

Monthly Report (00)

2021.09 Data Set

Thursday 14th October, 2021

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.

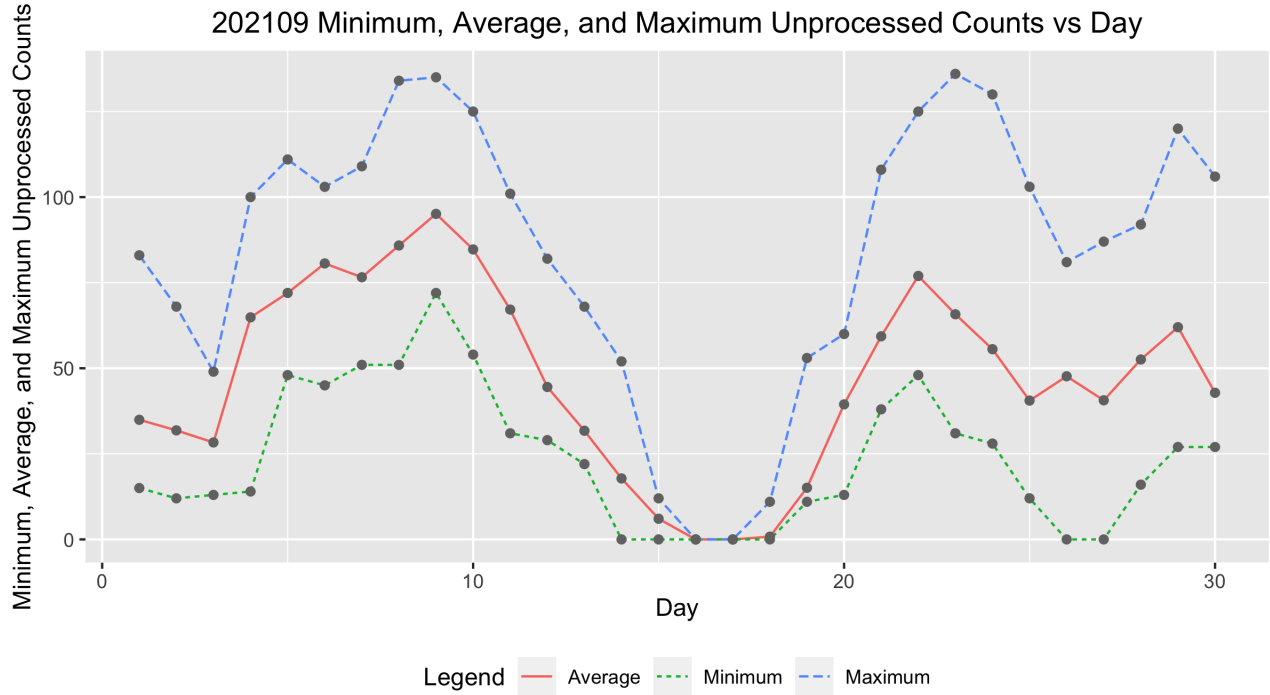


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202109 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	38.0000	15.0000	34.9474	83.0000
2.0000	43.0000	12.0000	31.8605	68.0000
3.0000	46.0000	13.0000	28.3261	49.0000
4.0000	47.0000	14.0000	64.8723	100.0000
5.0000	46.0000	48.0000	72.0000	111.0000
6.0000	48.0000	45.0000	80.6250	103.0000
7.0000	46.0000	51.0000	76.5870	109.0000
8.0000	45.0000	51.0000	85.8667	134.0000
9.0000	40.0000	72.0000	95.1000	135.0000
10.0000	42.0000	54.0000	84.7143	125.0000
11.0000	43.0000	31.0000	67.1395	101.0000
12.0000	45.0000	29.0000	44.5333	82.0000
13.0000	39.0000	22.0000	31.7436	68.0000
14.0000	33.0000	0.0000	17.8182	52.0000
15.0000	26.0000	0.0000	6.0385	12.0000
16.0000	32.0000	0.0000	0.0000	0.0000
17.0000	35.0000	0.0000	0.0000	0.0000
18.0000	41.0000	0.0000	0.8049	11.0000
19.0000	44.0000	11.0000	15.0909	53.0000
20.0000	40.0000	13.0000	39.4500	60.0000
21.0000	39.0000	38.0000	59.3333	108.0000
22.0000	38.0000	48.0000	76.9737	125.0000
23.0000	40.0000	31.0000	65.7750	136.0000
24.0000	42.0000	28.0000	55.5714	130.0000
25.0000	41.0000	12.0000	40.5610	103.0000
26.0000	41.0000	0.0000	47.6585	81.0000
27.0000	36.0000	0.0000	40.6389	87.0000
28.0000	39.0000	16.0000	52.5641	92.0000
29.0000	41.0000	27.0000	62.0000	120.0000
30.0000	37.0000	27.0000	42.8378	106.0000

3 Error Tables

Data are for the month of September 2021. 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	2.4115	3.1295	0.5000	1.0000
2009.01	5.5463	4.9516	6.1410	1.3000	1.3000
2009.02	4.7561	4.2320	5.2803	0.7000	1.2000
2009.03	6.3464	6.1020	6.5908	0.3000	0.6000
2009.04	7.2554	6.9982	7.5127	0.4000	1.2000
2009.05	7.2472	6.9641	7.5303	1.6000	2.9000
2009.06	6.5527	6.2225	6.8828	3.2000	6.3000
2009.07	6.3204	6.0680	6.5728	3.6000	5.5000
2009.08	6.8254	6.5609	7.0900	0.0000	0.0000
2009.09	7.5825	7.3158	7.8491	4.5000	7.1000
2009.10	6.9499	6.5883	7.3116	4.5000	7.7000
2009.11	7.2017	7.0055	7.3979	3.3000	6.9000
2009.12	6.5985	6.4128	6.7843	10.4000	16.3000
2010.01	20.7108	18.3751	23.0465	13.3000	19.5000
2010.02	16.1208	13.9498	18.2917	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	17.9698	15.7629	20.1768	15.4000	24.0000
2010.04	20.2809	17.9145	22.6473	7.0000	10.4000
2010.05	23.9009	23.4807	24.3210	8.4000	8.7000
2010.06	20.2817	19.9457	20.6178	11.0000	13.6000
2010.07	21.4108	21.1005	21.7212	15.2000	16.1000
2010.08	22.3614	21.9957	22.7271	18.3000	19.6000
2010.09	25.7840	25.3621	26.2058	22.8000	25.2000
2010.10	23.9144	23.5044	24.3245	21.0000	23.5000
2010.11	25.3076	24.8523	25.7630	20.9000	21.6000
2010.12	22.2863	21.8441	22.7285	13.9000	14.5000
2011.01	74.2209	72.7209	75.7210	17.7000	18.7000
2011.02	62.8890	61.5860	64.1921	29.1000	29.6000
2011.03	68.0588	66.7670	69.3506	48.0000	55.8000
2011.04	77.7049	76.3124	79.0973	47.3000	54.4000
2011.05	77.7404	76.4405	79.0404	37.3000	41.5000
2011.06	65.9367	64.7922	67.0813	35.2000	37.0000
2011.07	68.8750	67.7080	70.0419	41.5000	43.8000
2011.08	72.7674	71.6074	73.9274	42.4000	50.5000
2011.09	82.5158	81.0994	83.9322	73.8000	78.0000
2011.10	76.6091	75.3291	77.8891	78.9000	88.0000
2011.11	80.8422	79.1737	82.5107	84.6000	96.7000
2011.12	69.9762	68.5505	71.4020	65.8000	73.0000
2012.01	79.6488	78.0876	81.2100	55.8000	58.2000
2012.02	66.2630	64.9196	67.6063	29.2000	33.1000
2012.03	72.5273	71.2476	73.8069	53.1000	64.1000
2012.04	81.5412	80.1148	82.9676	51.4000	55.2000
2012.05	83.1998	81.8329	84.5667	61.8000	69.0000
2012.06	69.8710	68.6913	71.0508	59.7000	64.5000
2012.07	73.4735	72.2741	74.6729	64.2000	51.3000
2012.08	74.8210	73.6223	76.0197	57.7000	63.1000
2012.09	85.4177	83.9390	86.8963	57.7000	61.5000
2012.10	80.0924	78.6315	81.5533	48.3000	53.3000
2012.11	84.5704	82.8749	86.2658	56.7000	61.4000
2012.12	73.3859	71.7980	74.9739	37.4000	40.8000
2013.01	88.4962	86.8074	90.1849	63.8000	62.9000
2013.02	73.7901	72.3081	75.2721	37.8000	38.0000
2013.03	78.2357	76.6427	79.8287	50.6000	57.9000
2013.04	88.9254	87.3603	90.4906	70.6000	72.4000
2013.05	88.6505	87.0700	90.2309	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	76.0060	74.6638	77.3482	51.0000	52.5000
2013.07	78.8813	77.6141	80.1486	57.0000	57.0000
2013.08	81.9636	80.6435	83.2836	60.0000	66.0000
2013.09	92.1469	90.5013	93.7926	34.6000	36.9000
2013.10	85.4087	83.8238	86.9937	74.5000	85.6000
2013.11	88.5509	86.5603	90.5414	73.9000	77.6000
2013.12	78.9996	77.3105	80.6887	77.8000	90.3000
2014.01	103.1551	100.9845	105.3256	77.4000	82.0000
2014.02	87.7527	86.0222	89.4833	93.9000	102.8000
2014.03	95.2675	93.5300	97.0051	80.9000	92.2000
2014.04	108.4532	106.5535	110.3529	76.9000	84.7000
2014.05	108.7473	106.8932	110.6013	72.3000	75.2000
2014.06	93.0067	91.4367	94.5768	67.2000	71.0000
2014.07	96.2104	94.6073	97.8135	72.5000	72.5000
2014.08	100.1184	98.5569	101.6800	71.2000	74.7000
2014.09	113.7889	111.7823	115.7955	83.2000	87.6000
2014.10	105.0400	103.1076	106.9724	59.5000	60.6000
2014.11	110.1361	107.8506	112.4217	65.8000	71.1000
2014.12	96.1279	93.9056	98.3502	75.8000	78.0000
2015.01	63.7278	62.4563	64.9993	65.9000	67.0000
2015.02	52.9363	51.7723	54.1002	42.4000	44.8000
2015.03	58.1915	57.1305	59.2525	38.0000	38.4000
2015.04	65.8691	64.6984	67.0397	49.0000	54.4000
2015.05	66.2978	65.2066	67.3890	56.3000	58.8000
2015.06	56.6159	55.6045	57.6273	50.2000	68.3000
2015.07	58.0728	57.0903	59.0554	47.9000	65.8000
2015.08	61.5662	60.5396	62.5927	39.5000	57.2000
2015.09	69.1503	67.9007	70.4000	49.2000	72.1000
2015.10	64.2945	63.0587	65.5304	39.3000	48.3000
2015.11	68.0416	66.5672	69.5160	39.6000	55.9000
2015.12	59.4929	58.1828	60.8029	36.4000	44.8000
2016.01	34.9061	34.1815	35.6306	33.7000	43.3000
2016.02	29.0960	28.4915	29.7004	38.3000	46.8000
2016.03	31.4639	30.8386	32.0892	30.5000	38.9000
2016.04	35.5066	34.8335	36.1797	26.6000	30.9000
2016.05	35.8520	35.2009	36.5030	33.7000	48.4000
2016.06	30.2568	29.7428	30.7709	13.1000	19.5000
2016.07	31.6087	31.1044	32.1130	21.2000	27.5000
2016.08	33.1745	32.5948	33.7542	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	38.1207	37.4296	38.8119	27.7000	37.1000
2016.10	35.0838	34.4123	35.7553	22.7000	31.7000
2016.11	36.7382	35.9746	37.5019	14.0000	22.2000
2016.12	32.5194	31.8251	33.2137	11.1000	20.0000
2017.01	18.9465	18.5492	19.3438	18.4000	26.2000
2017.02	15.8586	15.5114	16.2057	14.4000	20.6000
2017.03	17.3026	16.9743	17.6309	11.3000	15.5000
2017.04	19.7165	19.3706	20.0625	21.6000	33.2000
2017.05	19.5990	19.2622	19.9358	12.5000	18.1000
2017.06	16.5350	16.2602	16.8099	15.5000	19.3000
2017.07	17.3438	17.0672	17.6203	11.5000	16.3000
2017.08	18.1584	17.8408	18.4759	22.8000	35.7000
2017.09	21.2391	20.7859	21.6923	34.6000	42.9000
2017.10	19.0237	18.6306	19.4168	10.5000	11.0000
2017.11	19.7592	19.3407	20.1777	4.2000	5.6000
2017.12	17.4062	17.1413	17.6711	4.0000	4.6000
2018.01	5.2626	5.1510	5.3742	3.1000	6.3000
2018.02	4.3630	4.2581	4.4680	6.8000	11.8000
2018.03	4.6816	4.5871	4.7760	1.1000	1.2000
2018.04	5.2825	5.1775	5.3875	4.7000	7.5000
2018.05	5.3343	5.2353	5.4333	8.4000	14.0000
2018.06	4.5183	4.4390	4.5976	10.2000	13.6000
2018.07	4.7412	4.6876	4.7948	0.5000	1.7000
2018.08	4.9109	4.8274	4.9945	5.9000	9.5000
2018.09	5.5294	5.4260	5.6328	1.6000	2.9000
2018.10	5.2157	5.1136	5.3179	2.5000	5.6000
2018.11	5.4428	5.3295	5.5560	3.1000	4.2000
2018.12	4.8936	4.7981	4.9890	1.6000	2.3000
2019.01	3.4727	3.4068	3.5386	5.4000	2.3000
2019.02	2.9474	2.8896	3.0051	0.1000	1.2000
2019.03	3.1242	3.0710	3.1774	6.1000	12.1000
2019.04	3.5536	3.4865	3.6207	6.2000	9.3000
2019.05	3.4746	3.4143	3.5349	7.0000	11.9000
2019.06	2.9495	2.9001	2.9988	0.7000	1.5000
2019.07	3.0999	3.0539	3.1459	0.4000	2.2000
2019.08	3.2619	3.2139	3.3099	0.3000	0.8000
2019.09	3.7517	3.6933	3.8101	0.5000	1.0000
2019.10	3.4403	3.3825	3.4981	0.2000	0.5000
2019.11	3.6564	3.5871	3.7256	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	3.1984	3.1358	3.2611	0.8000	1.0000
2020.01	7.6847	7.5353	7.8342	4.0000	5.3000
2020.02	6.4353	6.3075	6.5631	0.1000	0.0000
2020.03	6.8899	6.7619	7.0178	1.2000	1.5000
2020.04	7.8898	7.7609	8.0186	3.0000	5.1000
2020.05	7.7976	7.6762	7.9190	0.1000	0.4000
2020.06	6.6641	6.5628	6.7653	3.9000	6.4000
2020.07	6.8928	6.7919	6.9937	4.2000	7.7000
2020.08	7.1359	7.0383	7.2334	5.3000	7.8000
2020.09	8.1906	8.0606	8.3205	0.4000	0.9000
2020.10	7.6933	7.5685	7.8182	9.9000	13.6000
2020.11	8.1532	8.0262	8.2803	21.2000	33.1000
2020.12	7.1917	7.0697	7.3137	15.4000	19.8000
2021.01	22.7543	22.3667	23.1420	7.0000	15.8000
2021.02	19.3537	19.0164	19.6910	5.8000	10.7000
2021.03	20.9153	20.5904	21.2402	11.0000	17.2000
2021.04	23.9185	23.5649	24.2722	18.5000	28.8000
2021.05	23.8638	23.5320	24.1956	15.9000	22.9000
2021.06	20.5231	20.2159	20.8304	19.9000	24.1000
2021.07	21.2681	20.9239	21.6124	23.8000	35.6000
2021.08	22.5451	22.1864	22.9039	15.7000	19.5000
2021.09	25.9407	25.4991	26.3823	39.1000	52.5000

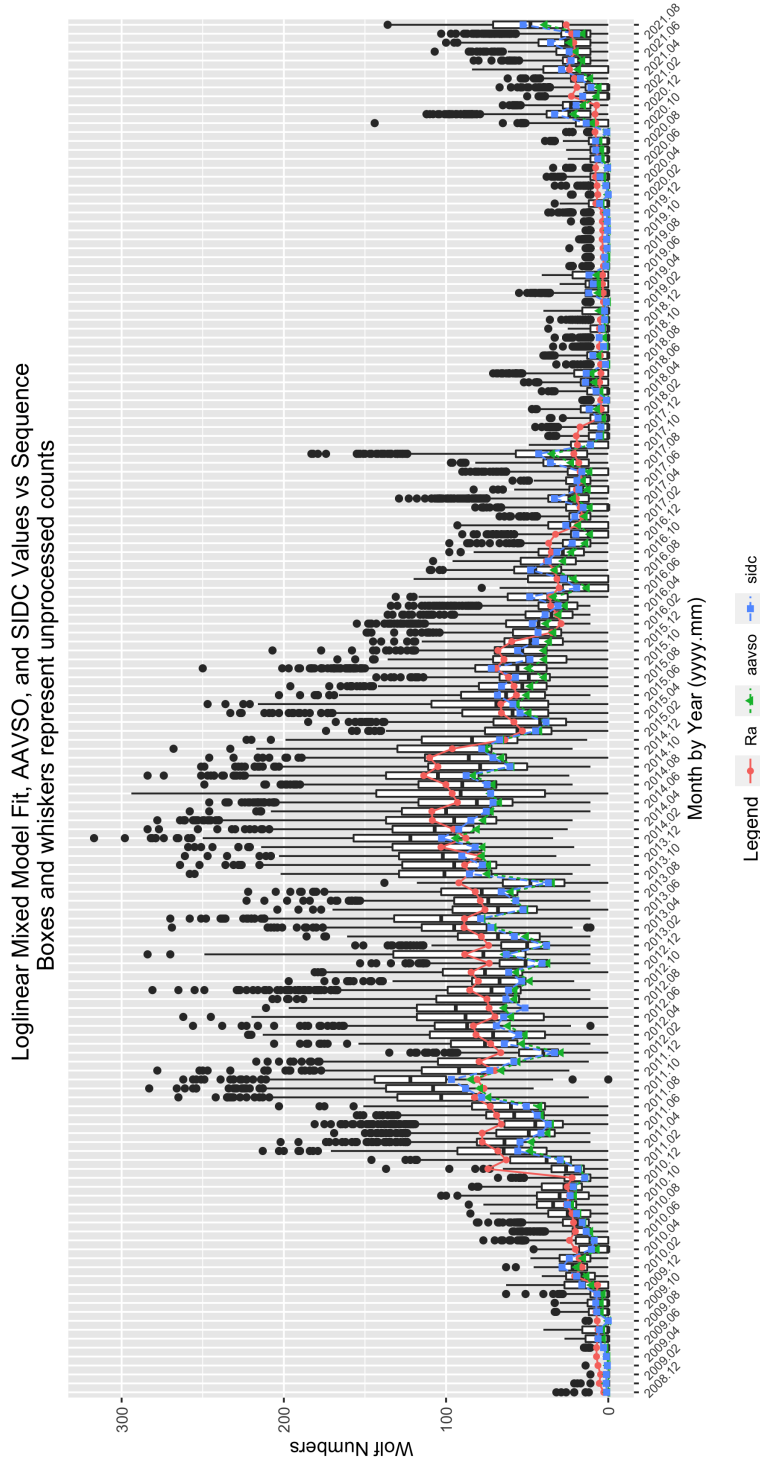


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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.

Table 3: 202109 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t)$
(Intercept)	1.4222	0.3122	4.5547	0.0000
seeF	-0.2213	0.0057	-38.6995	0.0000
seeG	-0.1222	0.0050	-24.4872	0.0000
seeM	-0.2001	0.0241	-8.2876	0.0000
seeP	-0.3203	0.0082	-39.1922	0.0000
sidc1	-0.0179	0.0240	-0.7451	0.4562
year2009	0.6540	0.3133	2.0874	0.0368
year2010	1.8754	0.3111	6.0272	0.0000
year2011	3.0055	0.3110	9.6624	0.0000
year2012	3.0442	0.3110	9.7872	0.0000
year2013	3.1401	0.3110	10.0954	0.0000
year2014	3.3371	0.3110	10.7288	0.0000
year2015	2.8518	0.3111	9.1682	0.0000
year2016	2.2352	0.3111	7.1851	0.0000
year2017	1.6280	0.3111	5.2326	0.0000
year2018	0.3384	0.3114	1.0867	0.2772
year2019	-0.0842	0.3116	-0.2701	0.7871
year2020	0.7197	0.3113	2.3122	0.0208
year2021	1.8205	0.3112	5.8505	0.0000
mon2	-0.1729	0.0091	-18.8953	0.0000
mon3	-0.0987	0.0085	-11.5988	0.0000
mon4	0.0200	0.0082	2.4409	0.0147
mon5	0.0170	0.0081	2.1053	0.0353
mon6	-0.1491	0.0084	-17.7478	0.0000
mon7	-0.1137	0.0082	-13.9218	0.0000
mon8	-0.0661	0.0080	-8.2247	0.0000
mon9	0.0702	0.0080	8.7660	0.0000
mon10	-0.0031	0.0084	-0.3722	0.7097
mon11	0.0576	0.0086	6.6670	0.0000
mon12	-0.0673	0.0088	-7.6036	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 contribute to both institutions tend to differ from those observers contributing only to the AAVSO.

5 Supporting Information

Table 4: 202109 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:146607	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 : 6.571	Mean :15.72		Mean :0.2506
3rd Qu.:2019	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2021	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202109 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:146607	Length:146607
1st Qu.: 0.000	1st Qu.: 0.00	1st Qu.: 0.00	Class :character	Class :character
Median : 2.000	Median : 7.00	Median : 27.00	Mode :character	Mode :character
Mean : 2.635	Mean : 15.41	Mean : 41.76		
3rd Qu.: 4.000	3rd Qu.: 23.00	3rd Qu.: 67.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202109 Summary of Sunspot Numbers

inst	filter	unit
Length:146607	Length:146607	Length:146607
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202109 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.: 4.00	1st Qu.: 34.0	1st Qu.: 40.0
Median : 80.00	Median : 14.00	Median : 900.0	Median : 57.5
Mean : 91.24	Mean : 33.72	Mean : 887.8	Mean : 181.9
3rd Qu.: 104.00	3rd Qu.: 23.00	3rd Qu.:1200.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :9990.0	Max. :4591.0

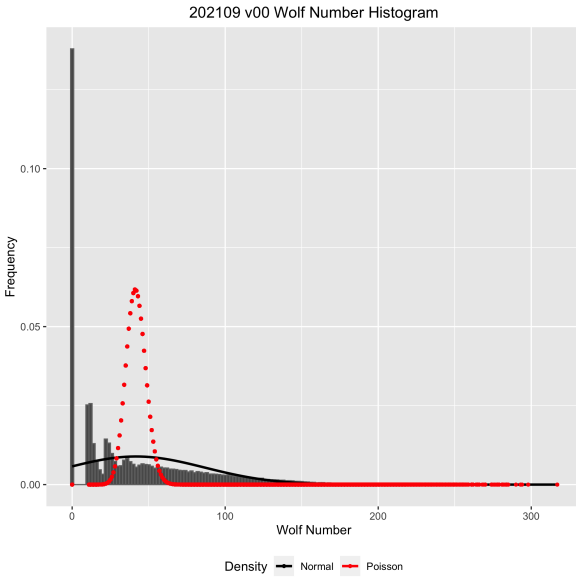


Figure 3: Box plots of raw Wolf number (w) by observer rank.

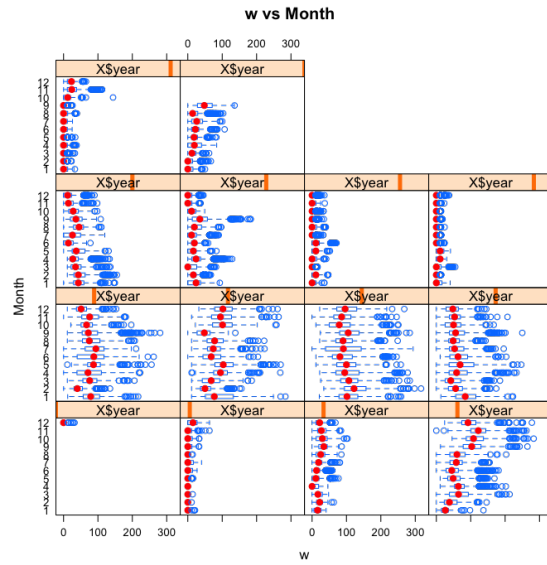


Figure 4: Box plots of raw Wolf number (w) by month and year.

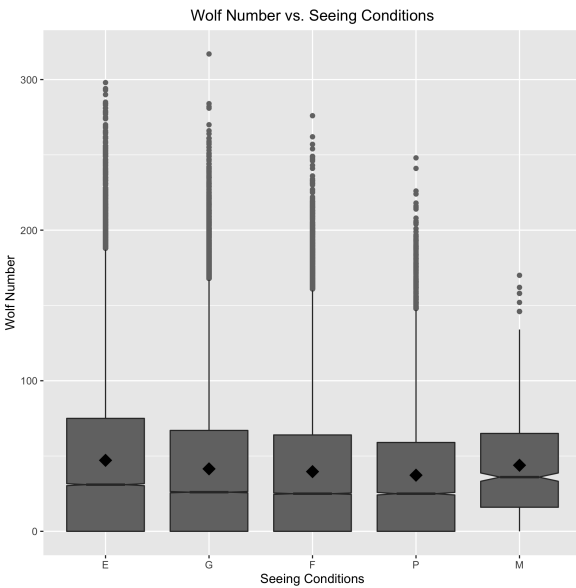


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

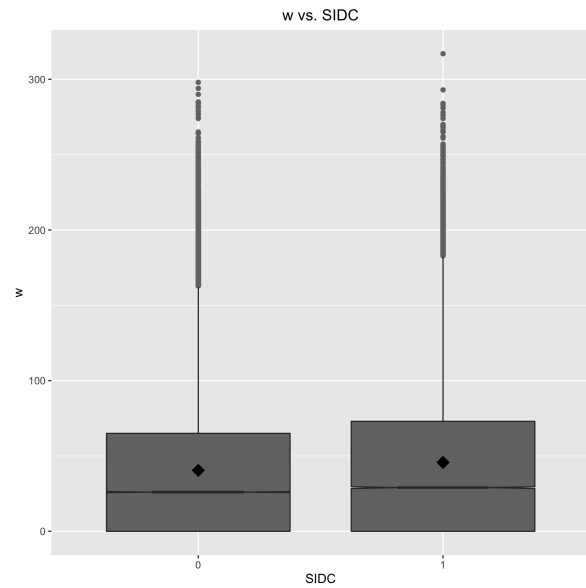


Figure 6: Box plots of raw Wolf number (w) by organization.

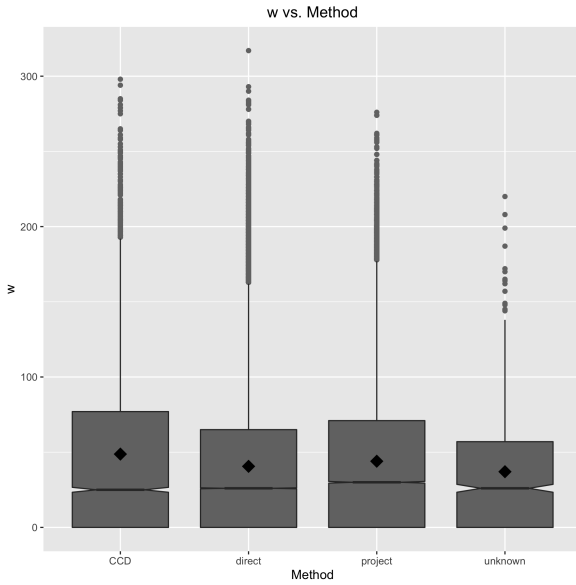


Figure 7: Box plots of raw Wolf number (w) by observer rank.

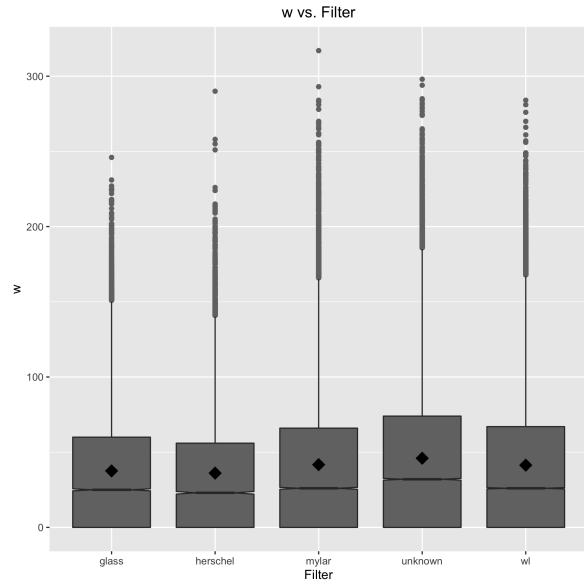


Figure 8: Box plots of raw Wolf number (w) by month and year.

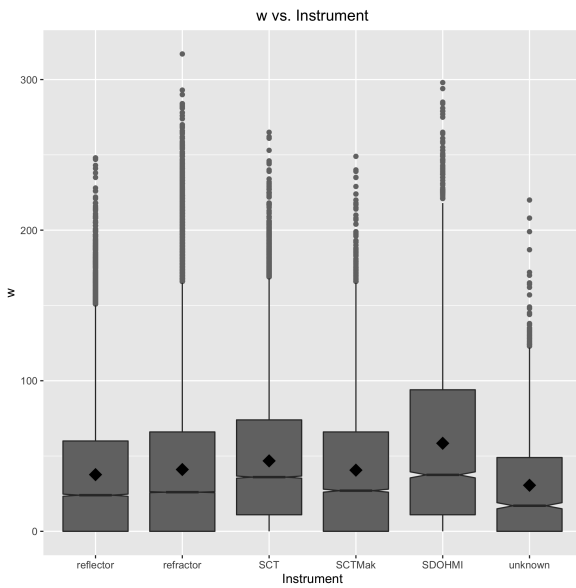


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

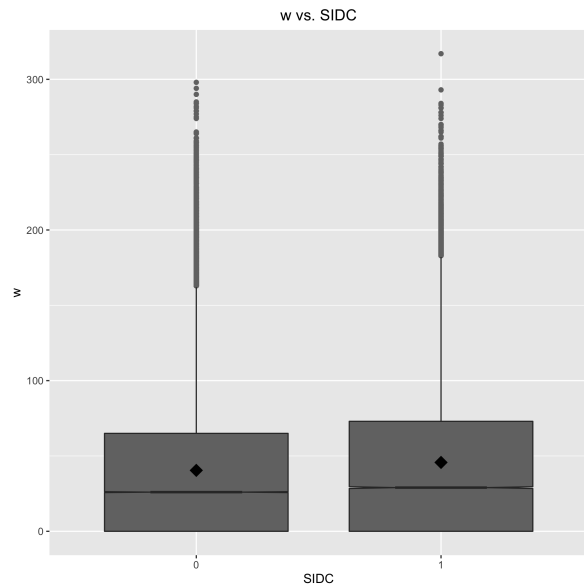


Figure 10: Box plots of raw Wolf number (w) by organization.

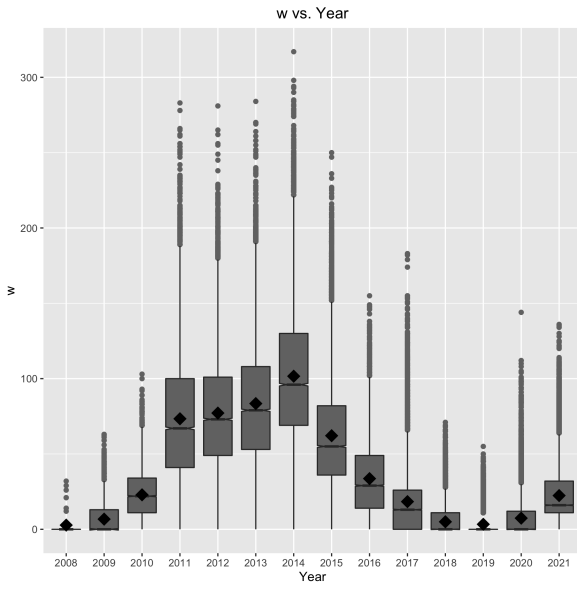


Figure 11: Box plots of raw Wolf number (w) by year.

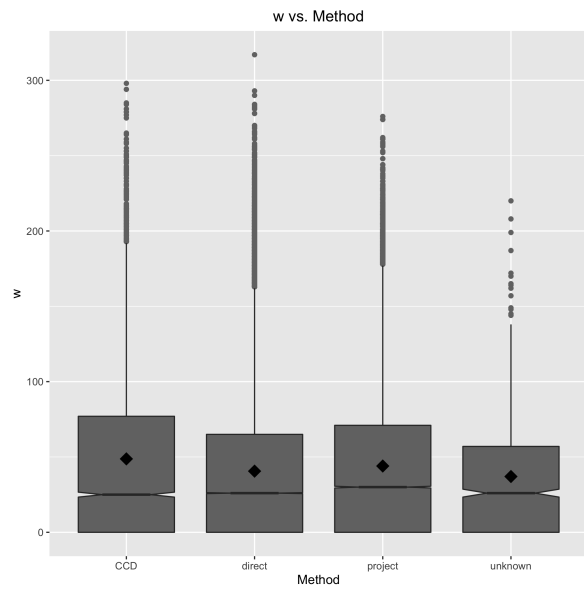


Figure 12: Box plots of raw Wolf number (w) by observing method.