

**Monthly Report (00)**  
**202110 Data Set**

**Monday 15<sup>th</sup> November, 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.

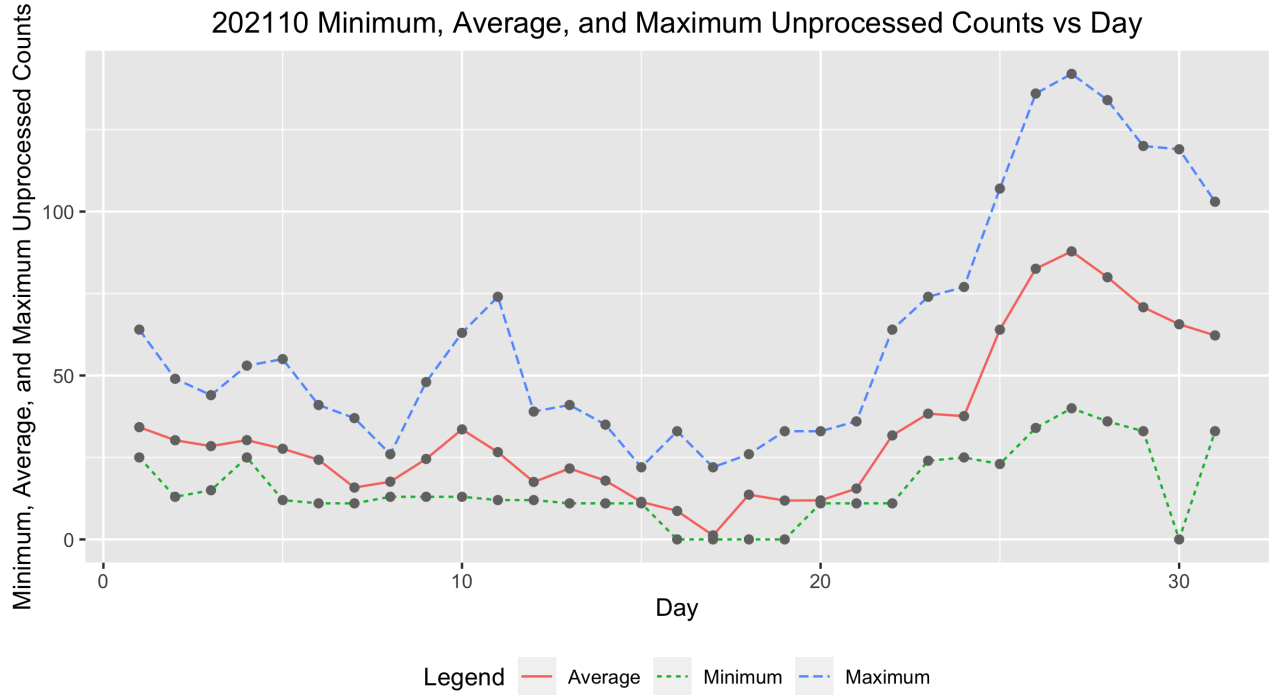


Figure 1: Raw average sunspot count by day of the month.

Table 1: 202110 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	46.0000	25.0000	34.2391	64.0000
2.0000	39.0000	13.0000	30.2564	49.0000
3.0000	35.0000	15.0000	28.4571	44.0000
4.0000	36.0000	25.0000	30.2778	53.0000
5.0000	38.0000	12.0000	27.6579	55.0000
6.0000	35.0000	11.0000	24.2857	41.0000
7.0000	40.0000	11.0000	15.8250	37.0000
8.0000	41.0000	13.0000	17.6098	26.0000
9.0000	42.0000	13.0000	24.5476	48.0000
10.0000	45.0000	13.0000	33.5556	63.0000
11.0000	39.0000	12.0000	26.6154	74.0000
12.0000	38.0000	12.0000	17.5263	39.0000
13.0000	41.0000	11.0000	21.6341	41.0000
14.0000	41.0000	11.0000	17.9268	35.0000
15.0000	41.0000	11.0000	11.4634	22.0000
16.0000	46.0000	0.0000	8.6739	33.0000
17.0000	36.0000	0.0000	1.2222	22.0000
18.0000	40.0000	0.0000	13.6500	26.0000
19.0000	41.0000	0.0000	11.8537	33.0000
20.0000	40.0000	11.0000	11.9000	33.0000
21.0000	37.0000	11.0000	15.5135	36.0000
22.0000	35.0000	11.0000	31.7143	64.0000
23.0000	40.0000	24.0000	38.3500	74.0000
24.0000	45.0000	25.0000	37.6000	77.0000
25.0000	35.0000	23.0000	63.9714	107.0000
26.0000	34.0000	34.0000	82.5588	136.0000
27.0000	40.0000	40.0000	87.8500	142.0000
28.0000	42.0000	36.0000	79.9762	134.0000
29.0000	37.0000	33.0000	70.8108	120.0000
30.0000	27.0000	0.0000	65.6296	119.0000
31.0000	32.0000	33.0000	62.2188	103.0000

### 3 Error Tables

Data are for the month of October 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 25<sup>th</sup> through the 75<sup>th</sup> quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25<sup>th</sup> quartile, and 1.5 times the IQR above the 75<sup>th</sup> 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	2.4124	3.1285	0.5000	1.0000
2009.01	5.5379	4.9458	6.1301	1.3000	1.3000
2009.02	4.7484	4.2265	5.2704	0.7000	1.2000
2009.03	6.3314	6.0887	6.5742	0.3000	0.6000
2009.04	7.2398	6.9844	7.4952	0.4000	1.2000
2009.05	7.2327	6.9514	7.5139	1.6000	2.9000
2009.06	6.5386	6.2103	6.8669	3.2000	6.3000
2009.07	6.3097	6.0585	6.5609	3.6000	5.5000
2009.08	6.8153	6.5525	7.0780	0.0000	0.0000
2009.09	7.5693	7.3043	7.8343	4.5000	7.1000
2009.10	7.0678	6.7012	7.4343	4.5000	7.7000
2009.11	7.2028	7.0068	7.3988	3.3000	6.9000
2009.12	6.5992	6.4138	6.7847	10.4000	16.3000
2010.01	20.6650	18.3407	22.9892	13.3000	19.5000
2010.02	16.0821	13.9225	18.2417	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	17.9300	15.7338	20.1262	15.4000	24.0000
2010.04	20.2361	17.8813	22.5910	7.0000	10.4000
2010.05	23.8376	23.4191	24.2561	8.4000	8.7000
2010.06	20.2262	19.8911	20.5613	11.0000	13.6000
2010.07	21.3593	21.0496	21.6689	15.2000	16.1000
2010.08	22.3086	21.9437	22.6735	18.3000	19.6000
2010.09	25.7213	25.3006	26.1420	22.8000	25.2000
2010.10	24.3027	23.8860	24.7195	21.0000	23.5000
2010.11	25.2917	24.8369	25.7465	20.9000	21.6000
2010.12	22.2739	21.8323	22.7154	13.9000	14.5000
2011.01	74.0503	72.5548	75.5458	17.7000	18.7000
2011.02	62.7322	61.4332	64.0313	29.1000	29.6000
2011.03	67.8932	66.6047	69.1816	48.0000	55.8000
2011.04	77.5230	76.1326	78.9133	47.3000	54.4000
2011.05	77.5810	76.2831	78.8789	37.3000	41.5000
2011.06	65.7981	64.6552	66.9410	35.2000	37.0000
2011.07	68.7528	67.5874	69.9182	41.5000	43.8000
2011.08	72.6392	71.4800	73.7984	42.4000	50.5000
2011.09	82.3696	80.9537	83.7854	73.8000	78.0000
2011.10	77.9022	76.5995	79.2048	78.9000	88.0000
2011.11	80.8281	79.1597	82.4964	84.6000	96.7000
2011.12	69.9603	68.5346	71.3860	65.8000	73.0000
2012.01	79.4895	77.9311	81.0479	55.8000	58.2000
2012.02	66.1226	64.7815	67.4637	29.2000	33.1000
2012.03	72.3692	71.0915	73.6470	53.1000	64.1000
2012.04	81.3717	79.9463	82.7970	51.4000	55.2000
2012.05	83.0308	81.6648	84.3968	61.8000	69.0000
2012.06	69.7399	68.5602	70.9195	59.7000	64.5000
2012.07	73.3511	72.1518	74.5505	64.2000	51.3000
2012.08	74.6967	73.4986	75.8948	57.7000	63.1000
2012.09	85.2665	83.7898	86.7431	57.7000	61.5000
2012.10	81.4426	79.9563	82.9290	48.3000	53.3000
2012.11	84.5775	82.8810	86.2741	56.7000	61.4000
2012.12	73.3928	71.8042	74.9813	37.4000	40.8000
2013.01	88.3251	86.6388	90.0115	63.8000	62.9000
2013.02	73.6321	72.1526	75.1116	37.8000	38.0000
2013.03	78.0694	76.4795	79.6594	50.6000	57.9000
2013.04	88.7422	87.1794	90.3049	70.6000	72.4000
2013.05	88.4863	86.9075	90.0651	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	75.8628	74.5217	77.2038	51.0000	52.5000
2013.07	78.7532	77.4872	80.0193	57.0000	57.0000
2013.08	81.8260	80.5076	83.1445	60.0000	66.0000
2013.09	91.9905	90.3475	93.6335	34.6000	36.9000
2013.10	86.8591	85.2466	88.4717	74.5000	85.6000
2013.11	88.5611	86.5694	90.5527	73.9000	77.6000
2013.12	79.0012	77.3118	80.6906	77.8000	90.3000
2014.01	102.9576	100.7905	105.1246	77.4000	82.0000
2014.02	87.5691	85.8411	89.2971	93.9000	102.8000
2014.03	95.0608	93.3263	96.7953	80.9000	92.2000
2014.04	108.2301	106.3335	110.1267	76.9000	84.7000
2014.05	108.5252	106.6737	110.3767	72.3000	75.2000
2014.06	92.8260	91.2578	94.3942	67.2000	71.0000
2014.07	96.0522	94.4504	97.6540	72.5000	72.5000
2014.08	99.9556	98.3956	101.5156	71.2000	74.7000
2014.09	113.5978	111.5935	115.6022	83.2000	87.6000
2014.10	106.8330	104.8666	108.7995	59.5000	60.6000
2014.11	110.1383	107.8507	112.4260	65.8000	71.1000
2014.12	96.1256	93.9021	98.3492	75.8000	78.0000
2015.01	63.5977	62.3279	64.8675	65.9000	67.0000
2015.02	52.8280	51.6654	53.9906	42.4000	44.8000
2015.03	58.0677	57.0082	59.1273	38.0000	38.4000
2015.04	65.7333	64.5637	66.9030	49.0000	54.4000
2015.05	66.1634	65.0731	67.2538	56.3000	58.8000
2015.06	56.5014	55.4912	57.5115	50.2000	68.3000
2015.07	57.9752	56.9939	58.9566	47.9000	65.8000
2015.08	61.4663	60.4412	62.4914	39.5000	57.2000
2015.09	69.0397	67.7914	70.2879	49.2000	72.1000
2015.10	65.3925	64.1348	66.6503	39.3000	48.3000
2015.11	68.0475	66.5720	69.5230	39.6000	55.9000
2015.12	59.5066	58.1958	60.8174	36.4000	44.8000
2016.01	34.8413	34.1176	35.5650	33.7000	43.3000
2016.02	29.0370	28.4334	29.6406	38.3000	46.8000
2016.03	31.3982	30.7737	32.0228	30.5000	38.9000
2016.04	35.4358	34.7635	36.1082	26.6000	30.9000
2016.05	35.7828	35.1325	36.4330	33.7000	48.4000
2016.06	30.1976	29.6842	30.7110	13.1000	19.5000
2016.07	31.5534	31.0495	32.0572	21.2000	27.5000
2016.08	33.1148	32.5355	33.6940	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	38.0562	37.3658	38.7466	27.7000	37.1000
2016.10	35.6822	34.9985	36.3658	22.7000	31.7000
2016.11	36.7380	35.9735	37.5024	14.0000	22.2000
2016.12	32.5244	31.8296	33.2193	11.1000	20.0000
2017.01	18.9107	18.5139	19.3075	18.4000	26.2000
2017.02	15.8238	15.4772	16.1704	14.4000	20.6000
2017.03	17.2637	16.9359	17.5916	11.3000	15.5000
2017.04	19.6723	19.3268	20.0179	21.6000	33.2000
2017.05	19.5561	19.2198	19.8925	12.5000	18.1000
2017.06	16.5035	16.2289	16.7781	15.5000	19.3000
2017.07	17.3167	17.0406	17.5929	11.5000	16.3000
2017.08	18.1309	17.8141	18.4478	22.8000	35.7000
2017.09	21.1994	20.7480	21.6509	34.6000	42.9000
2017.10	19.3506	18.9520	19.7493	10.5000	11.0000
2017.11	19.7620	19.3442	20.1798	4.2000	5.6000
2017.12	17.4074	17.1426	17.6722	4.0000	4.6000
2018.01	5.2547	5.1433	5.3661	3.1000	6.3000
2018.02	4.3568	4.2522	4.4614	6.8000	11.8000
2018.03	4.6749	4.5806	4.7692	1.1000	1.2000
2018.04	5.2741	5.1694	5.3788	4.7000	7.5000
2018.05	5.3262	5.2275	5.4249	8.4000	14.0000
2018.06	4.5097	4.4306	4.5889	10.2000	13.6000
2018.07	4.7321	4.6785	4.7857	0.5000	1.7000
2018.08	4.9009	4.8173	4.9845	5.9000	9.5000
2018.09	5.5203	5.4170	5.6237	1.6000	2.9000
2018.10	5.3051	5.2012	5.4091	2.5000	5.6000
2018.11	5.4435	5.3302	5.5568	3.1000	4.2000
2018.12	4.8938	4.7981	4.9894	1.6000	2.3000
2019.01	3.4664	3.4005	3.5324	5.4000	2.3000
2019.02	2.9417	2.8840	2.9994	0.1000	1.2000
2019.03	3.1168	3.0636	3.1701	6.1000	12.1000
2019.04	3.5465	3.4794	3.6135	6.2000	9.3000
2019.05	3.4676	3.4072	3.5280	7.0000	11.9000
2019.06	2.9442	2.8948	2.9937	0.7000	1.5000
2019.07	3.0942	3.0482	3.1403	0.4000	2.2000
2019.08	3.2558	3.2077	3.3039	0.3000	0.8000
2019.09	3.7454	3.6868	3.8039	0.5000	1.0000
2019.10	3.4980	3.4388	3.5571	0.2000	0.5000
2019.11	3.6564	3.5868	3.7259	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	3.1993	3.1364	3.2621	0.8000	1.0000
2020.01	7.6733	7.5233	7.8232	4.0000	5.3000
2020.02	6.4239	6.2958	6.5521	0.1000	0.0000
2020.03	6.8787	6.7506	7.0068	1.2000	1.5000
2020.04	7.8771	7.7479	8.0062	3.0000	5.1000
2020.05	7.7847	7.6632	7.9062	0.1000	0.4000
2020.06	6.6505	6.5488	6.7522	3.9000	6.4000
2020.07	6.8806	6.7794	6.9819	4.2000	7.7000
2020.08	7.1225	7.0244	7.2206	5.3000	7.8000
2020.09	8.1737	8.0432	8.3041	0.4000	0.9000
2020.10	7.8222	7.6945	7.9499	9.9000	13.6000
2020.11	8.1490	8.0211	8.2769	21.2000	33.1000
2020.12	7.1859	7.0633	7.3086	15.4000	19.8000
2021.01	23.5598	23.1573	23.9623	7.0000	15.8000
2021.02	20.0363	19.6868	20.3858	5.8000	10.7000
2021.03	21.6530	21.3173	21.9886	11.0000	17.2000
2021.04	24.7450	24.3767	25.1134	18.5000	28.8000
2021.05	24.6967	24.3524	25.0410	15.9000	22.9000
2021.06	21.2257	20.9099	21.5415	19.9000	24.1000
2021.07	21.9802	21.6295	22.3309	23.8000	35.6000
2021.08	23.3096	22.9438	23.6754	15.7000	19.5000
2021.09	26.8022	26.3551	27.2493	39.1000	52.5000
2021.10	25.6712	25.2383	26.1041	27.1000	37.0000

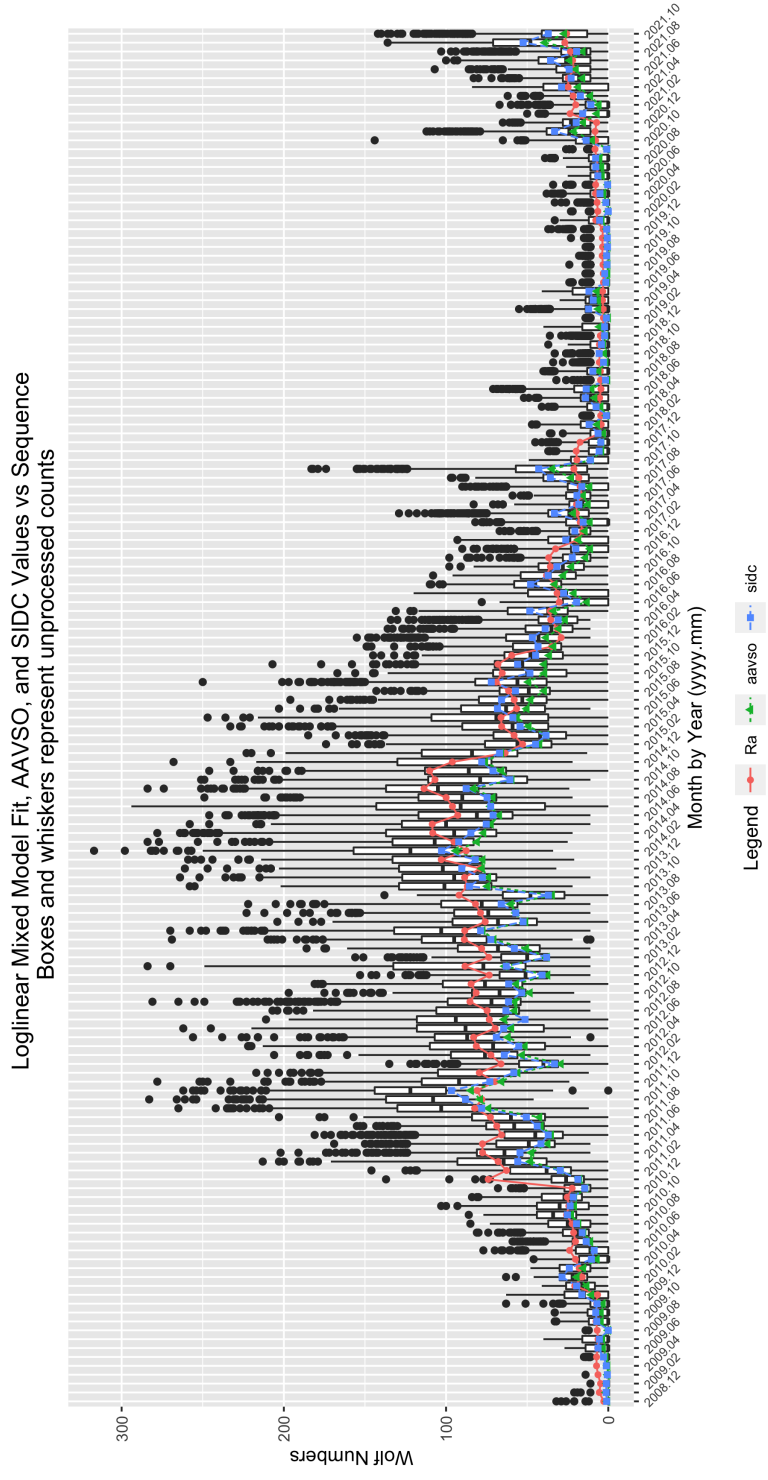


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 202110 Parameter Estimates

	Estimate	Std. Error	t-value	$Pr(> t )$
(Intercept)	1.4236	0.3125	4.5561	0.0000
seeF	-0.2216	0.0057	-38.8352	0.0000
seeG	-0.1223	0.0050	-24.5456	0.0000
seeM	-0.1990	0.0242	-8.2383	0.0000
seeP	-0.3197	0.0082	-39.2201	0.0000
sidc1	-0.0167	0.0224	-0.7457	0.4559
year2009	0.6544	0.3136	2.0869	0.0369
year2010	1.8751	0.3114	6.0215	0.0000
year2011	3.0057	0.3113	9.6553	0.0000
year2012	3.0447	0.3113	9.7808	0.0000
year2013	3.1406	0.3113	10.0890	0.0000
year2014	3.3377	0.3113	10.7222	0.0000
year2015	2.8526	0.3113	9.1634	0.0000
year2016	2.2360	0.3113	7.1820	0.0000
year2017	1.6288	0.3114	5.2310	0.0000
year2018	0.3397	0.3117	1.0900	0.2757
year2019	-0.0828	0.3119	-0.2655	0.7907
year2020	0.7218	0.3115	2.3169	0.0205
year2021	1.8598	0.3114	5.9723	0.0000
mon2	-0.1731	0.0092	-18.9021	0.0000
mon3	-0.0989	0.0085	-11.6118	0.0000
mon4	0.0199	0.0082	2.4238	0.0154
mon5	0.0169	0.0081	2.1002	0.0357
mon6	-0.1491	0.0084	-17.7372	0.0000
mon7	-0.1134	0.0082	-13.8769	0.0000
mon8	-0.0658	0.0080	-8.1784	0.0000
mon9	0.0705	0.0080	8.7989	0.0000
mon10	0.0158	0.0082	1.9229	0.0545
mon11	0.0597	0.0086	6.9022	0.0000
mon12	-0.0652	0.0089	-7.3622	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: 202110 Summary of Sunspot Numbers

year	mon	day	obs	sidc
Min. :2008	Min. : 1.000	Min. : 0.00	Length:147811	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 : 6.599	Mean :15.72		Mean :0.2499
3rd Qu.:2019	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:0.0000
Max. :2021	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 202110 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:147811	Length:147811
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 : 2.631	Mean : 15.37	Mean : 41.69		
3rd Qu.: 4.000	3rd Qu.: 23.00	3rd Qu.: 67.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 202110 Summary of Sunspot Numbers

inst	filter	unit
Length:147811	Length:147811	Length:147811
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 202110 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.0	Min. : 0.0	Min. : 0.0
1st Qu.: 60.00	1st Qu.: 4.5	1st Qu.: 34.0	1st Qu.: 40.0
Median : 80.00	Median : 14.0	Median : 900.0	Median : 57.5
Mean : 91.31	Mean : 33.9	Mean : 888.4	Mean : 181.7
3rd Qu.: 104.00	3rd Qu.: 23.0	3rd Qu.:1200.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.0	Max. :9990.0	Max. :4591.0

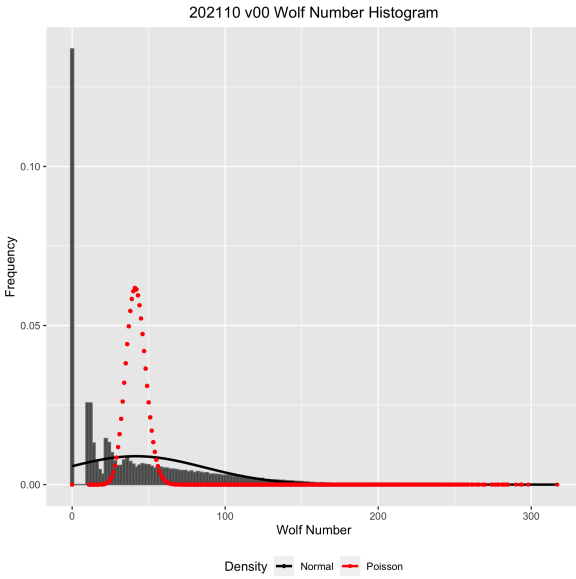


Figure 3: Box plots of raw Wolf number (w) by observer rank.

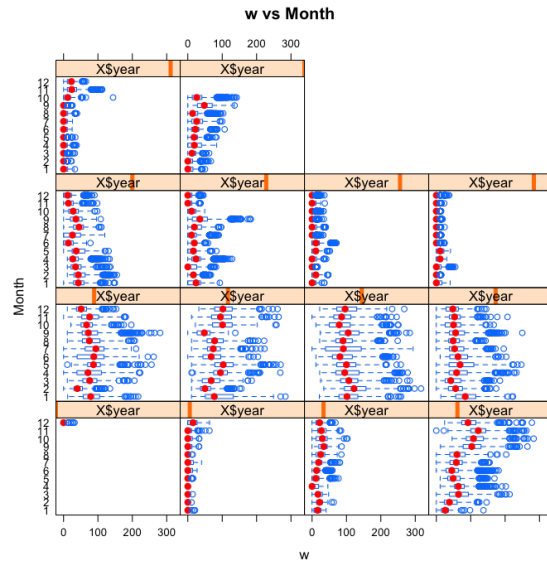


Figure 4: Box plots of raw Wolf number (w) by month and year.

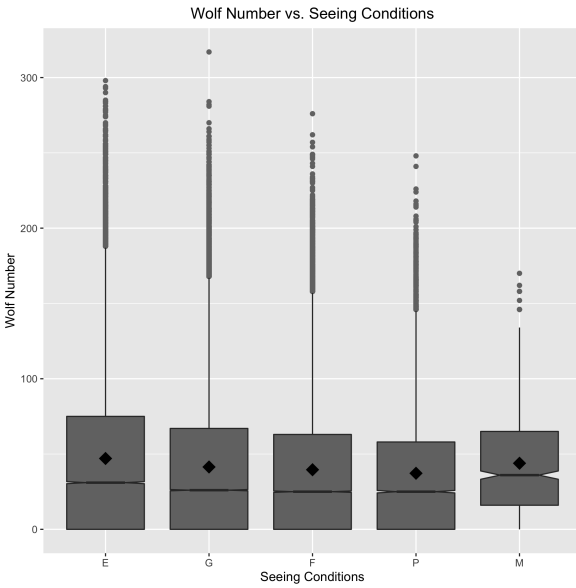


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

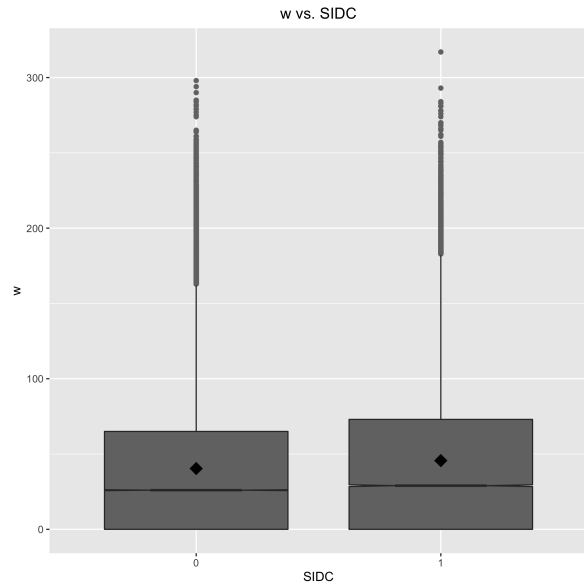


Figure 6: Box plots of raw Wolf number (w) by organization.

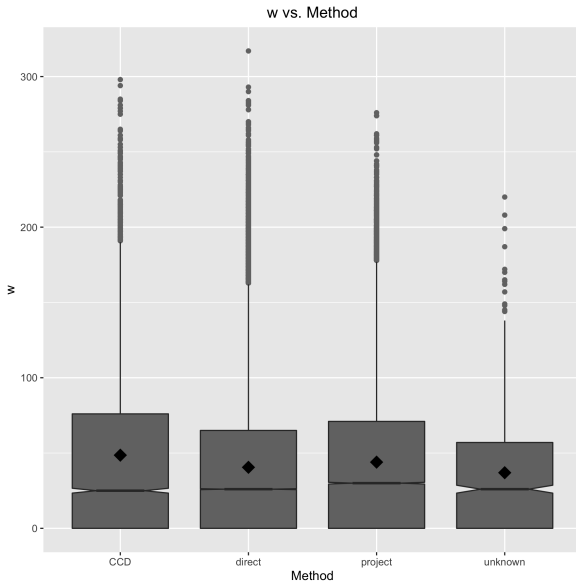


Figure 7: Box plots of raw Wolf number ( $w$ ) by observer rank.

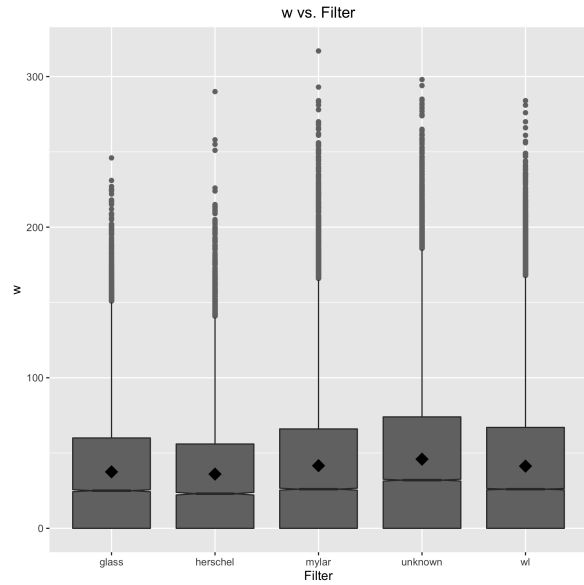


Figure 8: Box plots of raw Wolf number ( $w$ ) by month and year.

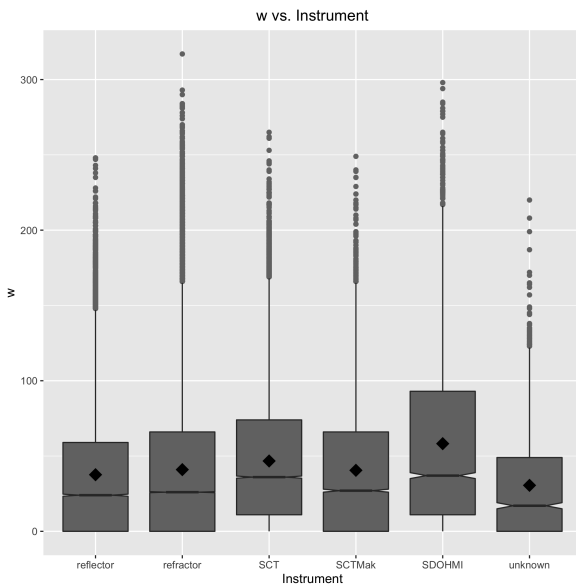


Figure 9: Box plots of raw Wolf number ( $w$ ) by seeing condition.

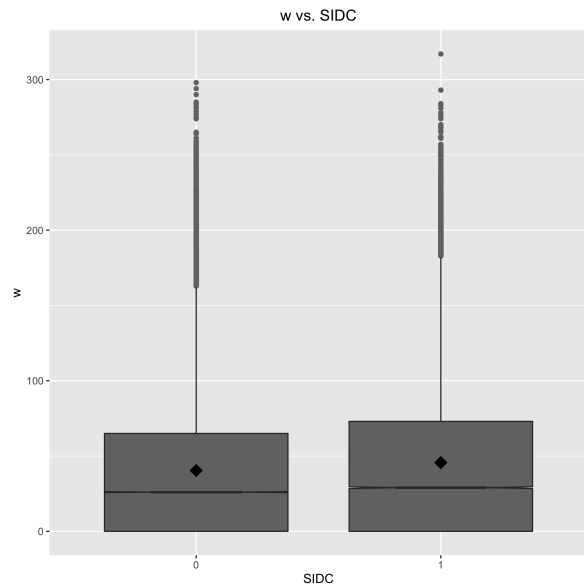


Figure 10: Box plots of raw Wolf number ( $w$ ) by organization.



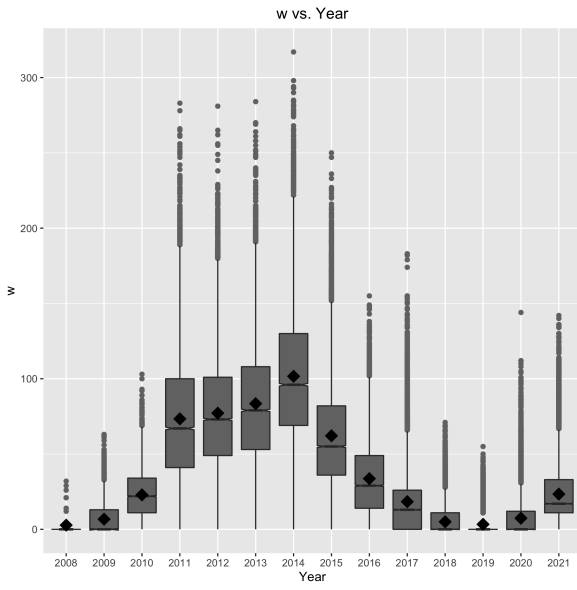


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

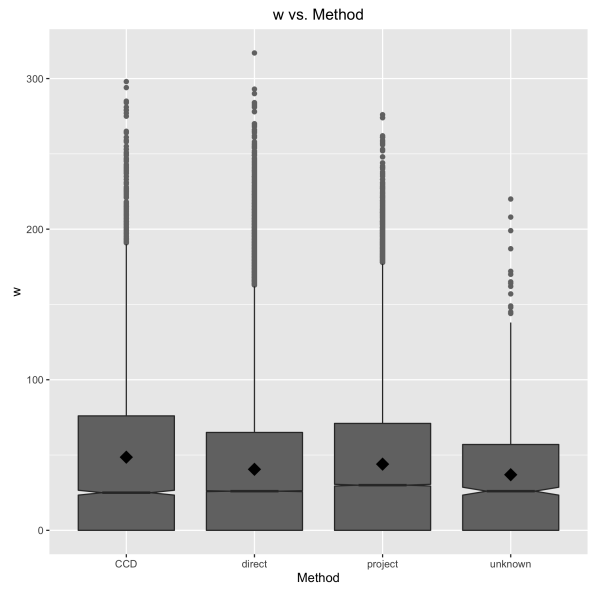


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.