

Monthly Report (00)

201811 Data Set

Thursday 13th December, 2018

Prepared for

Statistics for Physical and Engineering Sciences

by

Jamie Riggs, Ph.D.

Principal Statistician
Statistics for Physical and Engineering Sciences Institute

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.

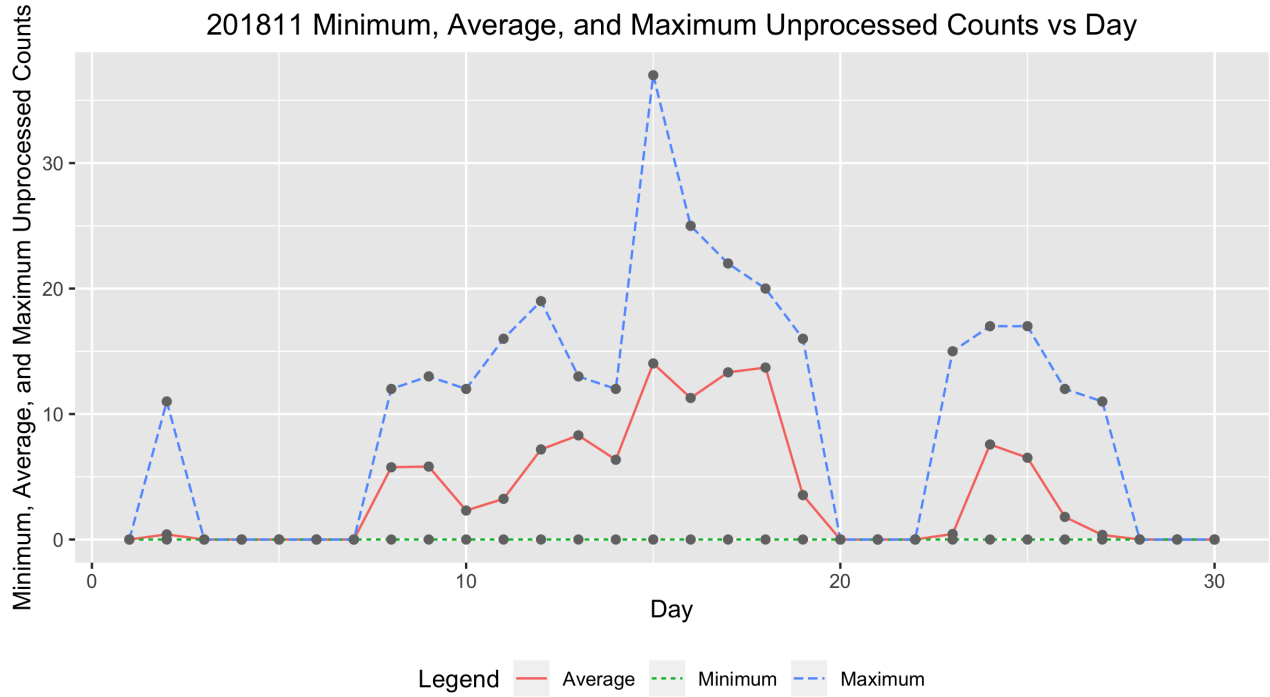


Figure 1: Raw average sunspot count by day of the month.

Table 1: 201811 Daily Raw Counts

Day	Submissions	Minimum	Average	Maximum
1.0000	31.0000	0.0000	0.0000	0.0000
2.0000	27.0000	0.0000	0.4074	11.0000
3.0000	36.0000	0.0000	0.0000	0.0000
4.0000	32.0000	0.0000	0.0000	0.0000
5.0000	26.0000	0.0000	0.0000	0.0000
6.0000	23.0000	0.0000	0.0000	0.0000
7.0000	32.0000	0.0000	0.0000	0.0000
8.0000	29.0000	0.0000	5.7586	12.0000
9.0000	27.0000	0.0000	5.8148	13.0000
10.0000	29.0000	0.0000	2.3103	12.0000
11.0000	33.0000	0.0000	3.2424	16.0000
12.0000	28.0000	0.0000	7.1786	19.0000
13.0000	30.0000	0.0000	8.3000	13.0000
14.0000	28.0000	0.0000	6.3571	12.0000
15.0000	32.0000	0.0000	14.0312	37.0000
16.0000	25.0000	0.0000	11.2800	25.0000
17.0000	37.0000	0.0000	13.3243	22.0000
18.0000	27.0000	0.0000	13.7037	20.0000
19.0000	26.0000	0.0000	3.5385	16.0000
20.0000	23.0000	0.0000	0.0000	0.0000
21.0000	31.0000	0.0000	0.0000	0.0000
22.0000	21.0000	0.0000	0.0000	0.0000
23.0000	34.0000	0.0000	0.4412	15.0000
24.0000	26.0000	0.0000	7.5769	17.0000
25.0000	29.0000	0.0000	6.5172	17.0000
26.0000	25.0000	0.0000	1.8000	12.0000
27.0000	30.0000	0.0000	0.3667	11.0000
28.0000	32.0000	0.0000	0.0000	0.0000
29.0000	24.0000	0.0000	0.0000	0.0000
30.0000	31.0000	0.0000	0.0000	0.0000

3 Error Tables

Data are for the month of November 2018. 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	2.4073	3.1336	0.5000	1.0000
2009.01	5.8077	5.1780	6.4373	1.3000	1.3000
2009.02	5.1201	4.5499	5.6903	0.7000	1.2000
2009.03	6.5845	6.3228	6.8463	0.3000	0.6000
2009.04	7.4057	7.1340	7.6775	0.4000	1.2000
2009.05	7.5115	7.2063	7.8166	1.6000	2.9000
2009.06	6.6765	6.3325	7.0206	3.2000	6.3000
2009.07	6.3670	6.1060	6.6279	3.6000	5.5000
2009.08	7.0515	6.7652	7.3378	0.0000	0.0000
2009.09	7.5390	7.2650	7.8131	4.5000	7.1000
2009.10	7.0445	6.6664	7.4225	4.5000	7.7000
2009.11	7.0068	6.8129	7.2006	3.3000	6.9000
2009.12	6.5434	6.3561	6.7307	10.4000	16.3000
2010.01	21.4491	19.0044	23.8937	13.3000	19.5000
2010.02	17.1782	14.8392	19.5171	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	18.3942	16.1080	20.6805	15.4000	24.0000
2010.04	20.4285	18.0159	22.8410	7.0000	10.4000
2010.05	24.4974	24.0622	24.9326	8.4000	8.7000
2010.06	20.4137	20.0738	20.7537	11.0000	13.6000
2010.07	21.3463	21.0362	21.6564	15.2000	16.1000
2010.08	22.8482	22.4726	23.2237	18.3000	19.6000
2010.09	25.3668	24.9480	25.7856	22.8000	25.2000
2010.10	23.9817	23.5669	24.3965	21.0000	23.5000
2010.11	24.4345	23.9903	24.8788	20.9000	21.6000
2010.12	21.8769	21.4351	22.3186	13.9000	14.5000
2011.01	76.3496	74.7667	77.9324	17.7000	18.7000
2011.02	66.4490	65.0259	67.8721	29.1000	29.6000
2011.03	69.2482	67.9250	70.5715	48.0000	55.8000
2011.04	77.7447	76.3469	79.1426	47.3000	54.4000
2011.05	79.0131	77.6757	80.3504	37.3000	41.5000
2011.06	65.8366	64.6811	66.9920	35.2000	37.0000
2011.07	68.1271	66.9591	69.2952	41.5000	43.8000
2011.08	73.7953	72.6048	74.9858	42.4000	50.5000
2011.09	80.5452	79.1505	81.9399	73.8000	78.0000
2011.10	76.1852	74.9014	77.4690	78.9000	88.0000
2011.11	77.3665	75.7483	78.9848	84.6000	96.7000
2011.12	68.2028	66.7964	69.6093	65.8000	73.0000
2012.01	81.9665	80.3548	83.5781	55.8000	58.2000
2012.02	70.1392	68.7126	71.5658	29.2000	33.1000
2012.03	73.7485	72.4416	75.0554	53.1000	64.1000
2012.04	81.5777	80.1512	83.0043	51.4000	55.2000
2012.05	84.4794	83.0857	85.8730	61.8000	69.0000
2012.06	69.7037	68.5182	70.8893	59.7000	64.5000
2012.07	72.5240	71.3334	73.7146	64.2000	51.3000
2012.08	75.7541	74.5372	76.9710	57.7000	63.1000
2012.09	83.2109	81.7662	84.6557	57.7000	61.5000
2012.10	79.5599	78.1036	81.0162	48.3000	53.3000
2012.11	80.7874	79.1661	82.4088	56.7000	61.4000
2012.12	71.3811	69.8314	72.9309	37.4000	40.8000
2013.01	91.1354	89.3933	92.8775	63.8000	62.9000
2013.02	78.1432	76.5705	79.7160	37.8000	38.0000
2013.03	79.5624	77.9462	81.1786	50.6000	57.9000
2013.04	88.9715	87.4085	90.5345	70.6000	72.4000
2013.05	90.0518	88.4500	91.6537	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	75.8111	74.4708	77.1513	51.0000	52.5000
2013.07	77.8997	76.6492	79.1502	57.0000	57.0000
2013.08	82.9289	81.5962	84.2617	60.0000	66.0000
2013.09	89.8029	88.2018	91.4041	34.6000	36.9000
2013.10	84.8045	83.2330	86.3760	74.5000	85.6000
2013.11	84.5496	82.6546	86.4446	73.9000	77.6000
2013.12	76.8335	75.1938	78.4733	77.8000	90.3000
2014.01	106.1663	103.9330	108.3997	77.4000	82.0000
2014.02	92.8520	91.0236	94.6805	93.9000	102.8000
2014.03	96.7642	95.0028	98.5255	80.9000	92.2000
2014.04	108.3713	106.4801	110.2626	76.9000	84.7000
2014.05	110.3617	108.4788	112.2446	72.3000	75.2000
2014.06	92.7019	91.1343	94.2696	67.2000	71.0000
2014.07	94.9651	93.3848	96.5455	72.5000	72.5000
2014.08	101.2537	99.6717	102.8357	71.2000	74.7000
2014.09	110.7916	108.8386	112.7446	83.2000	87.6000
2014.10	104.3097	102.3890	106.2303	59.5000	60.6000
2014.11	105.0204	102.8329	107.2078	65.8000	71.1000
2014.12	93.4793	91.3120	95.6466	75.8000	78.0000
2015.01	65.6704	64.3549	66.9859	65.9000	67.0000
2015.02	56.0088	54.7736	57.2439	42.4000	44.8000
2015.03	59.1380	58.0538	60.2222	38.0000	38.4000
2015.04	65.7935	64.6112	66.9758	49.0000	54.4000
2015.05	67.3148	66.1982	68.4315	56.3000	58.8000
2015.06	56.4428	55.4217	57.4639	50.2000	68.3000
2015.07	57.3113	56.3300	58.2926	47.9000	65.8000
2015.08	62.3589	61.3078	63.4101	39.5000	57.2000
2015.09	67.3413	66.1141	68.5684	49.2000	72.1000
2015.10	63.9008	62.6636	65.1379	39.3000	48.3000
2015.11	65.0590	63.6431	66.4749	39.6000	55.9000
2015.12	57.9819	56.7055	59.2584	36.4000	44.8000
2016.01	35.9391	35.1877	36.6905	33.7000	43.3000
2016.02	30.7995	30.1563	31.4426	38.3000	46.8000
2016.03	31.9958	31.3562	32.6355	30.5000	38.9000
2016.04	35.4939	34.8156	36.1723	26.6000	30.9000
2016.05	36.4038	35.7362	37.0714	33.7000	48.4000
2016.06	30.1912	29.6746	30.7078	13.1000	19.5000
2016.07	31.2260	30.7222	31.7297	21.2000	27.5000
2016.08	33.6032	33.0102	34.1963	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	37.1496	36.4693	37.8300	27.7000	37.1000
2016.10	34.8497	34.1754	35.5240	22.7000	31.7000
2016.11	35.0831	34.3479	35.8184	14.0000	22.2000
2016.12	31.6675	30.9900	32.3449	11.1000	20.0000
2017.01	19.5520	19.1402	19.9639	18.4000	26.2000
2017.02	16.8221	16.4522	17.1920	14.4000	20.6000
2017.03	17.6292	17.2928	17.9656	11.3000	15.5000
2017.04	19.7732	19.4236	20.1229	21.6000	33.2000
2017.05	19.9499	19.6045	20.2953	12.5000	18.1000
2017.06	16.5597	16.2826	16.8369	15.5000	19.3000
2017.07	17.2016	16.9272	17.4759	11.5000	16.3000
2017.08	18.4467	18.1282	18.7653	22.8000	35.7000
2017.09	20.6670	20.2588	21.0752	34.6000	42.9000
2017.10	18.9575	18.5780	19.3370	10.5000	11.0000
2017.11	18.9368	18.5400	19.3336	4.2000	5.6000
2017.12	16.9815	16.7219	17.2410	4.0000	4.6000
2018.01	5.6246	5.5024	5.7469	3.1000	6.3000
2018.02	4.7935	4.6761	4.9110	6.8000	11.8000
2018.03	4.9354	4.8350	5.0358	1.1000	1.2000
2018.04	5.4883	5.3762	5.6004	4.7000	7.5000
2018.05	5.6744	5.5610	5.7879	8.4000	14.0000
2018.06	4.6963	4.6079	4.7847	10.2000	13.6000
2018.07	4.8535	4.7957	4.9112	0.5000	1.7000
2018.08	5.1543	5.0581	5.2504	5.9000	9.5000
2018.09	5.5643	5.4548	5.6737	1.6000	2.9000
2018.10	5.3835	5.2755	5.4915	2.5000	5.6000
2018.11	5.4055	5.2886	5.5224	3.1000	4.2000

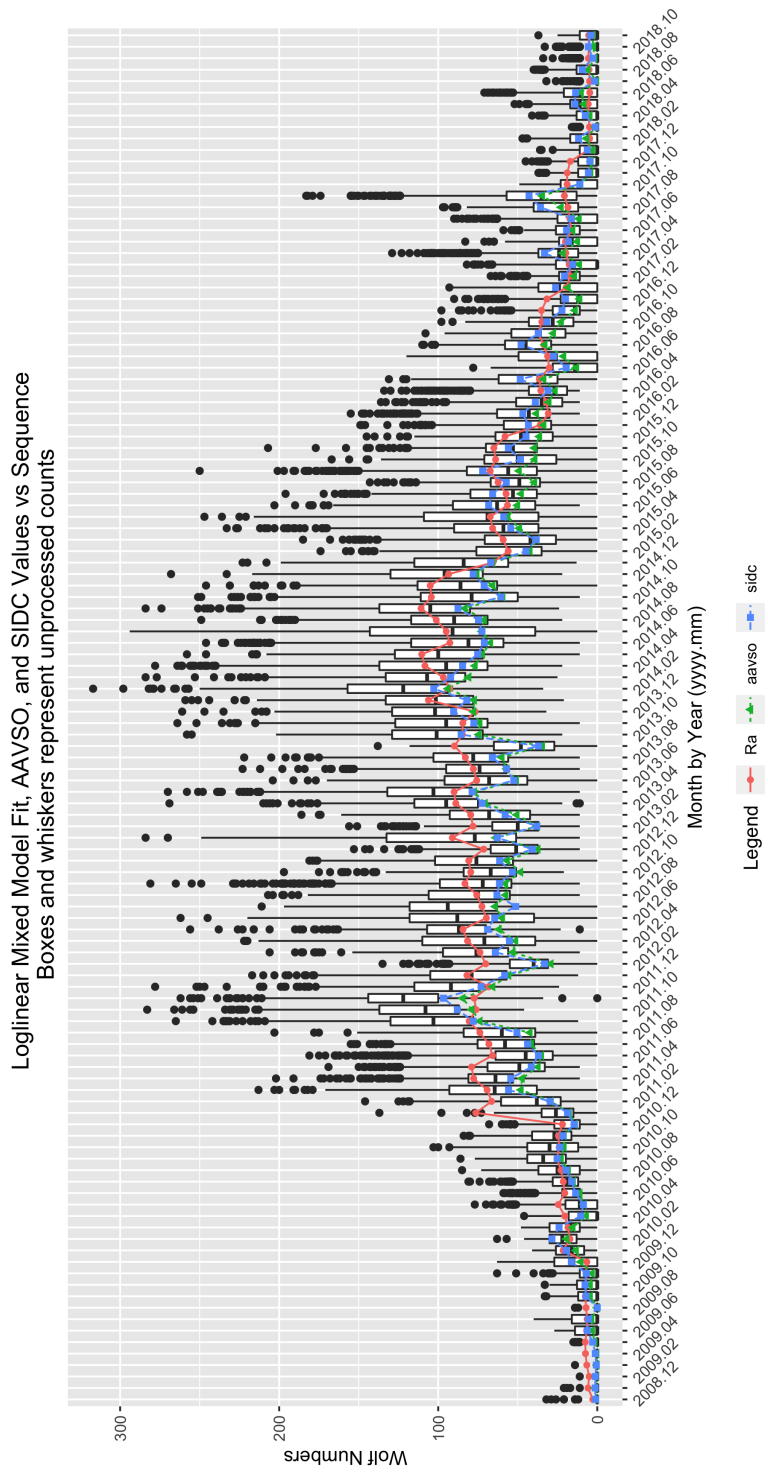


Figure 2: GLMM fitted data for R_a . AAVSO data: <https://www.aavso.org/category/tags/solar-bulletin>. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

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: 201811 Parameter Estimates

	Estimate	Std. Error	t-value	$\Pr(> t)$
(Intercept)	1.4247	0.3165	4.5014	0.0000
seeF	-0.2188	0.0060	-36.5240	0.0000
seeG	-0.1160	0.0052	-22.2356	0.0000
seeM	-0.1972	0.0246	-8.0228	0.0000
seeP	-0.3254	0.0086	-37.9210	0.0000
sidc1	0.1633	0.0704	2.3188	0.0204
year2009	0.6446	0.3175	2.0306	0.0423
year2010	1.8551	0.3153	5.8843	0.0000
year2011	2.9756	0.3152	9.4414	0.0000
year2012	3.0131	0.3152	9.5605	0.0000
year2013	3.1091	0.3152	9.8653	0.0000
year2014	3.3061	0.3152	10.4905	0.0000
year2015	2.8216	0.3152	8.9528	0.0000
year2016	2.2046	0.3152	6.9943	0.0000
year2017	1.5997	0.3152	5.0745	0.0000
year2018	0.3454	0.3156	1.0946	0.2737
mon2	-0.1449	0.0095	-15.3308	0.0000
mon3	-0.1114	0.0089	-12.5308	0.0000
mon4	-0.0089	0.0086	-1.0408	0.2980
mon5	0.0035	0.0084	0.4136	0.6791
mon6	-0.1811	0.0088	-20.5765	0.0000
mon7	-0.1555	0.0086	-18.1697	0.0000
mon8	-0.0830	0.0084	-9.9127	0.0000
mon9	0.0150	0.0084	1.7868	0.0740
mon10	-0.0391	0.0086	-4.5201	0.0000
mon11	-0.0174	0.0090	-1.9237	0.0544
mon12	-0.1238	0.0092	-13.4323	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: 201811 Summary of Sunspot Numbers

year	mon	day	obs	side
Min. :2008	Min. : 1.000	Min. : 0.00	Length:106893	Min. :0.0000
1st Qu.:2012	1st Qu.: 4.000	1st Qu.: 8.00	Class :character	1st Qu.:0.0000
Median :2014	Median : 7.000	Median :16.00	Mode :character	Median :0.0000
Mean :2014	Mean : 6.679	Mean :15.73		Mean :0.2628
3rd Qu.:2016	3rd Qu.: 9.000	3rd Qu.:23.00		3rd Qu.:1.0000
Max. :2018	Max. :12.000	Max. :31.00		Max. :1.0000

Table 5: 201811 Summary of Sunspot Numbers

g	s	w	see	method
Min. : 0.000	Min. : 0.00	Min. : 0.0	Length:106893	Length:106893
1st Qu.: 1.000	1st Qu.: 3.00	1st Qu.: 14.0	Class :character	Class :character
Median : 3.000	Median : 13.00	Median : 44.0	Mode :character	Mode :character
Mean : 3.348	Mean : 20.02	Mean : 53.5		
3rd Qu.: 5.000	3rd Qu.: 30.00	3rd Qu.: 82.0		
Max. :19.000	Max. :204.00	Max. :317.0		

Table 6: 201811 Summary of Sunspot Numbers

inst	filter	unit
Length:106893	Length:106893	Length:106893
Class :character	Class :character	Class :character
Mode :character	Mode :character	Mode :character

Table 7: 201811 Summary of Sunspot Numbers

aperture	eyep	foclen	mag
Min. : 0.0	Min. : 0.00	Min. : 0	Min. : 0.0
1st Qu.: 76.0	1st Qu.: 2.00	1st Qu.: 700	1st Qu.: 40.0
Median : 90.0	Median : 13.00	Median : 914	Median : 57.5
Mean : 106.4	Mean : 21.95	Mean :1065	Mean : 186.6
3rd Qu.: 125.0	3rd Qu.: 23.00	3rd Qu.:1260	3rd Qu.: 76.0
Max. :1524.0	Max. :2010.00	Max. :4300	Max. :4591.0

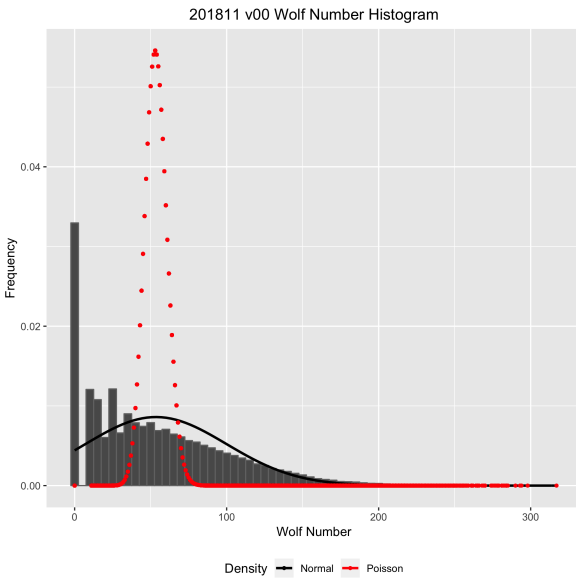


Figure 3: Box plots of raw Wolf number (w) by observer rank.

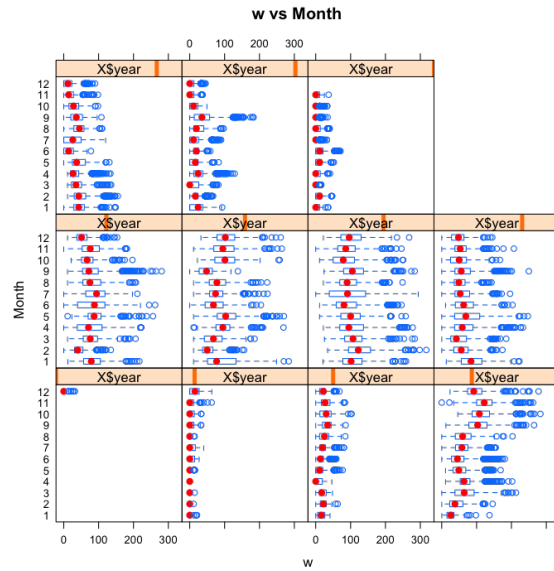


Figure 4: Box plots of raw Wolf number (w) by month and year.

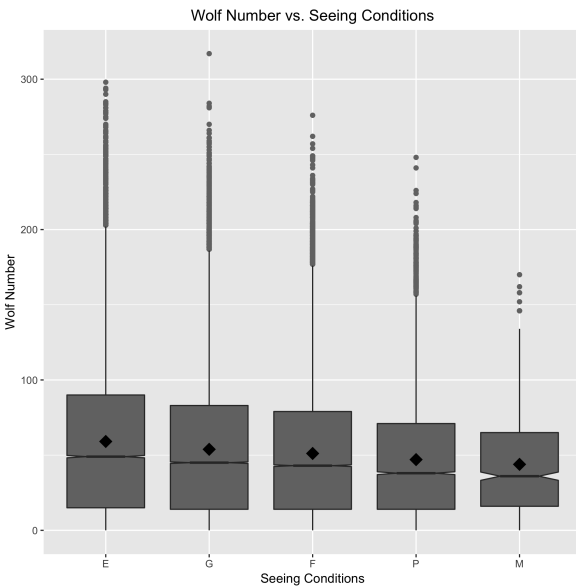


Figure 5: Box plots of raw Wolf number (w) by seeing condition.

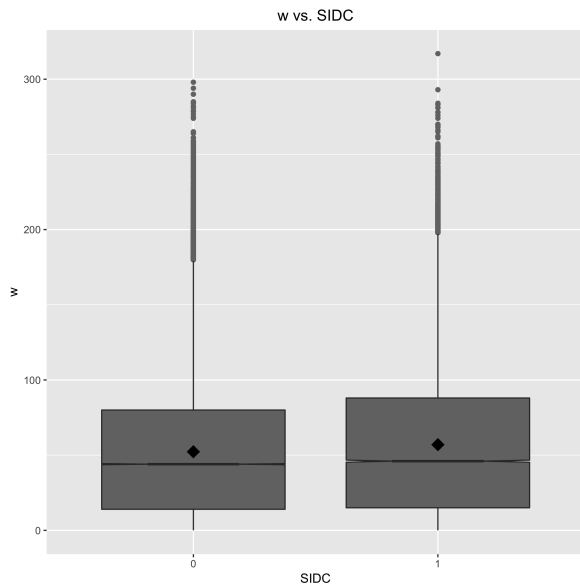


Figure 6: Box plots of raw Wolf number (w) by organization.

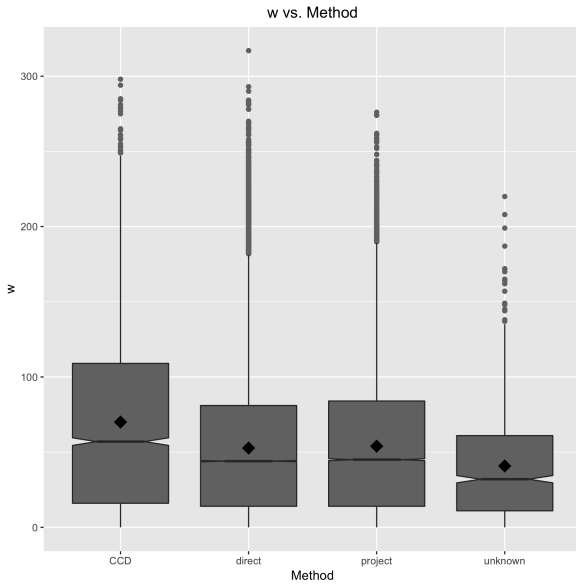


Figure 7: Box plots of raw Wolf number (w) by observer rank.

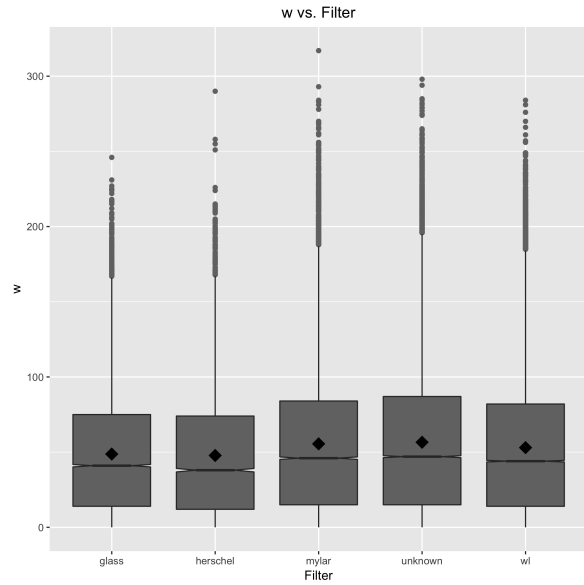


Figure 8: Box plots of raw Wolf number (w) by month and year.

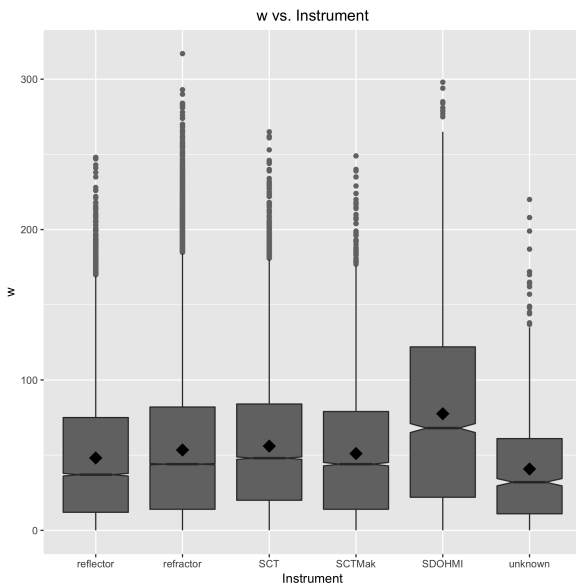


Figure 9: Box plots of raw Wolf number (w) by seeing condition.

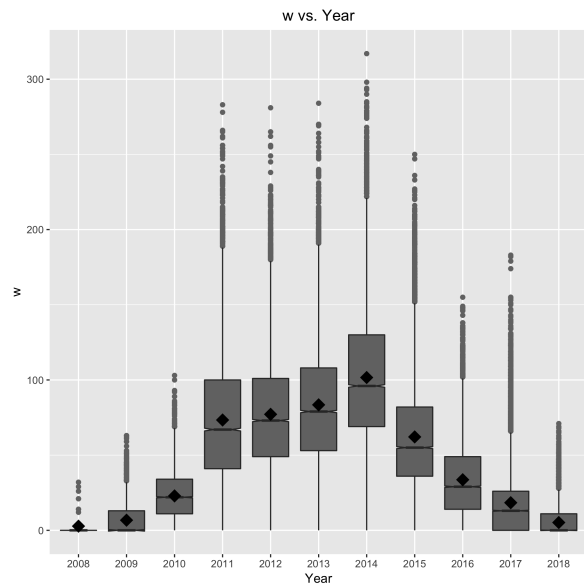


Figure 10: Box plots of raw Wolf number (w) by organization.

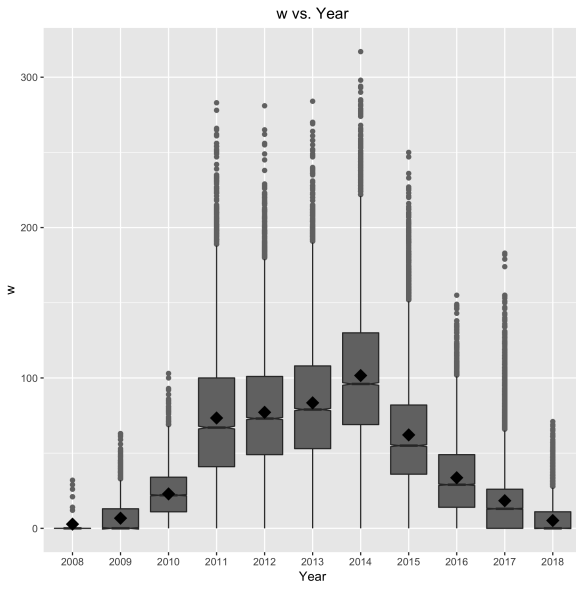


Figure 11: Box plots of raw Wolf number (w) by year.

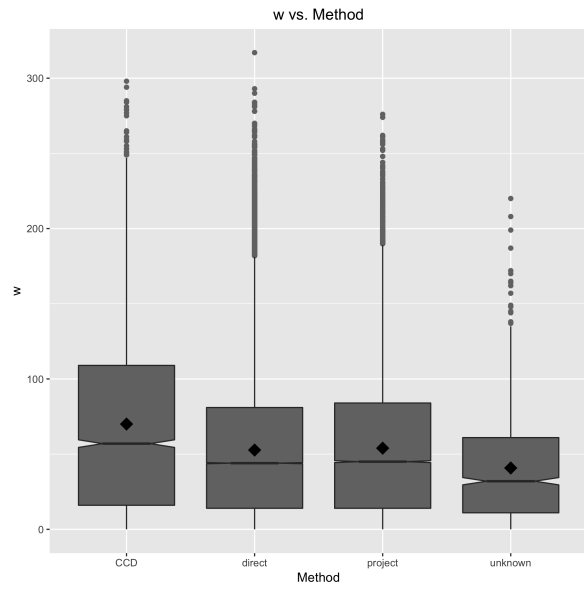


Figure 12: Box plots of raw Wolf number (w) by observing method.