

**Monthly Report (00)**  
**201910 Data Set**

**Wednesday 13<sup>th</sup> November, 2019**

**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.

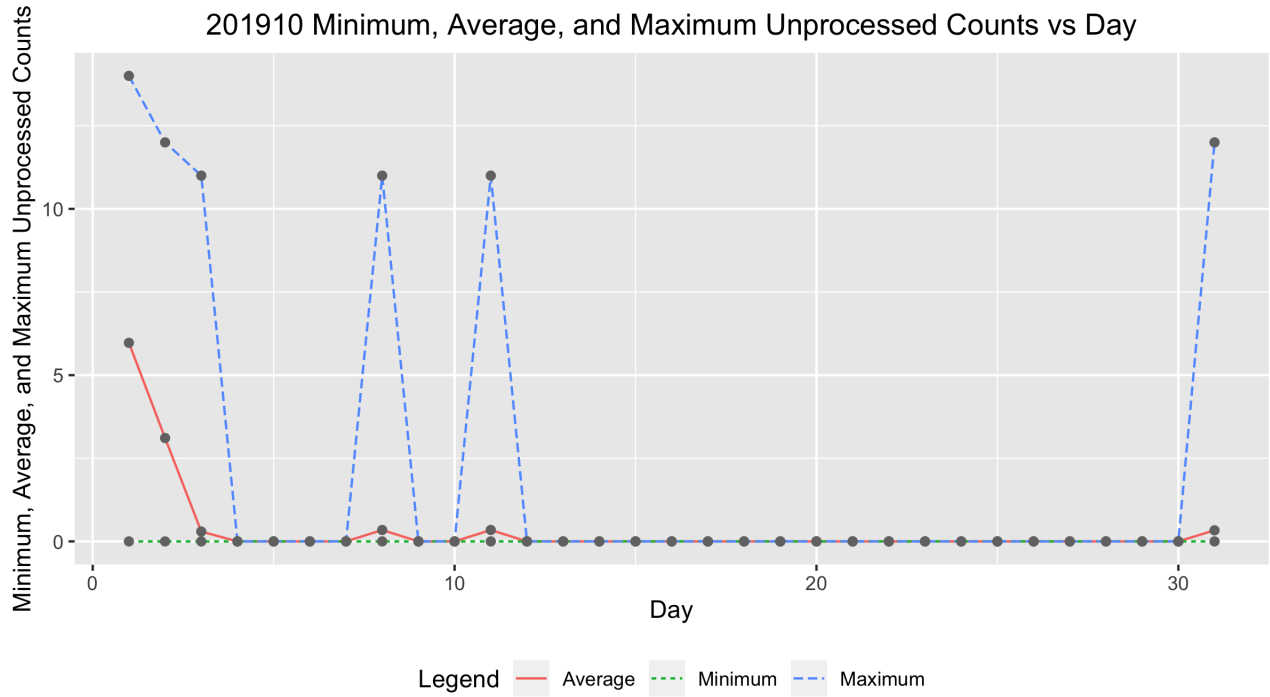


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201910 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	37.0000	0.0000	5.9730	14.0000
2.0000	37.0000	0.0000	3.1081	12.0000
3.0000	37.0000	0.0000	0.2973	11.0000
4.0000	39.0000	0.0000	0.0000	0.0000
5.0000	44.0000	0.0000	0.0000	0.0000
6.0000	34.0000	0.0000	0.0000	0.0000
7.0000	33.0000	0.0000	0.0000	0.0000
8.0000	32.0000	0.0000	0.3438	11.0000
9.0000	44.0000	0.0000	0.0000	0.0000
10.0000	41.0000	0.0000	0.0000	0.0000
11.0000	32.0000	0.0000	0.3438	11.0000
12.0000	36.0000	0.0000	0.0000	0.0000
13.0000	46.0000	0.0000	0.0000	0.0000
14.0000	35.0000	0.0000	0.0000	0.0000
15.0000	41.0000	0.0000	0.0000	0.0000
16.0000	32.0000	0.0000	0.0000	0.0000
17.0000	28.0000	0.0000	0.0000	0.0000
18.0000	31.0000	0.0000	0.0000	0.0000
19.0000	36.0000	0.0000	0.0000	0.0000
20.0000	38.0000	0.0000	0.0000	0.0000
21.0000	30.0000	0.0000	0.0000	0.0000
22.0000	34.0000	0.0000	0.0000	0.0000
23.0000	39.0000	0.0000	0.0000	0.0000
24.0000	39.0000	0.0000	0.0000	0.0000
25.0000	29.0000	0.0000	0.0000	0.0000
26.0000	37.0000	0.0000	0.0000	0.0000
27.0000	36.0000	0.0000	0.0000	0.0000
28.0000	43.0000	0.0000	0.0000	0.0000
29.0000	30.0000	0.0000	0.0000	0.0000
30.0000	34.0000	0.0000	0.0000	0.0000
31.0000	36.0000	0.0000	0.3333	12.0000

### 3 Error Tables

Data are for the month of October 2019. 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	2.4040	3.1370	0.5000	1.0000
2009.01	5.8591	5.2176	6.5005	1.3000	1.3000
2009.02	5.0809	4.5095	5.6523	0.7000	1.2000
2009.03	6.6866	6.4211	6.9520	0.3000	0.6000
2009.04	7.4998	7.2248	7.7748	0.4000	1.2000
2009.05	7.6165	7.3078	7.9252	1.6000	2.9000
2009.06	6.6522	6.3096	6.9948	3.2000	6.3000
2009.07	6.3357	6.0764	6.5950	3.6000	5.5000
2009.08	7.0118	6.7279	7.2958	0.0000	0.0000
2009.09	7.4999	7.2277	7.7722	4.5000	7.1000
2009.10	7.0048	6.6298	7.3798	4.5000	7.7000
2009.11	7.0176	6.8230	7.2121	3.3000	6.9000
2009.12	6.5104	6.3237	6.6971	10.4000	16.3000
2010.01	21.6964	19.2000	24.1927	13.3000	19.5000
2010.02	17.0753	14.7265	19.4242	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	18.6729	16.3304	21.0153	15.4000	24.0000
2010.04	20.6859	18.2202	23.1515	7.0000	10.4000
2010.05	24.8595	24.4166	25.3025	8.4000	8.7000
2010.06	20.3705	20.0313	20.7097	11.0000	13.6000
2010.07	21.2668	20.9577	21.5760	15.2000	16.1000
2010.08	22.7574	22.3835	23.1312	18.3000	19.6000
2010.09	25.2681	24.8510	25.6852	22.8000	25.2000
2010.10	23.8791	23.4662	24.2921	21.0000	23.5000
2010.11	24.5042	24.0583	24.9501	20.9000	21.6000
2010.12	21.8027	21.3622	22.2432	13.9000	14.5000
2011.01	77.0637	75.4634	78.6639	17.7000	18.7000
2011.02	65.9597	64.5461	67.3732	29.1000	29.6000
2011.03	70.1934	68.8496	71.5373	48.0000	55.8000
2011.04	78.6143	77.2002	80.0285	47.3000	54.4000
2011.05	79.9777	78.6220	81.3334	37.3000	41.5000
2011.06	65.5094	64.3596	66.6591	35.2000	37.0000
2011.07	67.7050	66.5452	68.8649	41.5000	43.8000
2011.08	73.2990	72.1173	74.4806	42.4000	50.5000
2011.09	80.0314	78.6446	81.4182	73.8000	78.0000
2011.10	75.6478	74.3724	76.9231	78.9000	88.0000
2011.11	77.4094	75.7903	79.0286	84.6000	96.7000
2011.12	67.7829	66.3842	69.1815	65.8000	73.0000
2012.01	82.6893	81.0615	84.3171	55.8000	58.2000
2012.02	69.5956	68.1792	71.0121	29.2000	33.1000
2012.03	74.7368	73.4120	76.0616	53.1000	64.1000
2012.04	82.4630	81.0207	83.9053	51.4000	55.2000
2012.05	85.5116	84.1011	86.9220	61.8000	69.0000
2012.06	69.3303	68.1518	70.5089	59.7000	64.5000
2012.07	72.0375	70.8555	73.2194	64.2000	51.3000
2012.08	75.2279	74.0201	76.4356	57.7000	63.1000
2012.09	82.6469	81.2130	84.0808	57.7000	61.5000
2012.10	78.9815	77.5364	80.4267	48.3000	53.3000
2012.11	80.7941	79.1720	82.4163	56.7000	61.4000
2012.12	70.9261	69.3865	72.4656	37.4000	40.8000
2013.01	91.9606	90.2025	93.7186	63.8000	62.9000
2013.02	77.5457	75.9851	79.1064	37.8000	38.0000
2013.03	80.6508	79.0117	82.2898	50.6000	57.9000
2013.04	89.9326	88.3515	91.5136	70.6000	72.4000
2013.05	91.1447	89.5234	92.7661	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	75.4136	74.0808	76.7464	51.0000	52.5000
2013.07	77.3849	76.1429	78.6268	57.0000	57.0000
2013.08	82.3360	81.0123	83.6596	60.0000	66.0000
2013.09	89.1800	87.5894	90.7706	34.6000	36.9000
2013.10	84.1730	82.6124	85.7336	74.5000	85.6000
2013.11	84.5656	82.6687	86.4626	73.9000	77.6000
2013.12	76.3412	74.7107	77.9716	77.8000	90.3000
2014.01	107.1264	104.8722	109.3806	77.4000	82.0000
2014.02	92.1349	90.3195	93.9502	93.9000	102.8000
2014.03	98.0592	96.2731	99.8453	80.9000	92.2000
2014.04	109.5154	107.6029	111.4280	76.9000	84.7000
2014.05	111.6773	109.7711	113.5836	72.3000	75.2000
2014.06	92.2085	90.6498	93.7671	67.2000	71.0000
2014.07	94.3155	92.7458	95.8852	72.5000	72.5000
2014.08	100.5230	98.9524	102.0936	71.2000	74.7000
2014.09	110.0200	108.0804	111.9596	83.2000	87.6000
2014.10	103.5135	101.6069	105.4200	59.5000	60.6000
2014.11	105.0529	102.8654	107.2404	65.8000	71.1000
2014.12	92.8684	90.7146	95.0221	75.8000	78.0000
2015.01	66.2281	64.9020	67.5543	65.9000	67.0000
2015.02	55.5785	54.3545	56.8024	42.4000	44.8000
2015.03	59.9313	58.8342	61.0285	38.0000	38.4000
2015.04	66.4886	65.2961	67.6812	49.0000	54.4000
2015.05	68.1284	67.0014	69.2554	56.3000	58.8000
2015.06	56.1224	55.1090	57.1358	50.2000	68.3000
2015.07	56.9247	55.9522	57.8973	47.9000	65.8000
2015.08	61.8965	60.8553	62.9377	39.5000	57.2000
2015.09	66.8603	65.6435	68.0770	49.2000	72.1000
2015.10	63.4072	62.1814	64.6330	39.3000	48.3000
2015.11	65.0612	63.6476	66.4748	39.6000	55.9000
2015.12	57.5917	56.3252	58.8582	36.4000	44.8000
2016.01	36.2676	35.5106	37.0246	33.7000	43.3000
2016.02	30.5677	29.9301	31.2052	38.3000	46.8000
2016.03	32.4331	31.7857	33.0806	30.5000	38.9000
2016.04	35.8911	35.2068	36.5755	26.6000	30.9000
2016.05	36.8568	36.1830	37.5306	33.7000	48.4000
2016.06	30.0368	29.5241	30.5494	13.1000	19.5000
2016.07	31.0109	30.5121	31.5098	21.2000	27.5000
2016.08	33.3634	32.7761	33.9506	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	36.8973	36.2234	37.5713	27.7000	37.1000
2016.10	34.5920	33.9246	35.2594	22.7000	31.7000
2016.11	35.0964	34.3625	35.8304	14.0000	22.2000
2016.12	31.4606	30.7879	32.1333	11.1000	20.0000
2017.01	19.7268	19.3116	20.1419	18.4000	26.2000
2017.02	16.6937	16.3270	17.0604	14.4000	20.6000
2017.03	17.8669	17.5264	18.2074	11.3000	15.5000
2017.04	19.9816	19.6288	20.3343	21.6000	33.2000
2017.05	20.1893	19.8406	20.5380	12.5000	18.1000
2017.06	16.4651	16.1903	16.7399	15.5000	19.3000
2017.07	17.0833	16.8116	17.3550	11.5000	16.3000
2017.08	18.3204	18.0023	18.6385	22.8000	35.7000
2017.09	20.5826	20.1561	21.0091	34.6000	42.9000
2017.10	18.8300	18.4489	19.2111	10.5000	11.0000
2017.11	18.9472	18.5506	19.3437	4.2000	5.6000
2017.12	16.8973	16.6411	17.1535	4.0000	4.6000
2018.01	5.4753	5.3581	5.5925	3.1000	6.3000
2018.02	4.5969	4.4850	4.7088	6.8000	11.8000
2018.03	4.8288	4.7333	4.9242	1.1000	1.2000
2018.04	5.3542	5.2474	5.4609	4.7000	7.5000
2018.05	5.5062	5.4017	5.6107	8.4000	14.0000
2018.06	4.4922	4.4126	4.5718	10.2000	13.6000
2018.07	4.6536	4.6016	4.7057	0.5000	1.7000
2018.08	4.9373	4.8517	5.0230	5.9000	9.5000
2018.09	5.3387	5.2391	5.4382	1.6000	2.9000
2018.10	5.1550	5.0554	5.2546	2.5000	5.6000
2018.11	5.2300	5.1230	5.3370	3.1000	4.2000
2018.12	4.7627	4.6702	4.8552	1.6000	2.3000
2019.01	4.0080	3.9331	4.0828	5.4000	2.3000
2019.02	3.4456	3.3783	3.5129	0.1000	1.2000
2019.03	3.5722	3.5110	3.6334	6.1000	12.1000
2019.04	3.9827	3.9074	4.0580	6.2000	9.3000
2019.05	3.9429	3.8724	4.0133	7.0000	11.9000
2019.06	3.2170	3.1601	3.2738	0.7000	1.5000
2019.07	3.3472	3.2946	3.3997	0.4000	2.2000
2019.08	3.6156	3.5592	3.6720	0.3000	0.8000
2019.09	3.9982	3.9324	4.0640	0.5000	1.0000
2019.10	3.7420	3.6753	3.8086	0.2000	0.5000

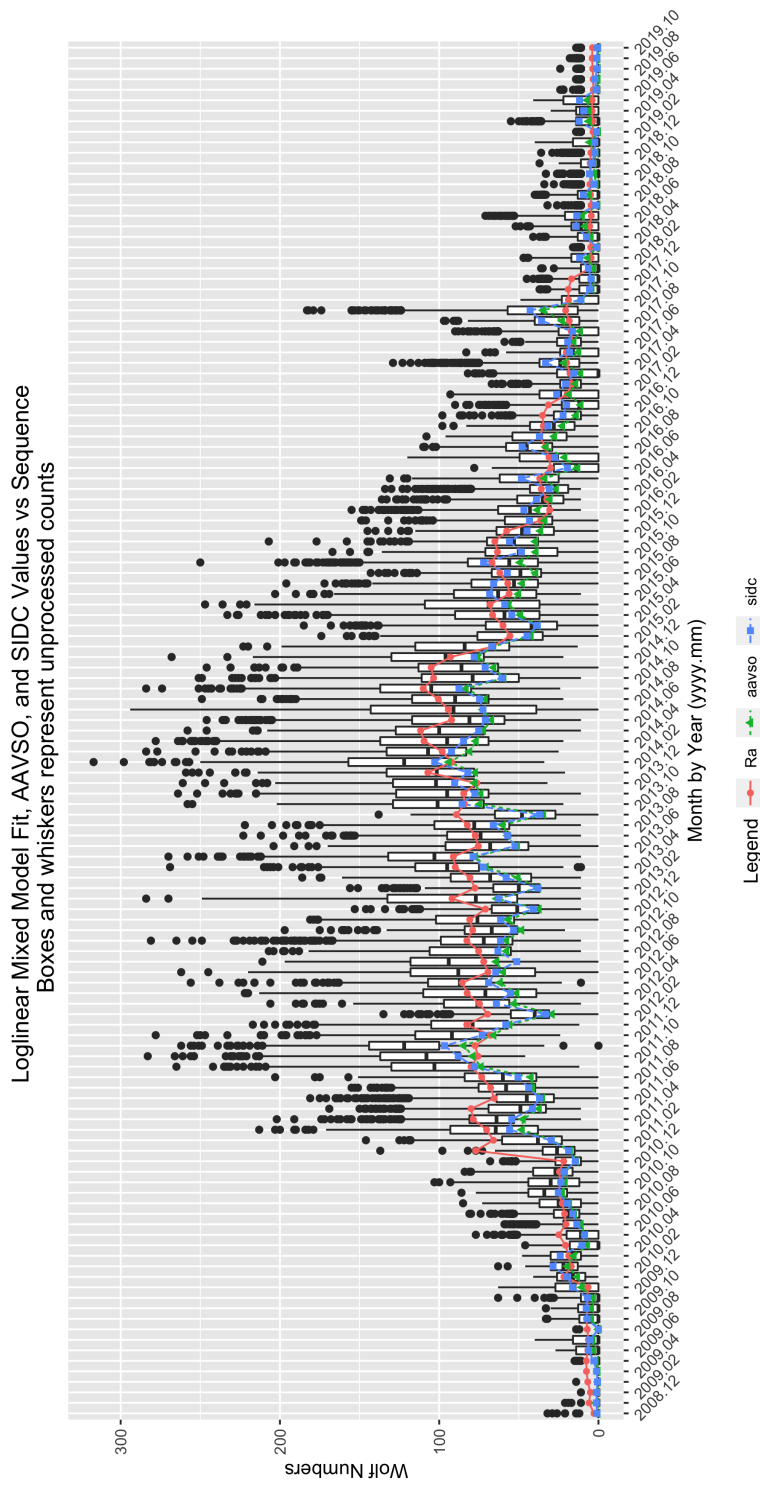


Figure 2: GLMM fitted data for  $R_a$ . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201910 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t )$
(Intercept)	1.4496	0.3110	4.6604	0.0000
seeF	-0.2187	0.0059	-37.2980	0.0000
seeG	-0.1169	0.0051	-22.8829	0.0000
seeM	-0.2020	0.0241	-8.3689	0.0000
seeP	-0.3244	0.0084	-38.6319	0.0000
sidc1	0.1360	0.0699	1.9460	0.0517
year2009	0.6381	0.3119	2.0455	0.0408
year2010	1.8504	0.3098	5.9735	0.0000
year2011	2.9682	0.3097	9.5850	0.0000
year2012	3.0050	0.3097	9.7038	0.0000
year2013	3.1010	0.3097	10.0140	0.0000
year2014	3.2979	0.3097	10.6498	0.0000
year2015	2.8130	0.3097	9.0835	0.0000
year2016	2.1962	0.3097	7.0912	0.0000
year2017	1.5909	0.3097	5.1361	0.0000
year2018	0.2949	0.3101	0.9511	0.3416
year2019	-0.0292	0.3103	-0.0940	0.9251
mon2	-0.1616	0.0092	-17.4693	0.0000
mon3	-0.1068	0.0086	-12.3564	0.0000
mon4	-0.0070	0.0083	-0.8386	0.4017
mon5	0.0067	0.0082	0.8177	0.4136
mon6	-0.1953	0.0086	-22.7010	0.0000
mon7	-0.1711	0.0084	-20.4576	0.0000
mon8	-0.0991	0.0082	-12.1080	0.0000
mon9	-0.0009	0.0082	-0.1084	0.9137
mon10	-0.0555	0.0084	-6.5720	0.0000
mon11	-0.0262	0.0088	-2.9636	0.0030
mon12	-0.1394	0.0090	-15.4733	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: 201910 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:119288	Min. :0.0000
1st Qu.:2012	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 : 6.628	Mean :15.74		Mean :0.2595
3rd Qu.:2017	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2019	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 201910 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.00	Length:119288	Length:119288
1st Qu.: 1.000	1st Qu.: 1.00	1st Qu.: 11.00	Class :character	Class :character
Median : 2.000	Median : 10.00	Median : 37.00	Mode :character	Mode :character
Mean : 3.027	Mean : 18.04	Mean : 48.31		
3rd Qu.: 5.000	3rd Qu.: 27.00	3rd Qu.: 77.00		
Max. :19.000	Max. :204.00	Max. :317.00		

Table 6: 201910 Summary of Sunspot Numbers

inst	filter	unit
Length:119288	Length:119288	Length:119288
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201910 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.0	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 64.0	1st Qu.: 3.00	1st Qu.: 480.0	1st Qu.: 40.0
Median : 80.0	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 96.7	Mean : 26.63	Mean : 955.7	Mean : 185.3
3rd Qu.: 114.0	3rd Qu.: 23.00	3rd Qu.:1203.0	3rd Qu.: 76.0
Max. :1524.0	Max. :2010.00	Max. :4300.0	Max. :4591.0

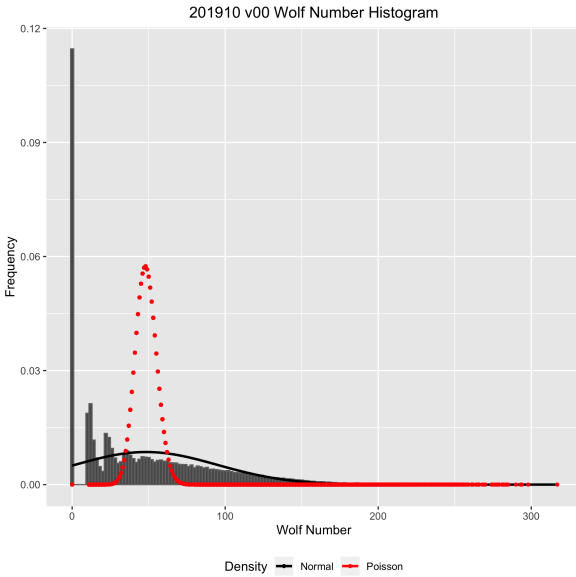


Figure 3: Box plots of raw Wolf number (w) by observer rank.

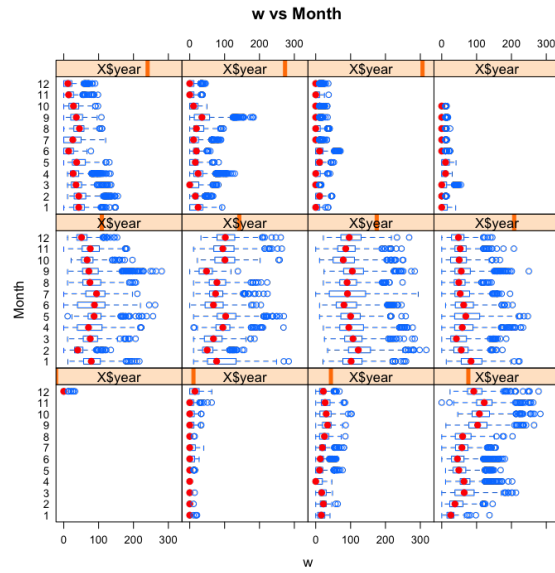


Figure 4: Box plots of raw Wolf number (w) by month and year.

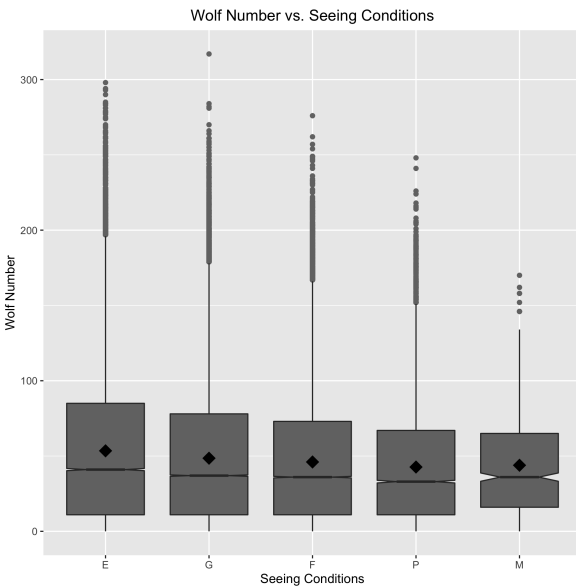


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

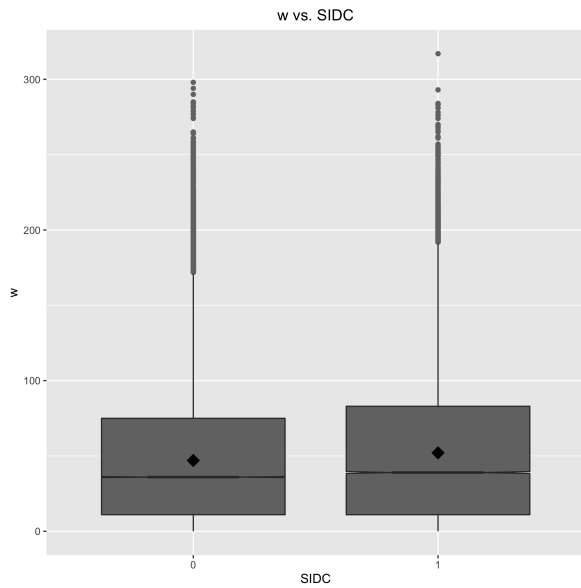


Figure 6: Box plots of raw Wolf number (w) by organization.

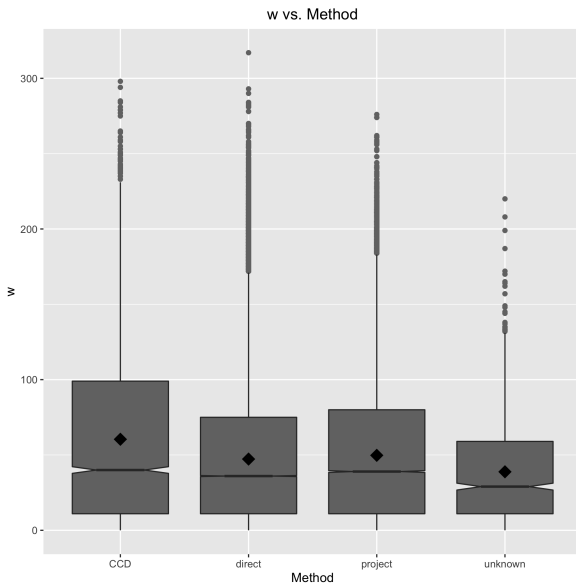


Figure 7: Box plots of raw Wolf number ( $w$ ) by observer rank.

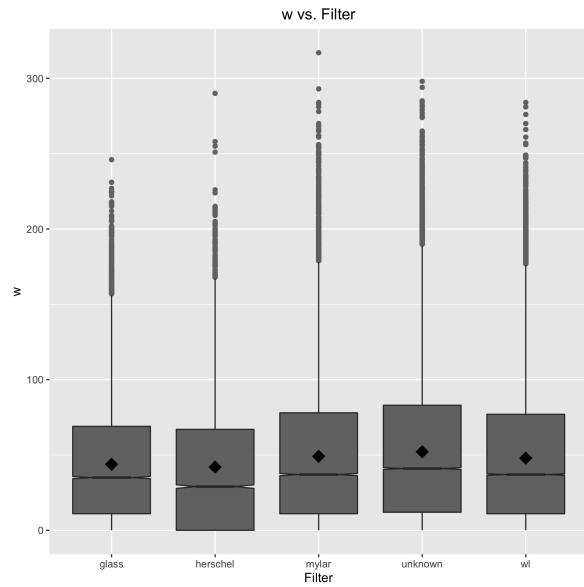


Figure 8: Box plots of raw Wolf number ( $w$ ) by month and year.

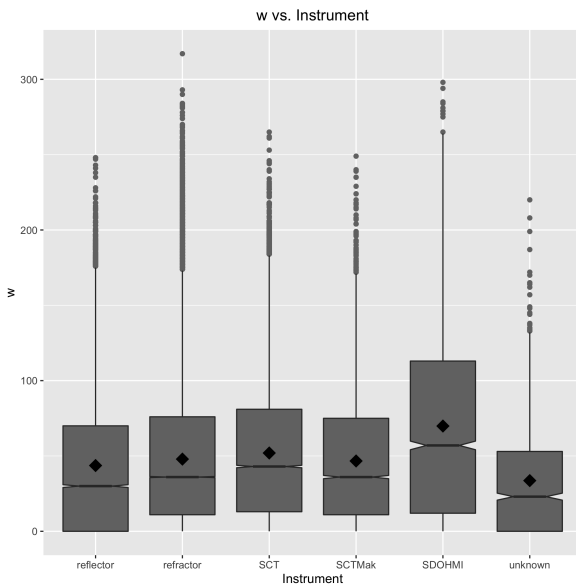


Figure 9: Box plots of raw Wolf number ( $w$ ) by seeing condition.

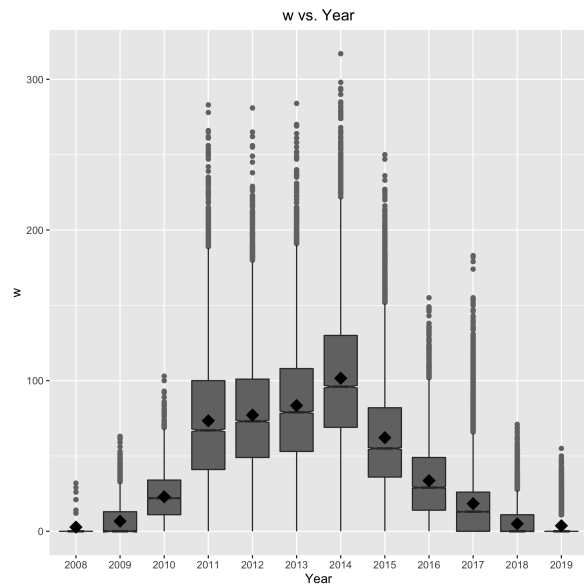


Figure 10: Box plots of raw Wolf number ( $w$ ) by organization.

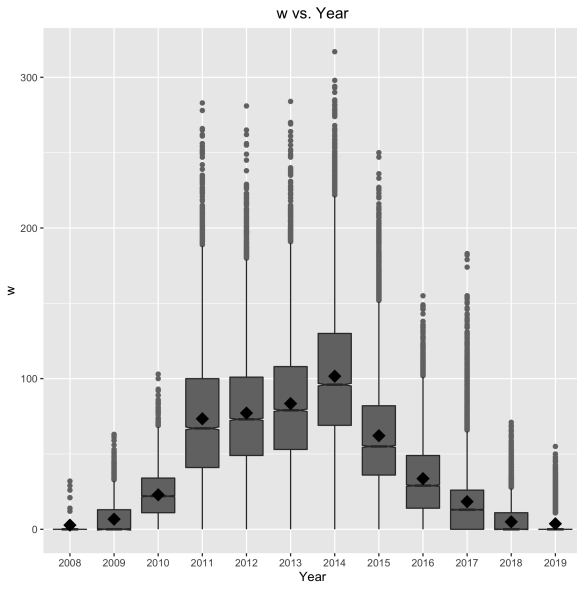


Figure 11: Box plots of raw Wolf number ( $w$ ) by year.

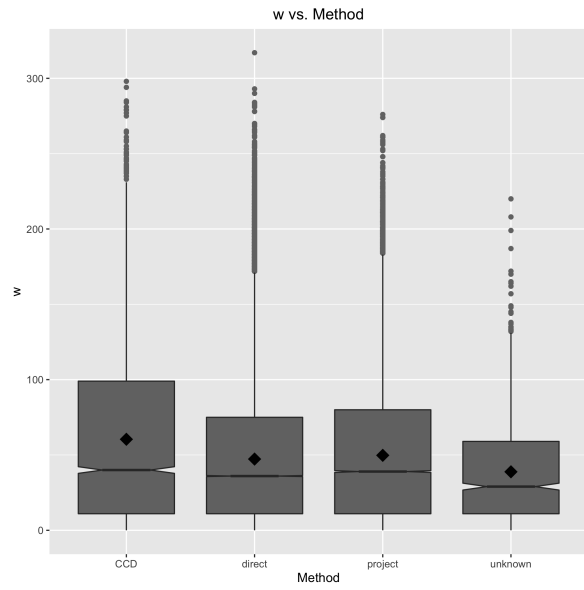


Figure 12: Box plots of raw Wolf number ( $w$ ) by observing method.