

Monthly Report (00)
201911 Data Set

Wednesday 11th December, 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.

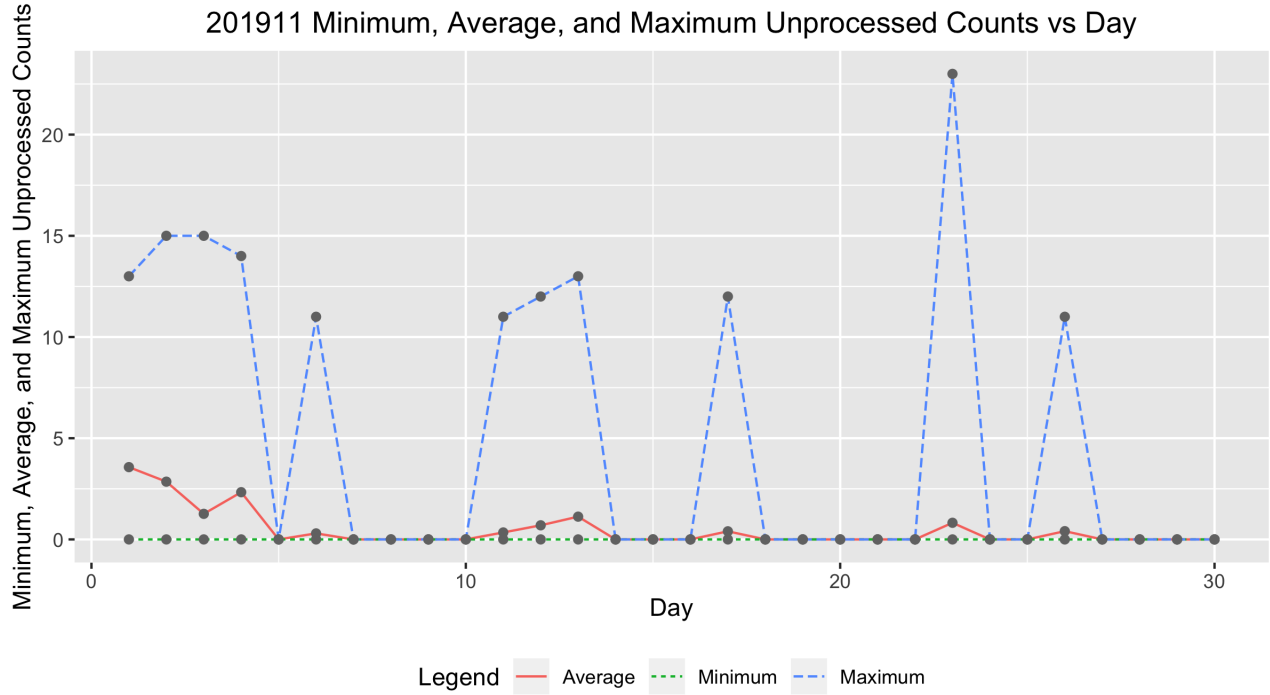


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201911 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	35.0000	0.0000	3.5714	13.0000
2.0000	34.0000	0.0000	2.8529	15.0000
3.0000	38.0000	0.0000	1.2632	15.0000
4.0000	36.0000	0.0000	2.3333	14.0000
5.0000	35.0000	0.0000	0.0000	0.0000
6.0000	37.0000	0.0000	0.2973	11.0000
7.0000	29.0000	0.0000	0.0000	0.0000
8.0000	36.0000	0.0000	0.0000	0.0000
9.0000	33.0000	0.0000	0.0000	0.0000
10.0000	32.0000	0.0000	0.0000	0.0000
11.0000	32.0000	0.0000	0.3438	11.0000
12.0000	33.0000	0.0000	0.6970	12.0000
13.0000	32.0000	0.0000	1.1250	13.0000
14.0000	27.0000	0.0000	0.0000	0.0000
15.0000	27.0000	0.0000	0.0000	0.0000
16.0000	37.0000	0.0000	0.0000	0.0000
17.0000	30.0000	0.0000	0.4000	12.0000
18.0000	32.0000	0.0000	0.0000	0.0000
19.0000	28.0000	0.0000	0.0000	0.0000
20.0000	31.0000	0.0000	0.0000	0.0000
21.0000	25.0000	0.0000	0.0000	0.0000
22.0000	25.0000	0.0000	0.0000	0.0000
23.0000	28.0000	0.0000	0.8214	23.0000
24.0000	29.0000	0.0000	0.0000	0.0000
25.0000	32.0000	0.0000	0.0000	0.0000
26.0000	27.0000	0.0000	0.4074	11.0000
27.0000	23.0000	0.0000	0.0000	0.0000
28.0000	16.0000	0.0000	0.0000	0.0000
29.0000	35.0000	0.0000	0.0000	0.0000
30.0000	35.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of November 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 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
2008.1200	2.7705	2.4036	3.1374	0.5000	1.0000
2009.0100	5.8730	5.2293	6.5168	1.3000	1.3000
2009.0200	5.0930	4.5195	5.6665	0.7000	1.2000
2009.0300	6.7041	6.4379	6.9702	0.3000	0.6000
2009.0400	7.5194	7.2437	7.7950	0.4000	1.2000
2009.0500	7.6359	7.3264	7.9453	1.6000	2.9000
2009.0600	6.6692	6.3258	7.0127	3.2000	6.3000
2009.0700	6.3520	6.0920	6.6120	3.6000	5.5000
2009.0800	7.0299	6.7452	7.3145	0.0000	0.0000
2009.0900	7.5191	7.2462	7.7921	4.5000	7.1000
2009.1000	7.0229	6.6470	7.3988	4.5000	7.7000
2009.1100	6.9830	6.7893	7.1767	3.3000	6.9000
2009.1200	6.5235	6.3362	6.7107	10.4000	16.3000
2010.0100	21.7125	19.2114	24.2136	13.3000	19.5000
2010.0200	17.0856	14.7323	19.4389	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
2010.0300	18.6848	16.3381	21.0316	15.4000	24.0000
2010.0400	20.6989	18.2288	23.1690	7.0000	10.4000
2010.0500	24.8787	24.4352	25.3222	8.4000	8.7000
2010.0600	20.3874	20.0478	20.7269	11.0000	13.6000
2010.0700	21.2845	20.9750	21.5940	15.2000	16.1000
2010.0800	22.7761	22.4018	23.1503	18.3000	19.6000
2010.0900	25.2899	24.8723	25.7075	22.8000	25.2000
2010.1000	23.8995	23.4860	24.3130	21.0000	23.5000
2010.1100	24.3425	23.8995	24.7855	20.9000	21.6000
2010.1200	21.8078	21.3670	22.2486	13.9000	14.5000
2011.0100	77.1101	75.5080	78.7122	17.7000	18.7000
2011.0200	65.9981	64.5831	67.4132	29.1000	29.6000
2011.0300	70.2388	68.8937	71.5839	48.0000	55.8000
2011.0400	78.6624	77.2472	80.0776	47.3000	54.4000
2011.0500	80.0208	78.6643	81.3774	37.3000	41.5000
2011.0600	65.5445	64.3940	66.6950	35.2000	37.0000
2011.0700	67.7425	66.5820	68.9031	41.5000	43.8000
2011.0800	73.3377	72.1554	74.5200	42.4000	50.5000
2011.0900	80.0754	78.6879	81.4630	73.8000	78.0000
2011.1000	75.6903	74.4141	76.9665	78.9000	88.0000
2011.1100	76.8740	75.2661	78.4819	84.6000	96.7000
2011.1200	67.7798	66.3812	69.1785	65.8000	73.0000
2012.0100	82.7415	81.1121	84.3708	55.8000	58.2000
2012.0200	69.6389	68.2212	71.0567	29.2000	33.1000
2012.0300	74.7833	73.4573	76.1093	53.1000	64.1000
2012.0400	82.5128	81.0693	83.9563	51.4000	55.2000
2012.0500	85.5573	84.1457	86.9689	61.8000	69.0000
2012.0600	69.3672	68.1878	70.5466	59.7000	64.5000
2012.0700	72.0771	70.8942	73.2599	64.2000	51.3000
2012.0800	75.2696	74.0610	76.4782	57.7000	63.1000
2012.0900	82.6941	81.2591	84.1291	57.7000	61.5000
2012.1000	79.0273	77.5809	80.4736	48.3000	53.3000
2012.1100	80.2369	78.6254	81.8483	56.7000	61.4000
2012.1200	70.9257	69.3857	72.4656	37.4000	40.8000
2013.0100	92.0172	90.2575	93.7769	63.8000	62.9000
2013.0200	77.5905	76.0285	79.1526	37.8000	38.0000
2013.0300	80.6987	79.0583	82.3391	50.6000	57.9000
2013.0400	89.9835	88.4011	91.5659	70.6000	72.4000
2013.0500	91.1899	89.5674	92.8124	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
2013.0600	75.4530	74.1192	76.7867	51.0000	52.5000
2013.0700	77.4263	76.1834	78.6691	57.0000	57.0000
2013.0800	82.3792	81.0545	83.7040	60.0000	66.0000
2013.0900	89.2292	87.6373	90.8210	34.6000	36.9000
2013.1000	84.2201	82.6581	85.7820	74.5000	85.6000
2013.1100	83.9790	82.0948	85.8633	73.9000	77.6000
2013.1200	76.3384	74.7075	77.9692	77.8000	90.3000
2014.0100	107.1930	104.9368	109.4492	77.4000	82.0000
2014.0200	92.1887	90.3717	94.0058	93.9000	102.8000
2014.0300	98.1182	96.3305	99.9059	80.9000	92.2000
2014.0400	109.5780	107.6638	111.4922	76.9000	84.7000
2014.0500	111.7341	109.8263	113.6419	72.3000	75.2000
2014.0600	92.2579	90.6979	93.8178	67.2000	71.0000
2014.0700	94.3660	92.7950	95.9370	72.5000	72.5000
2014.0800	100.5760	99.0042	102.1479	71.2000	74.7000
2014.0900	110.0789	108.1378	112.0199	83.2000	87.6000
2014.1000	103.5695	101.6613	105.4776	59.5000	60.6000
2014.1100	104.3249	102.1517	106.4980	65.8000	71.1000
2014.1200	92.8630	90.7086	95.0174	75.8000	78.0000
2015.0100	66.2702	64.9428	67.5975	65.9000	67.0000
2015.0200	55.6126	54.3875	56.8376	42.4000	44.8000
2015.0300	59.9680	58.8699	61.0661	38.0000	38.4000
2015.0400	66.5286	65.3352	67.7221	49.0000	54.4000
2015.0500	68.1650	67.0372	69.2928	56.3000	58.8000
2015.0600	56.1535	55.1393	57.1676	50.2000	68.3000
2015.0700	56.9564	55.9831	57.9297	47.9000	65.8000
2015.0800	61.9300	60.8881	62.9719	39.5000	57.2000
2015.0900	66.8969	65.6792	68.1147	49.2000	72.1000
2015.1000	63.4430	62.2163	64.6698	39.3000	48.3000
2015.1100	64.6116	63.2075	66.0156	39.6000	55.9000
2015.1200	57.5907	56.3241	58.8573	36.4000	44.8000
2016.0100	36.2908	35.5332	37.0485	33.7000	43.3000
2016.0200	30.5864	29.9483	31.2245	38.3000	46.8000
2016.0300	32.4533	31.8053	33.1013	30.5000	38.9000
2016.0400	35.9128	35.2279	36.5977	26.6000	30.9000
2016.0500	36.8775	36.2033	37.5518	33.7000	48.4000
2016.0600	30.0538	29.5407	30.5668	13.1000	19.5000
2016.0700	31.0299	30.5307	31.5291	21.2000	27.5000
2016.0800	33.3830	32.7954	33.9707	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
2016.0900	36.9192	36.2448	37.5936	27.7000	37.1000
2016.1000	34.6132	33.9452	35.2811	22.7000	31.7000
2016.1100	34.8545	34.1255	35.5835	14.0000	22.2000
2016.1200	31.4597	30.7869	32.1326	11.1000	20.0000
2017.0100	19.7393	19.3238	20.1548	18.4000	26.2000
2017.0200	16.7038	16.3368	17.0708	14.4000	20.6000
2017.0300	17.8779	17.5372	18.2187	11.3000	15.5000
2017.0400	19.9936	19.6406	20.3466	21.6000	33.2000
2017.0500	20.2001	19.8511	20.5490	12.5000	18.1000
2017.0600	16.4741	16.1992	16.7491	15.5000	19.3000
2017.0700	17.0925	16.8206	17.3644	11.5000	16.3000
2017.0800	18.3301	18.0117	18.6486	22.8000	35.7000
2017.0900	20.5982	20.1701	21.0263	34.6000	42.9000
2017.1000	18.8426	18.4610	19.2242	10.5000	11.0000
2017.1100	18.8170	18.4232	19.2109	4.2000	5.6000
2017.1200	16.8991	16.6429	17.1553	4.0000	4.6000
2018.0100	5.4772	5.3599	5.5944	3.1000	6.3000
2018.0200	4.5995	4.4875	4.7115	6.8000	11.8000
2018.0300	4.8316	4.7361	4.9270	1.1000	1.2000
2018.0400	5.3585	5.2515	5.4655	4.7000	7.5000
2018.0500	5.5102	5.4054	5.6149	8.4000	14.0000
2018.0600	4.4948	4.4151	4.5745	10.2000	13.6000
2018.0700	4.6561	4.6040	4.7081	0.5000	1.7000
2018.0800	4.9406	4.8549	5.0263	5.9000	9.5000
2018.0900	5.3422	5.2427	5.4417	1.6000	2.9000
2018.1000	5.1564	5.0569	5.2560	2.5000	5.6000
2018.1100	5.1918	5.0856	5.2980	3.1000	4.2000
2018.1200	4.7618	4.6692	4.8543	1.6000	2.3000
2019.0100	3.7400	3.6701	3.8099	5.4000	2.3000
2019.0200	3.2148	3.1520	3.2776	0.1000	1.2000
2019.0300	3.3331	3.2760	3.3902	6.1000	12.1000
2019.0400	3.7158	3.6456	3.7860	6.2000	9.3000
2019.0500	3.6788	3.6132	3.7444	7.0000	11.9000
2019.0600	3.0014	2.9484	3.0543	0.7000	1.5000
2019.0700	3.1228	3.0739	3.1717	0.4000	2.2000
2019.0800	3.3722	3.3195	3.4248	0.3000	0.8000
2019.0900	3.7290	3.6676	3.7904	0.5000	1.0000
2019.1000	3.4882	3.4257	3.5508	0.2000	0.5000

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Table 2: Year Month (ym) Relative Sunspot Numbers with 99% CI

ym	Ra	lci99	uci99	aavso	sidc
2019.1100	3.5717	3.5015	3.6418	0.3000	0.6000

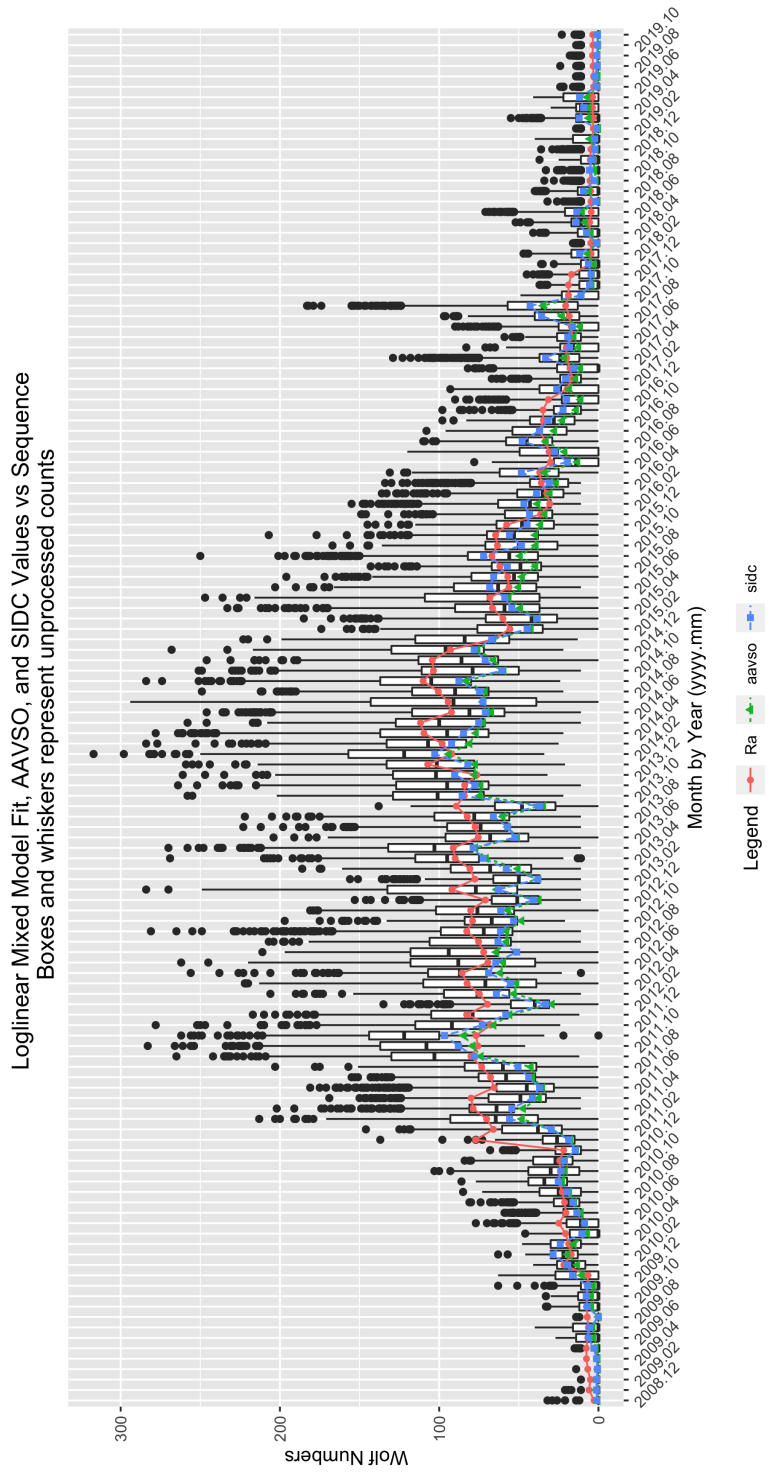


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201911 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4510	0.3104	4.6746	0.0000
seeF	-0.2187	0.0059	-37.3818	0.0000
seeG	-0.1169	0.0051	-22.9401	0.0000
seeM	-0.2021	0.0241	-8.3912	0.0000
seeP	-0.3243	0.0084	-38.7058	0.0000
sidc1	0.1367	0.0701	1.9500	0.0512
year2009	0.6398	0.3113	2.0553	0.0399
year2010	1.8504	0.3091	5.9860	0.0000
year2011	2.9679	0.3090	9.6041	0.0000
year2012	3.0046	0.3090	9.7231	0.0000
year2013	3.1006	0.3090	10.0338	0.0000
year2014	3.2975	0.3090	10.6709	0.0000
year2015	2.8126	0.3090	9.1014	0.0000
year2016	2.1958	0.3091	7.1049	0.0000
year2017	1.5905	0.3091	5.1456	0.0000
year2018	0.2937	0.3094	0.9493	0.3425
year2019	-0.1005	0.3097	-0.3246	0.7455
mon2	-0.1616	0.0092	-17.5092	0.0000
mon3	-0.1068	0.0086	-12.3838	0.0000
mon4	-0.0070	0.0083	-0.8440	0.3987
mon5	0.0066	0.0082	0.8073	0.4195
mon6	-0.1954	0.0086	-22.7573	0.0000
mon7	-0.1712	0.0083	-20.5084	0.0000
mon8	-0.0992	0.0082	-12.1433	0.0000
mon9	-0.0010	0.0082	-0.1174	0.9066
mon10	-0.0556	0.0084	-6.5938	0.0000
mon11	-0.0338	0.0088	-3.8336	0.0001
mon12	-0.1400	0.0090	-15.5811	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: 201911 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:120217	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 : 6.661	Mean :15.73		Mean :0.2593
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: 201911 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.0	Min. : 0.00	Length:120217	Length:120217
1st Qu.: 1.000	1st Qu.: 1.0	1st Qu.: 11.00	Class :character	Class :character
Median : 2.000	Median : 10.0	Median : 36.00	Mode :character	Mode :character
Mean : 3.004	Mean : 17.9	Mean : 47.94		
3rd Qu.: 5.000	3rd Qu.: 27.0	3rd Qu.: 76.00		
Max. :19.000	Max. :204.0	Max. :317.00		

Table 6: 201911 Summary of Sunspot Numbers

inst	filter	unit
Length:120217	Length:120217	Length:120217
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201911 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.00	Min. : 0.00	Min. : 0.0	Min. : 0.0
1st Qu.: 63.00	1st Qu.: 3.00	1st Qu.: 480.0	1st Qu.: 40.0
Median : 80.00	Median : 13.00	Median : 910.0	Median : 57.5
Mean : 96.06	Mean : 27.01	Mean : 948.4	Mean : 185.3
3rd Qu.: 114.00	3rd Qu.: 23.00	3rd Qu.:1203.0	3rd Qu.: 76.0
Max. :1524.00	Max. :2010.00	Max. :4300.0	Max. :4591.0

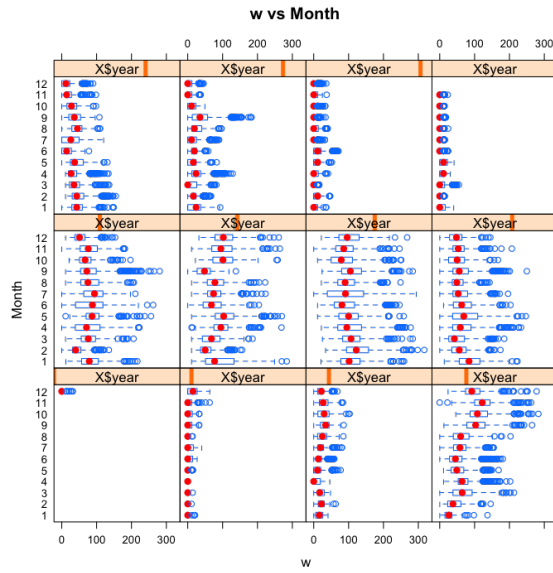
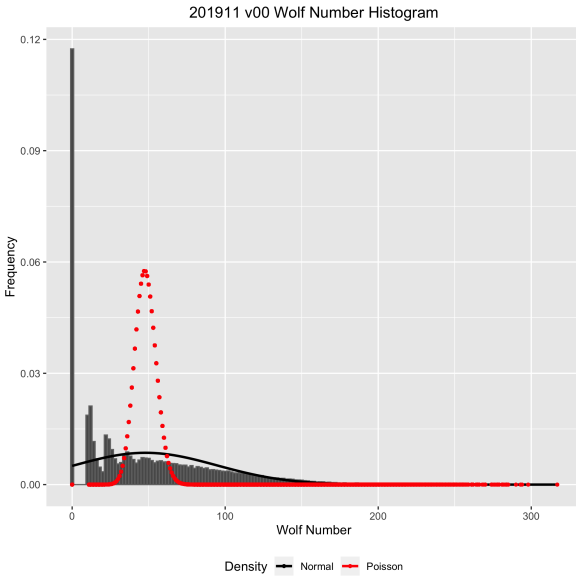


Figure 3: Box plots of raw Wolf number (w) by observer rank.

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

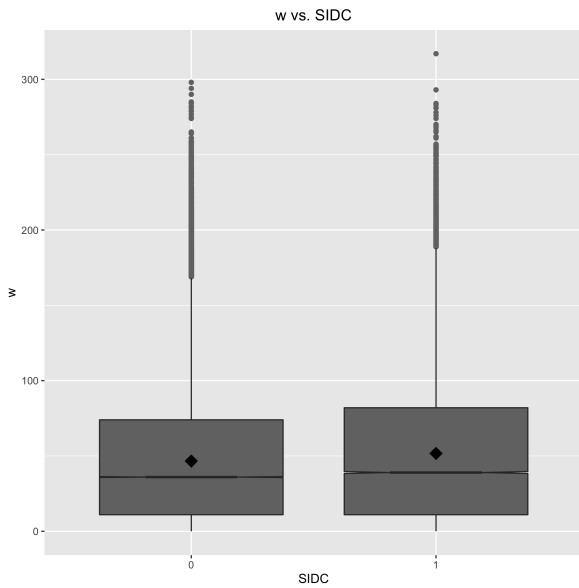
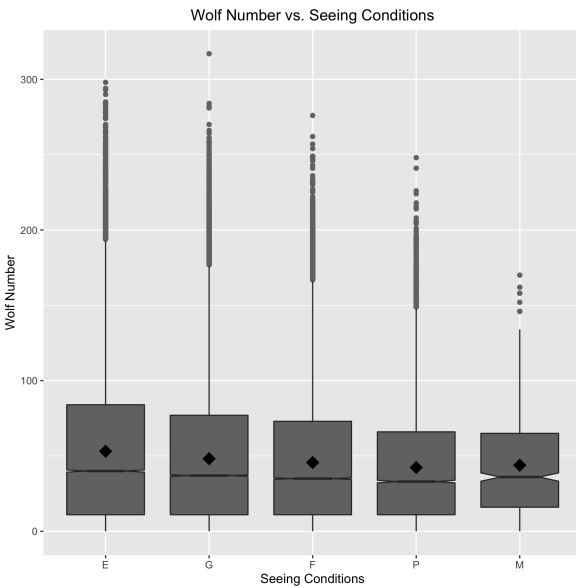


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

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

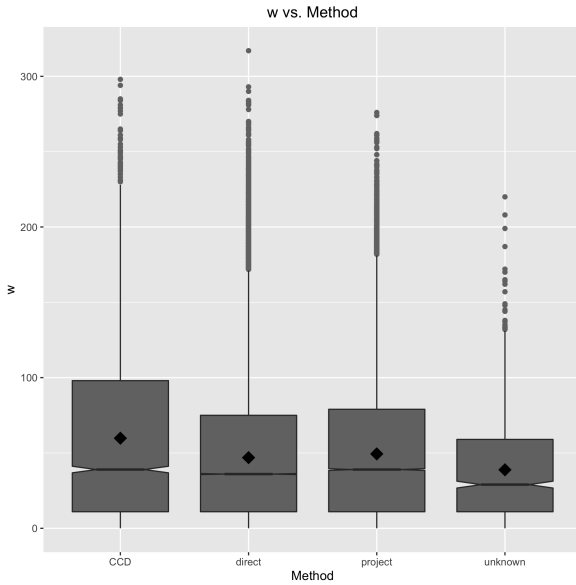


Figure 7: Box plots of raw Wolf number (w) by observer rank.

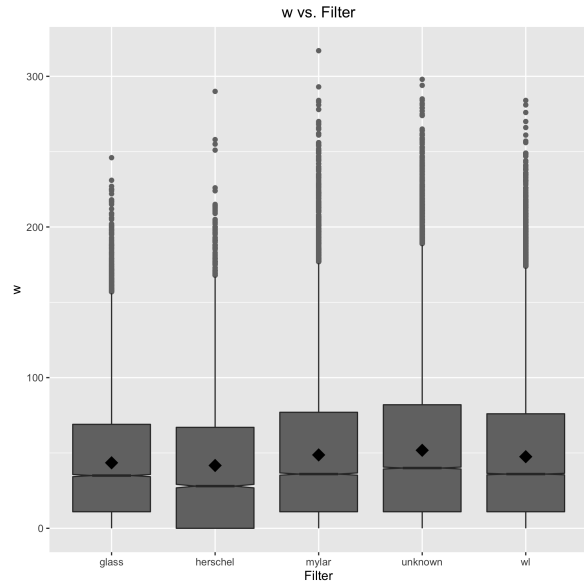


Figure 8: Box plots of raw Wolf number (w) by month and year.

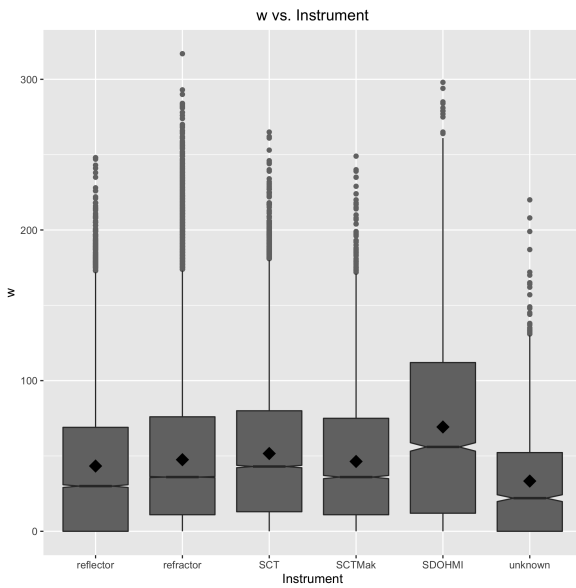


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

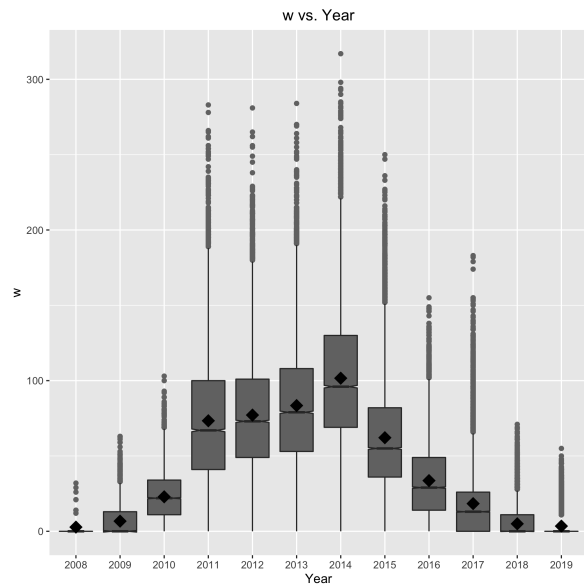


Figure 10: Box plots of raw Wolf number (w) by organization.

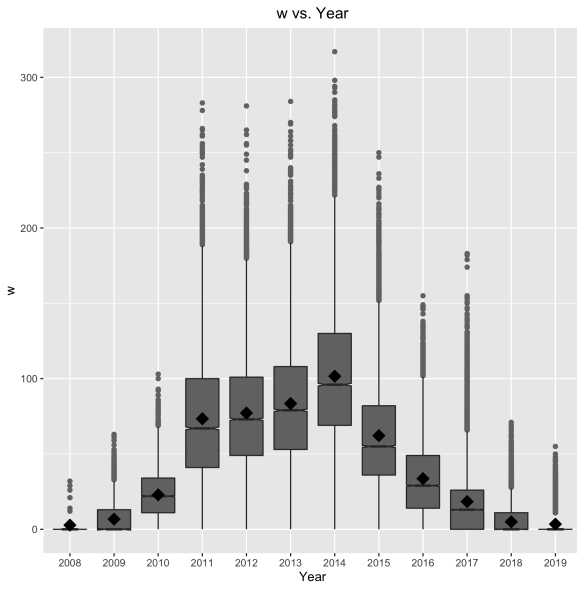


Figure 11: Box plots of raw Wolf number (w) by year.

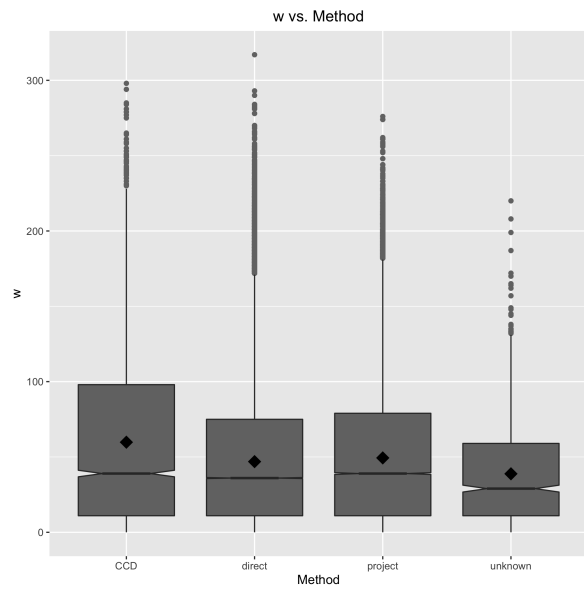


Figure 12: Box plots of raw Wolf number (w) by observing method.