Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

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The Solar Bulletin of the AAVSO is a summary of each month's solar activity recorded by visual solar observers' counts of group and sunspots, and the very low frequency (VLF) radio recordings of SID Events in the ionosphere. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Shapley's method with k-factors

Shapley's method with k-factors (`http://iopscience.iop.org/article/10.1086/126109/pdf`).

"The Shapley method is a statistical model that agglomerates variation due to random effects, such as observer group selection, and fixed effects, such as seeing condition.

$$\begin{aligned} \mu &= e^{\beta_0}\, e^{\beta_1 x_1}\, e^{\beta_2 x_2} \\ &= e^{\beta_0+\beta_1 x_1+\beta_2 x_2} \\ \Rightarrow \log \mu &= \beta_1 x_1 + \beta_2 x_2. \end{aligned} \tag{1}$$

where μ is the expected value of the Wolf number as generated by the model predictor variables x_1 = observer, say, and x_2 = observing method such as projection or direct filtering. The model estimation process calculates the values of β_0 (the model intercept), β_1, and β_2, estimated by likelihood methods, which connect the expected value of the Wolf number to the example's observer and corresponding observation method.

"It is important to note that the Wolf number (R_a) data are not transformed as $\log(R_a)$, rather the expected value of the Wolf number as given by a multiplication of exponential functions is transformed to yield the log of the mean as an additive relationship using the natural log link function as an example." (Dr. Jamie Riggs, 2017)

Table 1: 202301 K factor of observations by observer.

Observer Code	Number of observations	old K	new K
AAX	576	0.96	0.76
AJV	464	0.946	0.915
ARAG	798	1.083	0.593
ASA	517	0.936	0.889
ATE	675	0	0.779

Continued

Table 1: 202301 K factor of observations by observer.

Observer Code	Number of observations	old K	new K
BARH	102	1.045	1.336
BATR	225	0.875	0.806
BKL	185	0	1.001
BMF	582	0	0.842
BMIG	393	0	0.782
BRAF	182	0	0.686
BROB	597	0	0.848
BXZ	620	0	0.96
BZX	674	0.798	0.927
CHAG	130	0.898	0.853
CIOA	159	0.628	0.939
CKB	596	0.864	0.755
CNT	691	0.809	0.908
CVJ	184	1.21	0.957
DARB	389	0.836	1.134
DFR	242	1.014	0.966
DJOB	332	0.8	0.804
DMIB	641	0.72	0.805
DUBF	640	0.854	0.742
EHOA	439	0.96	0.875
ERB	443	0.894	1.433
FERA	311	0.895	1.203
FLET	633	0.965	0.804
GIGA	705	0.768	1.212
HALB	303	0.912	0.826
HKY	502	0.919	1.136
HMQ	153	1	1.047
HOWR	535	0.804	1.171
HRUT	283	0.807	0.774
IEWA	574	0.743	1.01
ILUB	130	0.86	0.813
JDAC	169	1.291	1.168
JGE	145	0.833	0.799
JSI	109	1.211	0.883
KAMB	351	0.833	1.087
KAND	507	1.098	0.825
KAPJ	408	1.019	1.316
KNJS	780	1.133	0.863
KZAD	194	0.83	1.058
LEVM	305	1.107	1.275
LKR	204	0.832	1.073
LRRA	461	0.944	1.238
MARC	189	0.863	1.02

Continued

Table 1: 202301 K factor of observations by observer.

Observer Code	Number of observations	old K	new K
MARE	173	1.186	0.858
MCE	563	0.903	0.79
MJAF	749	1.147	0.646
MJHA	740	1.047	1.232
MLL	332	1.142	1.106
MMAY	684	0.971	0.809
MMI	725	0.867	0.393
MUDG	159	0.799	0.951
MWU	547	0.717	0.862
OAAA	485	1.109	0.716
ONJ	379	1.105	1.113
PLUD	298	0	0.76
RFDA	244	0.981	0.938
RJV	490	0.98	0.693
SATH	211	0.742	1.089
SDOH	820	1.022	0.479
SNE	162	0.731	0.956
SQN	175	1.07	0.976
SRIE	283	0.928	0.865
STAB	127	0.914	0.918
SUZM	222	0.74	0.688
TDE	665	0.795	0.774
TST	479	1.322	1.387
URBP	497	0.826	0.849
VIDD	347	1.297	1.367
WND	138	0.917	0.557
WWM	496	0	0.832
Totals	30617	0.8274	0.92667

The old k - factor average of 0.8274 was calculated during the last solar minimum (2020 through 2022) and there are 0 k - factors for some observers. The new k - factor average of 0.92667 shows how from the start of this cycle 25 with new observers the k - factor average is closer to 1, the optimum for calculating the (R_a) index. There have to be at least 100 observations with the current telescope before the k - factor is calculated.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

September 2024 (Figure 1): There was an X4.5 flare during the day with both positive and a negative SID Events recorded here in Fort Collins, Colorado (U.S. Dept. of Commerce–NOAA, 2022).

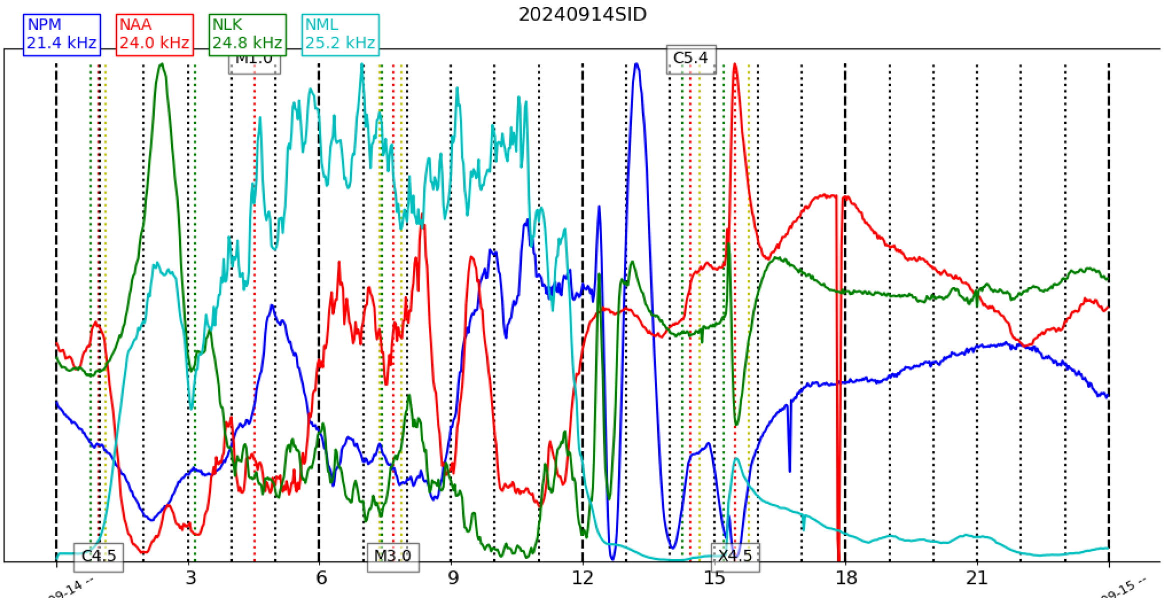

Figure 1: VLF recording from Fort Collins, Colorado for the 14th of September.

2.2 SID Observers

In September 2024 we had 11 AAVSO SID observers who submitted VLF data as listed in Table 2.

Table 2: 202409 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD ICV
J Karlovsky	A131	DHO FTA
S Aguirre	A138	NAA
L Pina	A148	NAA NML
J Wendler	A150	NAA
H Krumnow	A152	DHO FTA GBZ
J DeVries	A153	NAA
M Salo	A157	NLK

Figure 2 depicts the importance rating of the solar events. The duration in minutes are -1: LT 19, 1: 19-25, 1+: 26-32, 2: 33-45, 2+: 46-85, 3: 86-125, and 3+: GT 125.

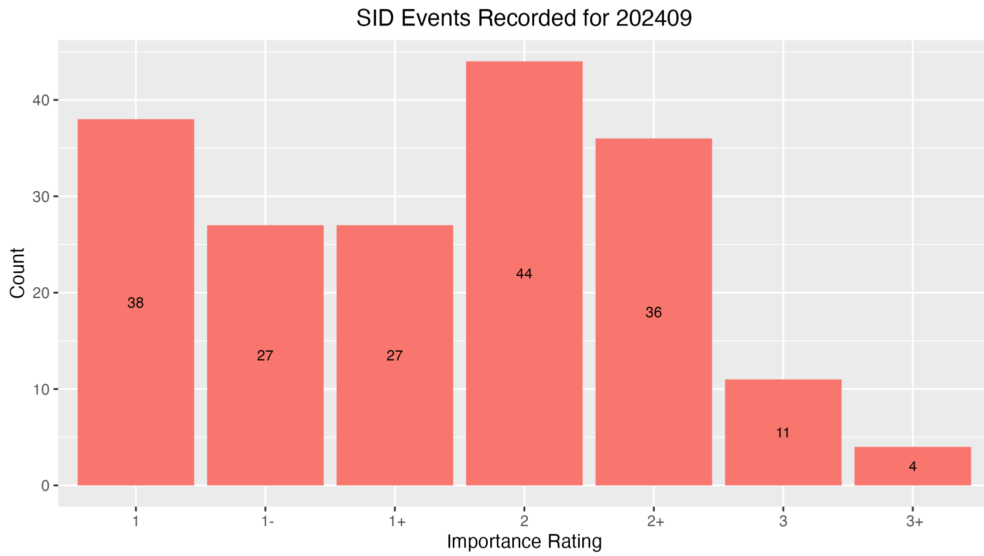

Figure 2: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In September 2024, there were 227 GOES-16 XRA flares: 2 X class, 66 M class, 159 C class. There was a lot less flaring this month compared to last. (U.S. Dept. of Commerce–NOAA, 2024). (see Figure 3).

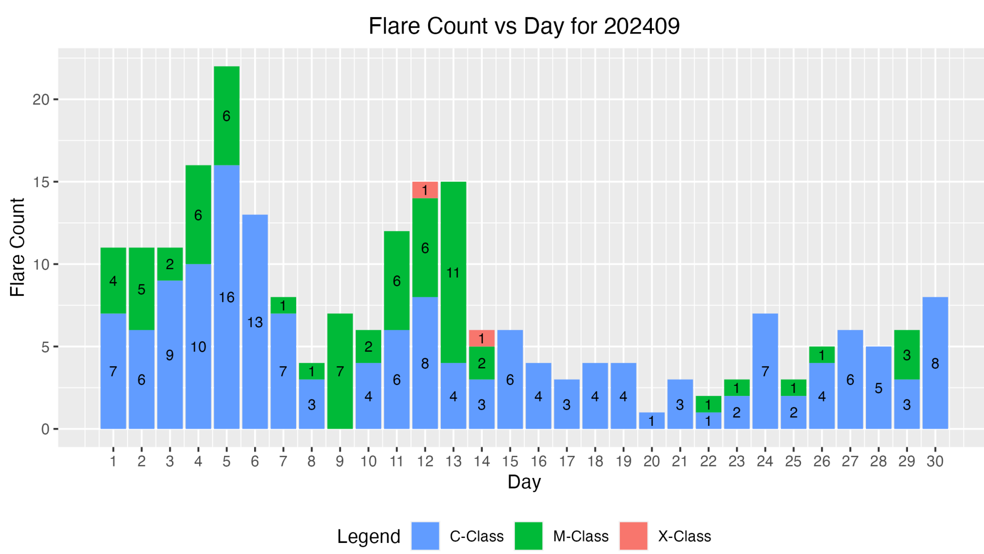

Figure 3: GOES-16 XRA flares (U.S. Dept. of Commerce–NOAA, 2024).

3 Relative Sunspot Numbers (R_a)

Reporting monthly sunspot numbers consists of submitting an individual observer's daily counts for a specific month to the AAVSO Solar Section. These data are maintained in a Structured Query Language (SQL) database. The monthly data then are extracted for analysis. This section is the portion of the analysis concerned with both the raw and daily average counts for a particular month. Scrubbing and filtering the data assure error-free data are used to determine the monthly sunspot numbers.

3.1 Raw Sunspot Counts

The raw daily sunspot counts consist of submitted counts from all observers who provided data in September 2024. These counts are reported by the day of the month. 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 4.

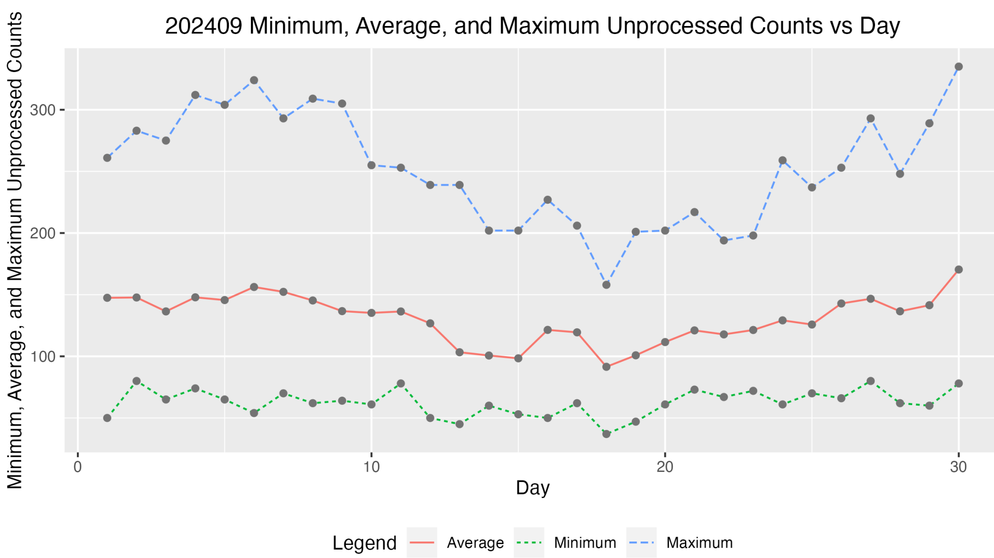

Figure 4: Raw Wolf number average, minimum and maximum by day of the month for all observers.

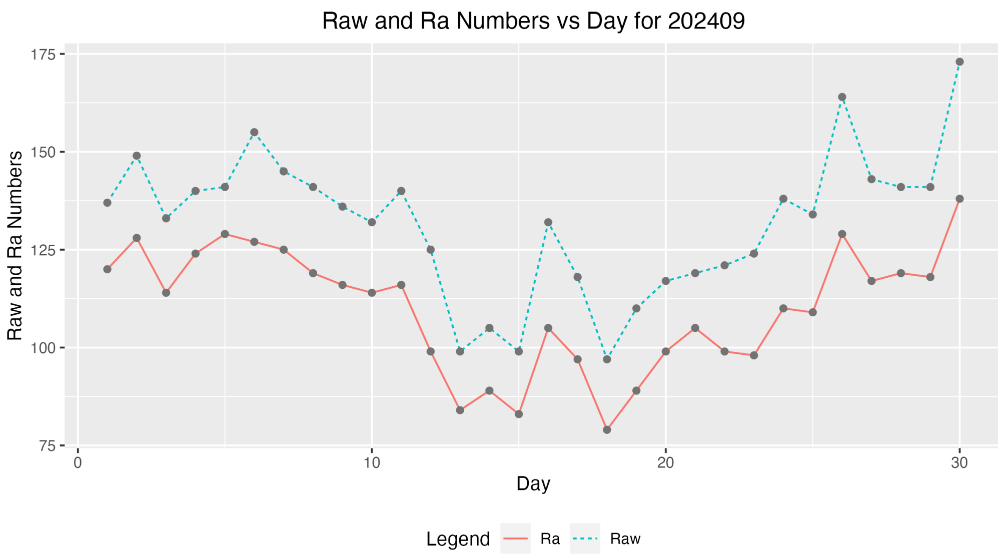

Figure 5: Raw Wolf average and R_a numbers by day of the month for all observers.

3.2 American Relative Sunspot Numbers

The relative sunspot numbers, R_a, contain the sunspot numbers after the submitted data are scrubbed and modeled by Shapley's method with k-factors (`http://iopscience.iop.org/article/10.1086/126109/pdf`). The Shapley method is a statistical model that agglomerates variation due to random effects, such as observer group selection, and fixed effects, such as seeing condition. The raw Wolf averages and calculated R_a are seen in Figure 5, and Table 3 shows the Day of the observation (column 1), the Number of Observers recording that day (column 2), the raw Wolf number (column 3), and the Shapley Correction (R_a) (column 4).

Table 3: 202409 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	36	137	120
2	33	149	128
3	35	133	114
4	34	140	124
5	30	141	129
6	29	155	127
7	31	145	125
8	33	141	119
9	33	136	116
10	39	132	114
11	26	140	116
12	25	125	99
13	29	99	84
14	38	105	89
15	38	99	83

Continued

Table 3: 202409 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
16	34	132	105
17	34	118	97
18	32	97	79
19	35	110	89
20	35	117	99
21	33	119	105
22	27	121	99
23	28	124	98
24	29	138	110
25	29	134	109
26	28	164	129
27	26	143	117
28	36	141	119
29	34	141	118
30	27	173	138
Averages	31.9	131.6	109.9

3.3 Sunspot Observers

Table 4 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for September 2024, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (64), and total number of observations submitted (956).

Table 4: 202409 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	21	Alexandre Amorim
AJV	12	J. Alonso
ARAG	30	Gema Araujo
ASA	4	Salvador Aguirre
BATR	2	Roberto Battaiola
BKL	3	John A. Blackwell
BMIG	23	Michel Besson
BTB	17	Thomas Bretl
BXZ	21	Jose Alberto Berdejo
BZX	25	A. Gonzalo Vargas
CKB	26	Brian Cudnik
CLDB	14	Laurent Cambon
CMAB	4	Maurizio Cervoni
CNT	20	Dean Chantiles
CVJ	4	Jose Carvajal

Continued

Table 4: 202409 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DARB	20	Aritra Das
DELS	2	Susan Delaney
DGIA	15	Giuseppe di Tommasco
DJOB	16	Jorge del Rosario
DJSA	8	Jeff DeVries
DJVA	26	Jacques van Delft
DMIB	17	Michel Deconinck
DUBF	16	Franky Dubois
EHOA	10	Howard Eskildsen
FLET	23	Tom Fleming
GFAD	13	Fabrizio Guida
GIGA	24	Igor Grageda Mendez
HALB	14	Brian Halls
HKY	17	Kim Hay
HOWR	22	Rodney Howe
HSR	14	Serge Hoste
IEWA	19	Ernest W. Iverson
ILUB	3	Luigi Iapichino
JGE	3	Gerardo Jimenez Lopez
JSI	3	Simon Jenner
KAND	24	Kandilli Observatory
KAPJ	11	John Kaplan
KNJS	28	James & Shirley Knight
KTOC	10	Tom Karnuta
LKR	8	Kristine Larsen
LRRA	17	Robert Little
LVY	29	David Levy
MARC	3	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	14	Etsuiku Mochizuki
MJHA	26	John McCammon
MLL	6	Jay Miller
MMI	30	Michael Moeller
MUDG	4	George Mudry
MWMB	16	William McShan
MWU	26	Walter Maluf
NMID	11	Milena Niemczyk
PLUD	20	Ludovic Perbet
RJV	7	Javier Ruiz Fernandez
SDOH	30	Solar Dynamics Obs - HMI
SNE	10	Neil Simmons
SQN	13	Lance Shaw
SRIE	6	Rick St. Hilaire

Continued

Table 4: 202409 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
TDE	16	David Teske
TPJB	3	Patrick Thibault
TST	20	Steven Toothman
URBP	27	Piotr Urbanski
VIDD	11	Dan Vidican
WND	6	Denis Wallian
Totals	956	64

3.4 Generalized Linear Model of Sunspot Numbers

Dr. Jamie Riggs, Solar System Science Section Head, International Astrostatistics Association, maintains a relative sunspot number (R_a) model containing the sunspot numbers after the submitted data are scrubbed and modeled by a Generalized Linear Mixed Model (GLMM), which is a different model method from the Shapley method of calculating R_a in Section 3 above. The GLMM is a statistical model that accounts for variation due to random effects and fixed effects. For the GLMM 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 the paper, *A Generalized Linear Mixed Model for Enumerated Sunspots* (see 'GLMM06' in the sunspot counts research page at http://www.spesi.org/?page_id=65).

Figure 6 shows the monthly GLMM R_a numbers for a rolling eleven-year (132-month) window beginning within the 24th solar cycle and ending with last month's sunspot numbers. The solid cyan curve that connects the red *X's* is the GLMM model R_a estimates of excellent seeing conditions, which in part explains why these R_a estimates often are higher than the Shapley R_a values. The dotted black curves on either side of the cyan curve depict a 99% confidence band about the GLMM estimates. The green dotted curve connecting the green triangles is the Shapley method R_a numbers. The dashed blue curve connecting the blue *O's* is the SILSO values for the monthly sunspot numbers.

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 plot represents the InterQuartile Range (IQR), which depicts from the 25^{th} through the 75^{th} quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25^{th} quartile, and 1.5 times the IQR above the 75^{th} quartile. The black dots below and above the whiskers traditionally are considered outliers, but with GLMM modeling, they are observations that are accounted for by the GLMM model.

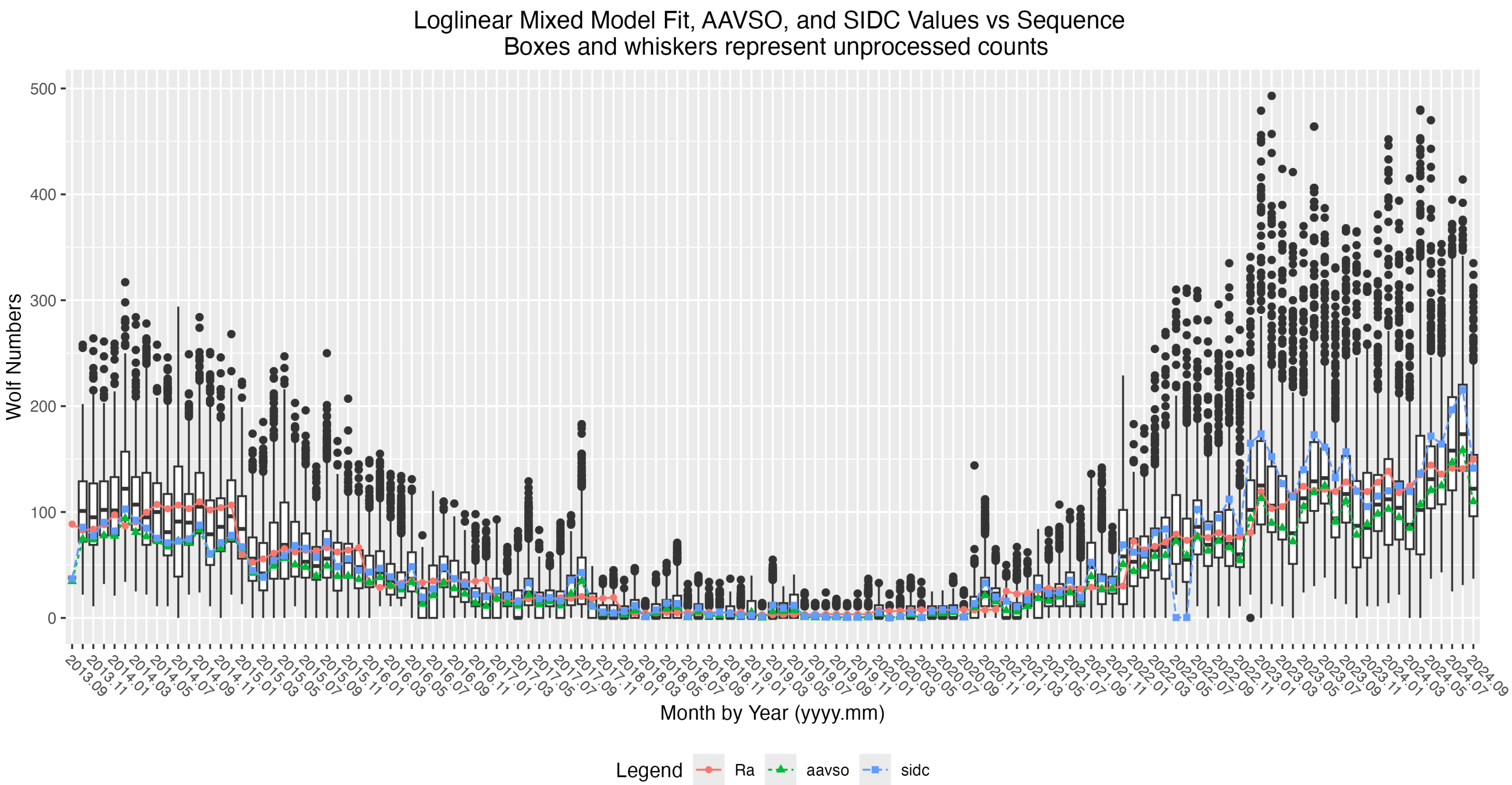

Figure 6: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

- Sunspot Reports: Kim Hay solar@aavso.org
- SID Solar Flare Reports: Rodney Howe rhowe137@icloud.com

The longest running AAVSO (R_a) index can be seen on the LASP site: (`https://lasp.colorado.edu/lisird/data/american_relative_sunspot_number_daily`) extracted from the NOAA compilations of 70 years of submitted Solar Bulletins.

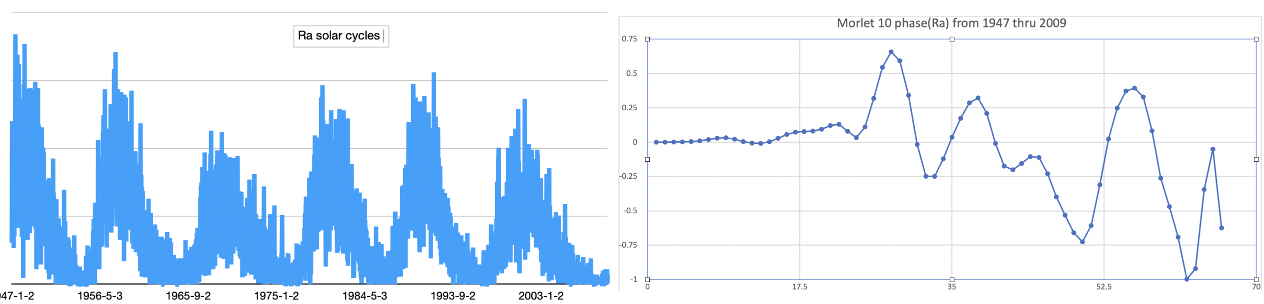

Figure 7: For example: these 6 solar cycles from 1947 through 2009 of AAVSO (R_a) index (left panel) come from the NOAA daily (R_a) numbers. When we run a Morlet FFT Wavelet we see downward phase pattern (right panel) - perhaps indicative of the downward solar cycle trend?

"In 1946, physicist Dennis Gabor, applying ideas from quantum physics, introduced the use of Gaussian-windowed sinusoids for time-frequency decomposition, which he referred to as atoms, and which provide the best trade-off between spatial and frequency resolution.[1] These are used in the Gabor transform, a type of short-time Fourier transform.[2] In 1984, Jean Morlet introduced Gabor's work to the seismology community and, with Goupillaud and Grossmann, modified it to keep the same wavelet shape over equal octave intervals, resulting in the first formalization of the continuous wavelet transform.[4]" (`https://en.wikipedia.org/wiki/Morlet_wavelet`)

5 Antique telescope project

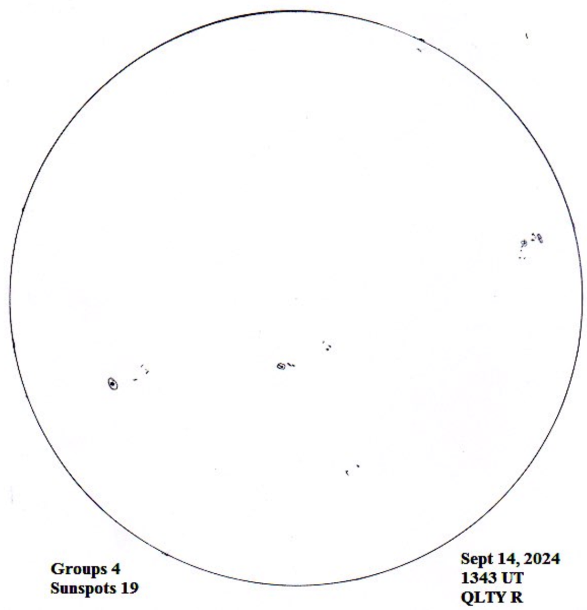

Figure 8: A recent replica of an antique telescope built by Gonzalo Vargas (BZX) in Cochabamba, Bolivia (left), and a drawing for the 14th of September (right).

6 References

Dr. Jamie Riggs (2017), Solar System Science Section Head, International Astrostatistics (using R Statistical Software (2023), TSA Libraries: (https://cran.r-project.org)

U.S. Dept. of Commerce–NOAA, Space Weather Prediction Center (2024). *GOES-16 XRA data.* ftp://ftp.swpc.noaa.gov/pub/indices/events/