3711	0.0000	0.0000
2009.09	7.5250	7.2522	7.7977	4.5000	7.1000
2009.10	7.0293	6.6539	7.4047	4.5000	7.7000
2009.11	6.9900	6.7967	7.1834	3.3000	6.9000
2009.12	6.5069	6.3207	6.6931	10.4000	16.3000
2010.01	21.7661	19.2632	24.2689	13.3000	19.5000
2010.02	16.9267	14.5997	19.2538	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	18.5754	16.2472	20.9036	15.4000	24.0000
2010.04	20.6873	18.2236	23.1510	7.0000	10.4000
2010.05	24.6341	24.1961	25.0721	8.4000	8.7000
2010.06	20.4731	20.1325	20.8136	11.0000	13.6000
2010.07	21.4090	21.0982	21.7199	15.2000	16.1000
2010.08	22.9175	22.5413	23.2937	18.3000	19.6000
2010.09	25.2670	24.8505	25.6836	22.8000	25.2000
2010.10	23.8805	23.4680	24.2930	21.0000	23.5000
2010.11	24.3235	23.8817	24.7654	20.9000	21.6000
2010.12	21.7149	21.2765	22.1533	13.9000	14.5000
2011.01	77.3414	75.7400	78.9428	17.7000	18.7000
2011.02	65.4311	64.0366	66.8256	29.1000	29.6000
2011.03	69.8717	68.5360	71.2075	48.0000	55.8000
2011.04	78.6532	77.2409	80.0655	47.3000	54.4000
2011.05	79.3111	77.9708	80.6514	37.3000	41.5000
2011.06	65.8696	64.7162	67.0229	35.2000	37.0000
2011.07	68.1906	67.0243	69.3569	41.5000	43.8000
2011.08	73.8572	72.6696	75.0448	42.4000	50.5000
2011.09	80.0751	78.6904	81.4597	73.8000	78.0000
2011.10	75.6929	74.4197	76.9661	78.9000	88.0000
2011.11	76.8735	75.2704	78.4767	84.6000	96.7000
2011.12	67.5483	66.1578	68.9388	65.8000	73.0000
2012.01	82.9886	81.3549	84.6224	55.8000	58.2000
2012.02	69.0166	67.6115	70.4216	29.2000	33.1000
2012.03	74.3869	73.0693	75.7046	53.1000	64.1000
2012.04	82.5102	81.0674	83.9529	51.4000	55.2000
2012.05	84.8057	83.4087	86.2028	61.8000	69.0000
2012.06	69.7224	68.5389	70.9059	59.7000	64.5000
2012.07	72.5775	71.3881	73.7669	64.2000	51.3000
2012.08	75.8226	74.6062	77.0391	57.7000	63.1000
2012.09	82.7170	81.2823	84.1517	57.7000	61.5000
2012.10	79.0535	77.6076	80.4994	48.3000	53.3000
2012.11	80.2648	78.6536	81.8760	56.7000	61.4000
2012.12	70.7055	69.1709	72.2401	37.4000	40.8000
2013.01	92.2717	90.5075	94.0359	63.8000	62.9000
2013.02	76.8861	75.3380	78.4342	37.8000	38.0000
2013.03	80.2558	78.6231	81.8885	50.6000	57.9000
2013.04	89.9661	88.3840	91.5482	70.6000	72.4000
2013.05	90.3759	88.7672	91.9845	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	75.8327	74.4928	77.1726	51.0000	52.5000
2013.07	77.9515	76.7003	79.2027	57.0000	57.0000
2013.08	82.9928	81.6582	84.3274	60.0000	66.0000
2013.09	89.2494	87.6569	90.8420	34.6000	36.9000
2013.10	84.2489	82.6860	85.8117	74.5000	85.6000
2013.11	83.9976	82.1113	85.8838	73.9000	77.6000
2013.12	76.0938	74.4670	77.7205	77.8000	90.3000
2014.01	107.4937	105.2298	109.7575	77.4000	82.0000
2014.02	91.3607	89.5589	93.1626	93.9000	102.8000
2014.03	97.6041	95.8250	99.3832	80.9000	92.2000
2014.04	109.5720	107.6571	111.4869	76.9000	84.7000
2014.05	110.7577	108.8674	112.6480	72.3000	75.2000
2014.06	92.7416	91.1738	94.3093	67.2000	71.0000
2014.07	95.0211	93.4392	96.6029	72.5000	72.5000
2014.08	101.3258	99.7420	102.9096	71.2000	74.7000
2014.09	110.1044	108.1626	112.0462	83.2000	87.6000
2014.10	103.5952	101.6866	105.5039	59.5000	60.6000
2014.11	104.3689	102.1946	106.5433	65.8000	71.1000
2014.12	92.5803	90.4319	94.7287	75.8000	78.0000
2015.01	66.4460	65.1148	67.7773	65.9000	67.0000
2015.02	55.1170	53.9028	56.3312	42.4000	44.8000
2015.03	59.6523	58.5604	60.7442	38.0000	38.4000
2015.04	66.5476	65.3565	67.7388	49.0000	54.4000
2015.05	67.5728	66.4561	68.6896	56.3000	58.8000
2015.06	56.4567	55.4392	57.4742	50.2000	68.3000
2015.07	57.3654	56.3867	58.3442	47.9000	65.8000
2015.08	62.3798	61.3315	63.4281	39.5000	57.2000
2015.09	66.9238	65.7069	68.1406	49.2000	72.1000
2015.10	63.4699	62.2435	64.6963	39.3000	48.3000
2015.11	64.6285	63.2246	66.0325	39.6000	55.9000
2015.12	57.4021	56.1399	58.6643	36.4000	44.8000
2016.01	36.3958	35.6363	37.1553	33.7000	43.3000
2016.02	30.3131	29.6806	30.9456	38.3000	46.8000
2016.03	32.2810	31.6365	32.9255	30.5000	38.9000
2016.04	35.9154	35.2310	36.5999	26.6000	30.9000
2016.05	36.5466	35.8789	37.2142	33.7000	48.4000
2016.06	30.2085	29.6932	30.7239	13.1000	19.5000
2016.07	31.2380	30.7359	31.7402	21.2000	27.5000
2016.08	33.6305	33.0395	34.2215	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	36.9337	36.2600	37.6074	27.7000	37.1000
2016.10	34.6239	33.9567	35.2911	22.7000	31.7000
2016.11	34.8723	34.1436	35.6010	14.0000	22.2000
2016.12	31.3509	30.6804	32.0215	11.1000	20.0000
2017.01	19.7977	19.3811	20.2143	18.4000	26.2000
2017.02	16.5567	16.1931	16.9203	14.4000	20.6000
2017.03	17.7844	17.4457	18.1231	11.3000	15.5000
2017.04	19.9946	19.6419	20.3473	21.6000	33.2000
2017.05	20.0294	19.6840	20.3749	12.5000	18.1000
2017.06	16.5568	16.2808	16.8328	15.5000	19.3000
2017.07	17.2081	16.9344	17.4818	11.5000	16.3000
2017.08	18.4634	18.1422	18.7846	22.8000	35.7000
2017.09	20.6086	20.1775	21.0397	34.6000	42.9000
2017.10	18.8494	18.4668	19.2320	10.5000	11.0000
2017.11	18.8290	18.4352	19.2229	4.2000	5.6000
2017.12	16.8562	16.6012	17.1113	4.0000	4.6000
2018.01	5.4833	5.3655	5.6010	3.1000	6.3000
2018.02	4.5531	4.4416	4.6647	6.8000	11.8000
2018.03	4.8043	4.7090	4.8996	1.1000	1.2000
2018.04	5.3572	5.2495	5.4649	4.7000	7.5000
2018.05	5.4508	5.3479	5.5537	8.4000	14.0000
2018.06	4.5137	4.4344	4.5929	10.2000	13.6000
2018.07	4.6925	4.6402	4.7449	0.5000	1.7000
2018.08	4.9788	4.8937	5.0639	5.9000	9.5000
2018.09	5.3523	5.2532	5.4514	1.6000	2.9000
2018.10	5.1543	5.0548	5.2539	2.5000	5.6000
2018.11	5.1804	5.0747	5.2861	3.1000	4.2000
2018.12	4.7320	4.6408	4.8232	1.6000	2.3000
2019.01	3.6315	3.5635	3.6994	5.4000	2.3000
2019.02	3.0783	3.0185	3.1381	0.1000	1.2000
2019.03	3.2100	3.1557	3.2643	6.1000	12.1000
2019.04	3.6004	3.5333	3.6675	6.2000	9.3000
2019.05	3.5476	3.4860	3.6091	7.0000	11.9000
2019.06	2.9384	2.8889	2.9878	0.7000	1.5000
2019.07	3.0652	3.0194	3.1110	0.4000	2.2000
2019.08	3.3059	3.2567	3.3551	0.3000	0.8000
2019.09	3.6251	3.5676	3.6825	0.5000	1.0000
2019.10	3.3849	3.3264	3.4434	0.2000	0.5000
2019.11	3.4658	3.3990	3.5326	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	3.0696	3.0085	3.1306	0.8000	1.0000
2020.01	4.2060	4.1231	4.2889	4.0000	5.3000
2020.02	3.5216	3.4509	3.5922	0.1000	0.0000
2020.03	3.7139	3.6448	3.7830	1.2000	1.5000
2020.04	4.2146	4.1464	4.2829	3.0000	5.1000
2020.05	4.1925	4.1266	4.2583	0.1000	0.4000
2020.06	3.4993	3.4453	3.5534	3.9000	6.4000
2020.07	3.5934	3.5400	3.6468	4.2000	7.7000
2020.08	3.8193	3.7670	3.8716	5.3000	7.8000

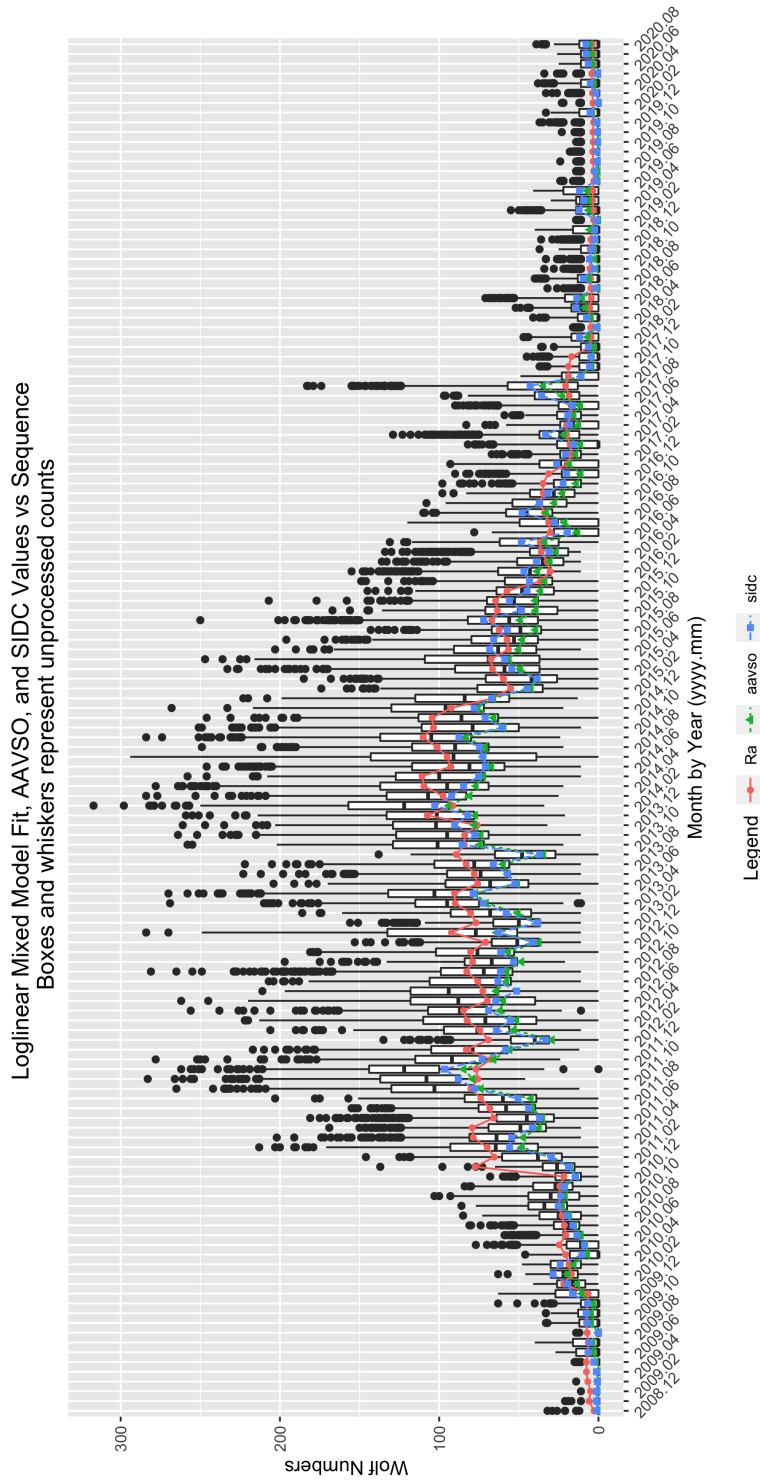


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202008 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4674	0.3056	4.8011	0.0000
seeF	-0.2178	0.0057	-37.9270	0.0000
seeG	-0.1169	0.0050	-23.3696	0.0000
seeM	-0.2008	0.0237	-8.4709	0.0000
seeP	-0.3226	0.0082	-39.2307	0.0000
sidc1	0.1377	0.0667	2.0636	0.0391
year2009	0.6377	0.3065	2.0805	0.0375
year2010	1.8468	0.3044	6.0671	0.0000
year2011	2.9654	0.3043	9.7451	0.0000
year2012	3.0023	0.3043	9.8665	0.0000
year2013	3.0981	0.3043	10.1815	0.0000
year2014	3.2950	0.3043	10.8286	0.0000
year2015	2.8102	0.3043	9.2348	0.0000
year2016	2.1934	0.3043	7.2073	0.0000
year2017	1.5881	0.3044	5.2177	0.0000
year2018	0.2913	0.3047	0.9561	0.3390
year2019	-0.1341	0.3049	-0.4397	0.6602
year2020	0.0267	0.3050	0.0875	0.9303
mon2	-0.1735	0.0091	-19.1490	0.0000
mon3	-0.1150	0.0085	-13.5918	0.0000
mon4	-0.0099	0.0082	-1.2143	0.2246
mon5	-0.0051	0.0080	-0.6406	0.5218
mon6	-0.1929	0.0084	-22.9722	0.0000
mon7	-0.1670	0.0082	-20.4550	0.0000
mon8	-0.0945	0.0080	-11.8350	0.0000
mon9	-0.0035	0.0081	-0.4343	0.6641
mon10	-0.0581	0.0083	-7.0197	0.0000
mon11	-0.0364	0.0086	-4.2096	0.0000
mon12	-0.1461	0.0088	-16.5769	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: 202008 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:130734	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 : 6.559	Mean :15.73		Mean :0.2576
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: 202008 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:130734	Length:130734
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 8.00	Median : 30.00	Mode :character	Mode :character
Mean : 2.786	Mean : 16.52	Mean : 44.38		
3rd Qu.: 5.000	3rd Qu.: 25.00	3rd Qu.: 72.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202008 Summary of Sunspot Numbers

inst	filter	unit
Length:130734	Length:130734	Length:130734
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202008 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 : 89.48	Mean : 30.14	Mean : 873.4	Mean : 184.3
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

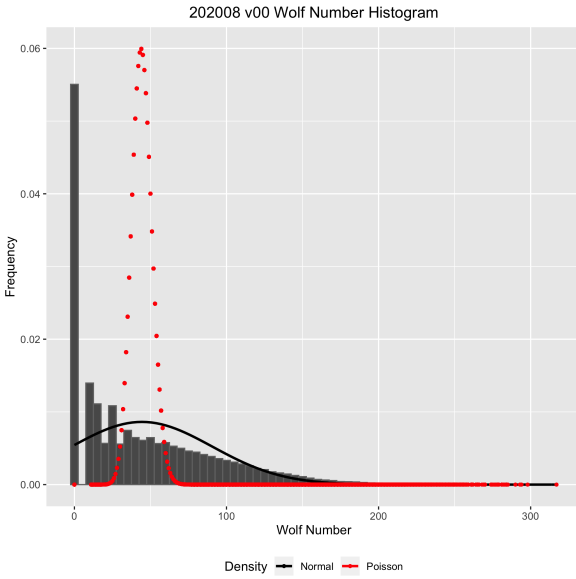


Figure 3: Box plots of raw Wolf number (w) by observer rank.

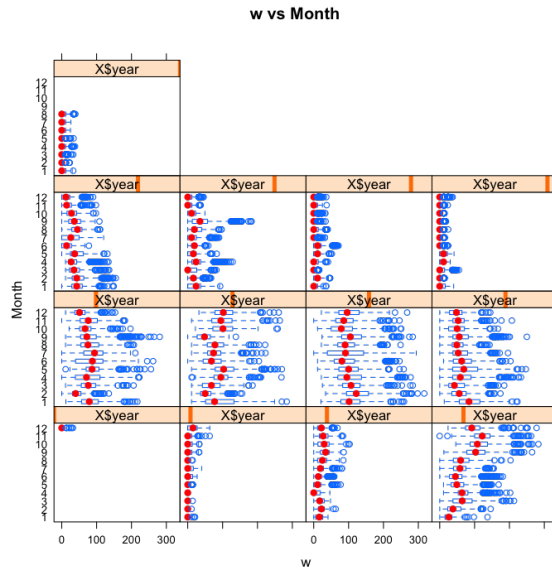


Figure 4: Box plots of raw Wolf number (w) by month and year.

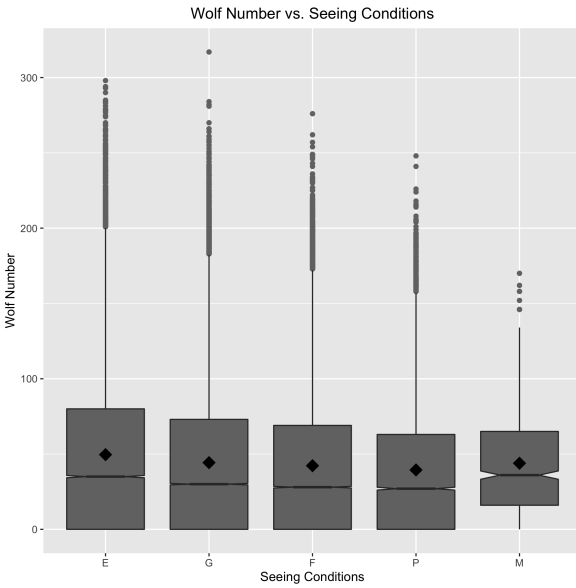


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

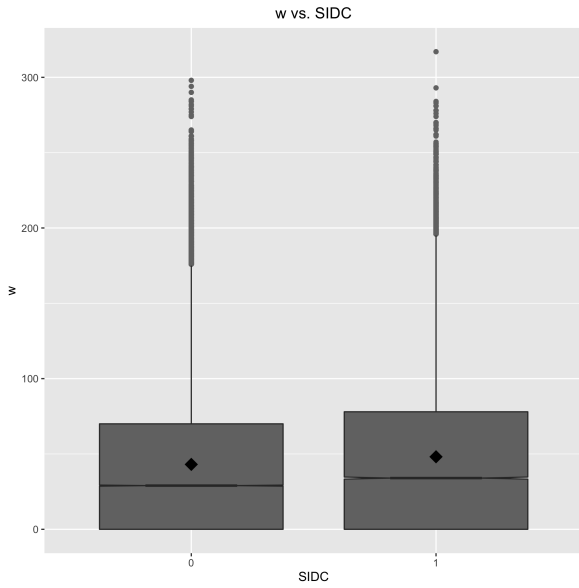


Figure 6: Box plots of raw Wolf number (w) by organization.

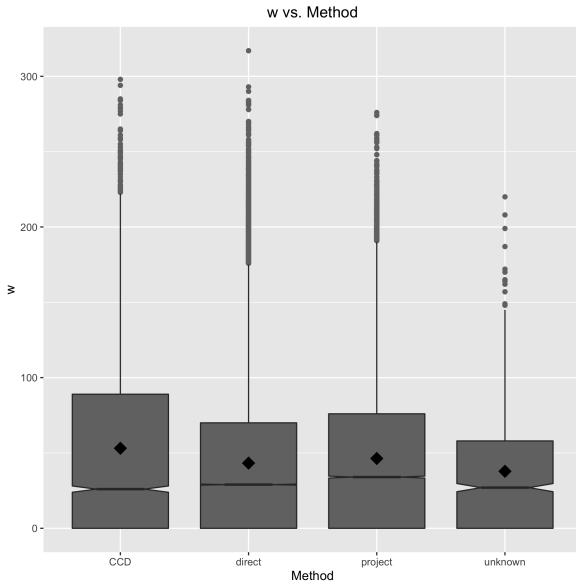


Figure 7: Box plots of raw Wolf number (w) by observer rank.

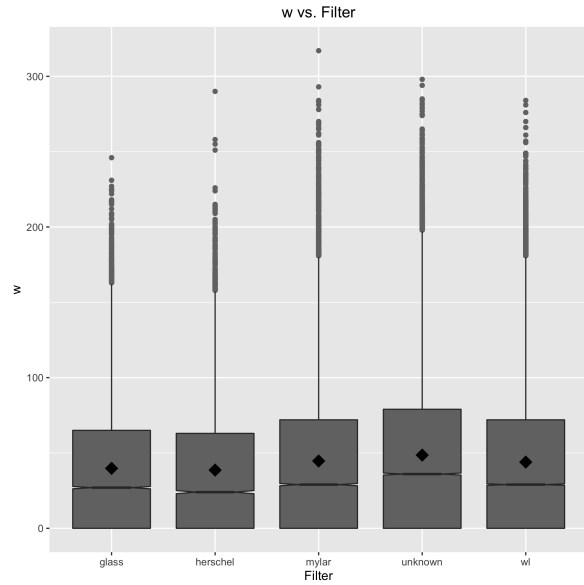


Figure 8: Box plots of raw Wolf number (w) by month and year.

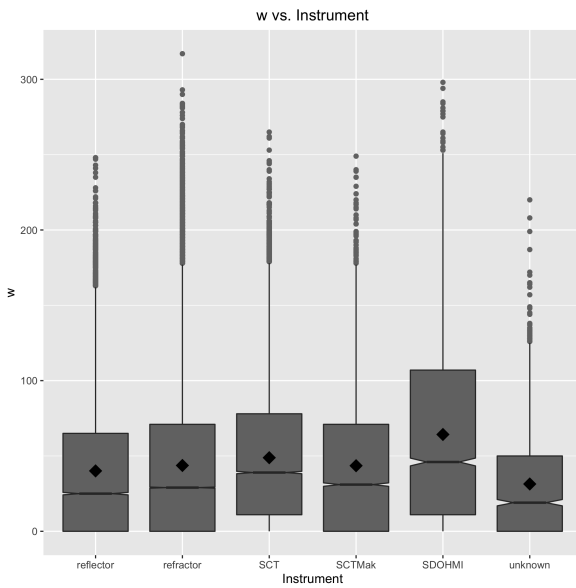


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

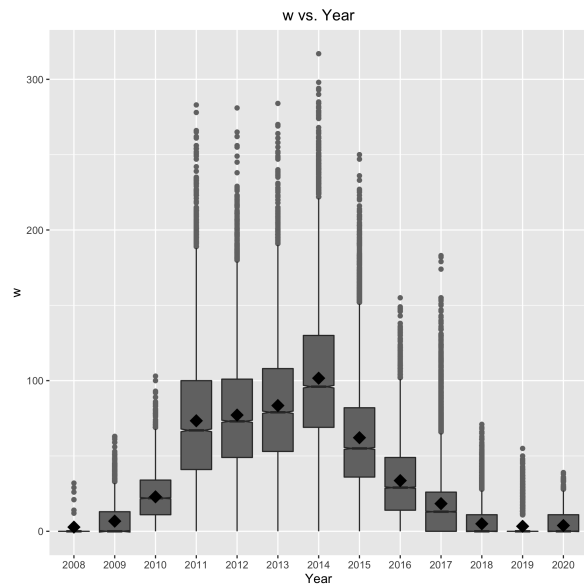


Figure 10: Box plots of raw Wolf number (w) by organization.

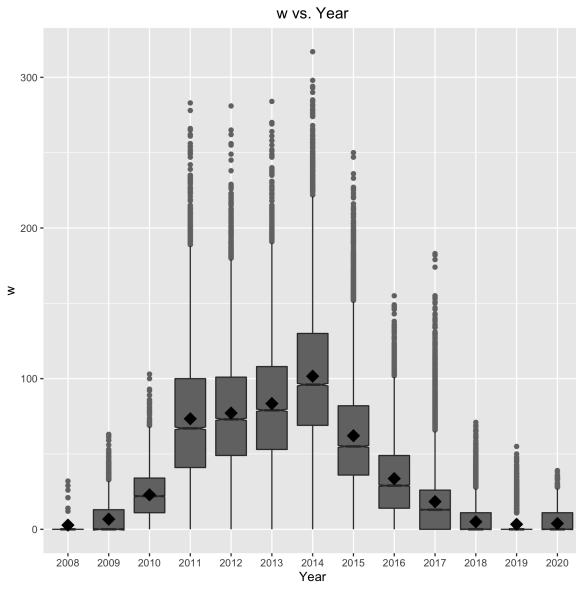


Figure 11: Box plots of raw Wolf number (w) by year.

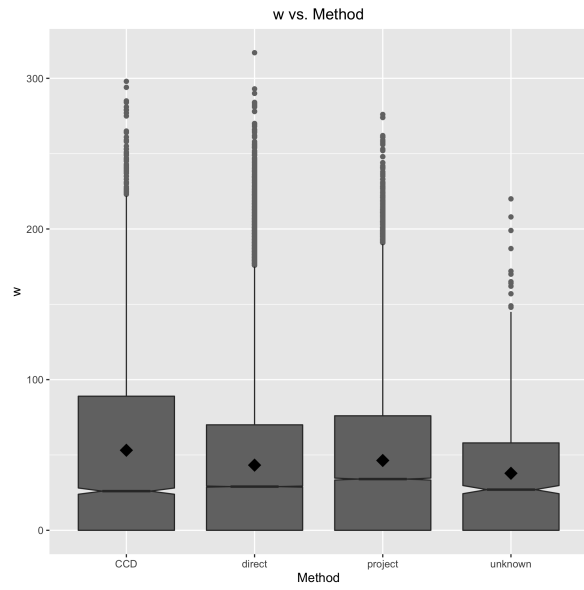


Figure 12: Box plots of raw Wolf number (w) by observing method.