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 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 Compare predictions for long-term and short-term sunspot observations

Using SILSO observations back to 1850, we can use Prophet R software to predict future sunspot cycles (`https://medium.com/dropout-analytics/intro-to-prophet-r-7f650f86adc7`). Then compare that with the AAVSO observations back to 2000. Solar cycle predictions are very different for different time series windows of solar cycles (Letham, 2017).

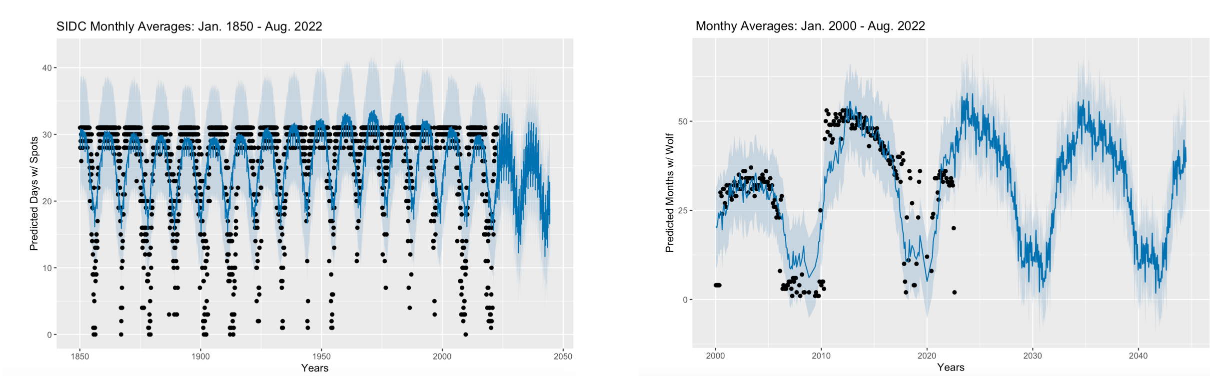

Figure 1: SILSO has re-constructed the international sunspot number (ISN) data back to 1850 for the last 15 solar cycles (SILSO, 2022). The Prophet software predicts the next couple solar cycles to be weaker than previous solar cycles. With the AAVSO observers' data from 2000 (short-term time series data), the Prophet software shows the next couple solar cycles to be about the same as the past two.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

July 2022 (Figure 2), there was a nice M1.4 flare on the 16th of July recorded here in Fort Collins, Colorado.

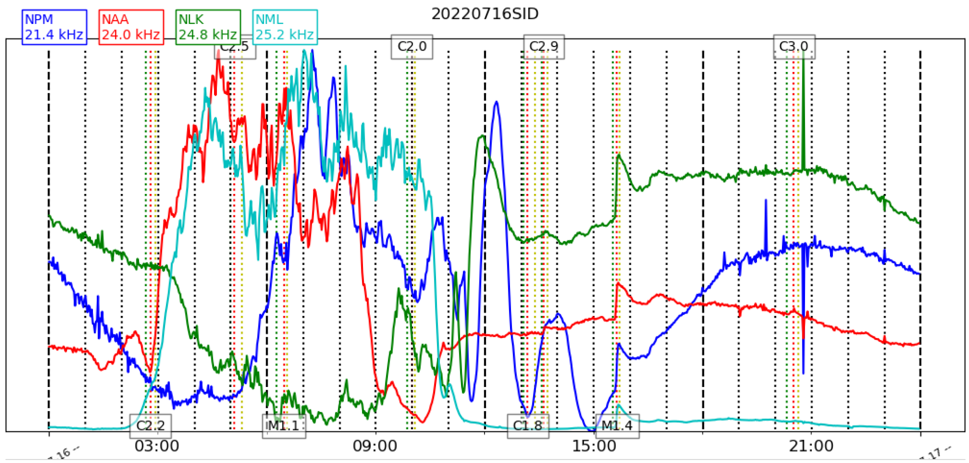

Figure 2: VLF recording on the 16th of July.

2.2 SID Observers

In July 2022, 18 AAVSO SID observers submitted VLF data as listed in Table 1.

Table 1: 202207 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD ICV
B Terrill	A120	NWC
F Adamson	A122	NWC
G Perry	A126	DHO
J Karlovsky	A131	DHO NAA TBB
R Green	A134	NWC
R Mrllak	A136	GQD NSY
S Aguirre	A138	NPM NAA
G Silvis	A141	NAA NML NLK
K Menzies	A146	NAA
L Pina	A148	NAA NLK NML
J Wendler	A150	NAA
H Krumnow	A152	FTA GBZ HWU
J DeVries	A153	NLK
R Mazur	A155	NLK NML

Figure 3 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.

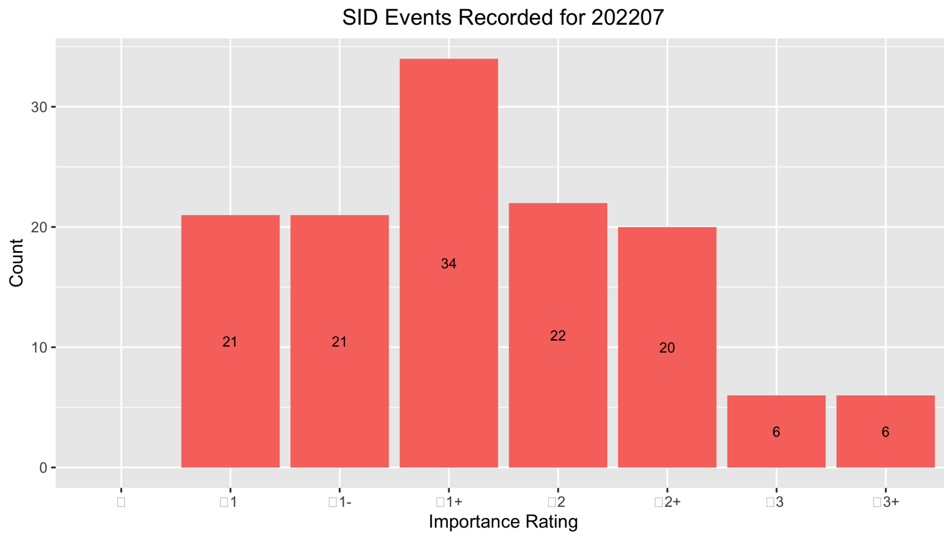

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In July 2022, there were 247 GOES-16 XRA flares: 7 M-class, 159 C-class, and 81 B-class flares. Far more this month compared to last month (Figure 4).

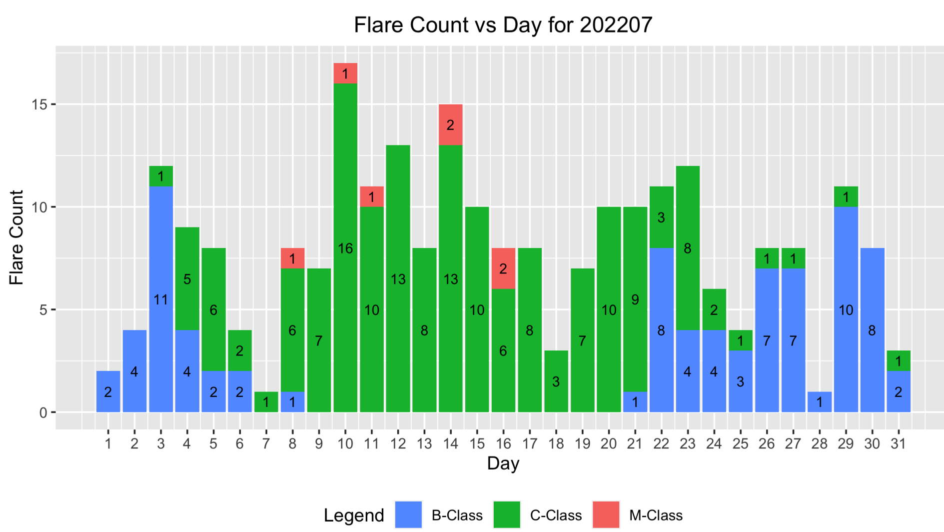

Figure 4: GOES-16 XRA (NOAA, 2022) flares.

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 July 2022. 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 5.

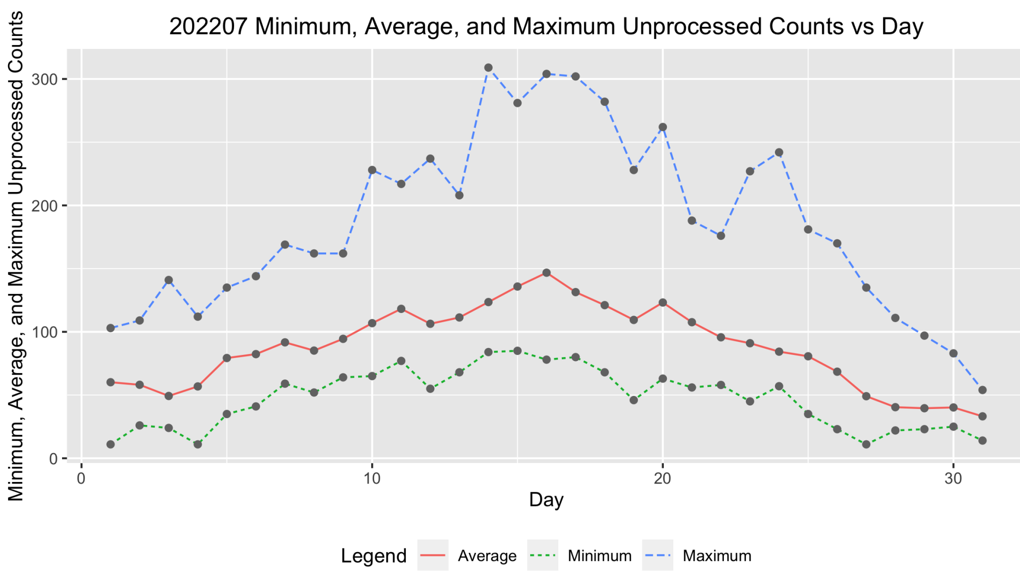

Figure 5: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

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 (`https://adsabs.harvard.edu/full/1949PASP...61...13S`). 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 6, and Table 2 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 2: 202207 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	47	64	57
2	40	58	49
3	41	50	40
4	44	57	50
5	38	81	69
6	41	84	70
7	44	91	79
8	46	87	75
9	46	97	83
10	48	109	95
11	43	118	103
12	43	113	99
13	44	118	102
14	37	126	110
15	46	139	119
16	40	154	125
17	41	141	113
18	35	127	108
19	48	115	101
20	43	124	109
21	39	111	90
22	40	95	82
23	42	94	81
24	36	84	68
25	36	81	69
26	34	72	59
27	36	51	42
28	37	43	34
29	38	40	33
30	42	43	37
31	37	33	28
Averages	41	90.3	76.7

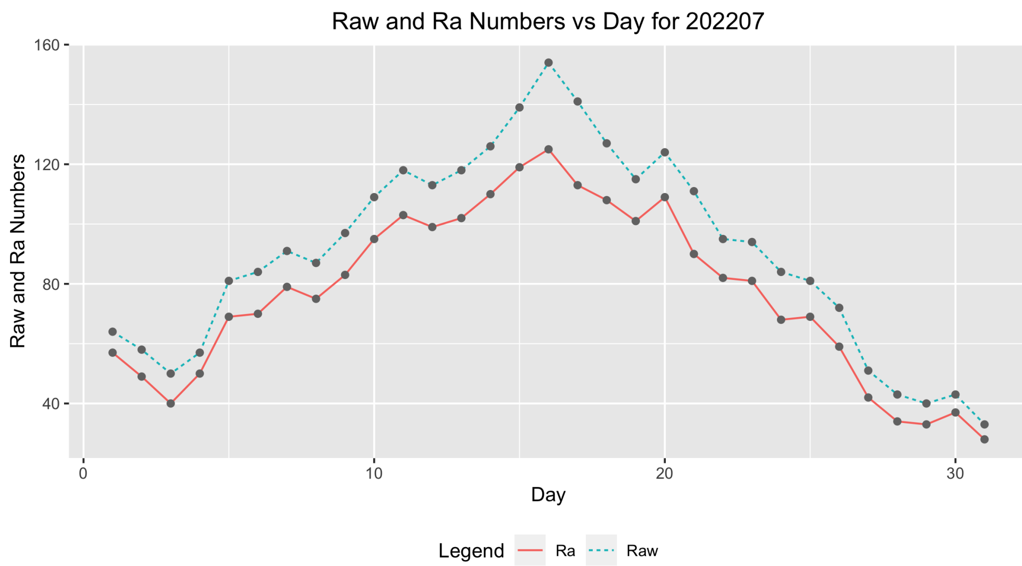

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for July 2022, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (69), and total number of observations submitted (1272).

Table 3: 202207 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	15	Alexandre Amorim
AJV	23	J. Alonso
ARAG	31	Gema Araujo
ASA	19	Salvador Aguirre
ATE	28	Teofilo Arranz Heras
BATR	7	Roberto Battaiola
BKL	20	John A. Blackwell
BMF	26	Michael Boschat
BMIG	31	Michel Besson
BROB	30	Robert Brown
BXZ	27	Jose Alberto Berdejo
BZX	25	A. Gonzalo Vargas
CANG	12	Andrew Corkill
CIOA	10	Ioannis Chouinavas
CKB	26	Brian Cudnik
CMOD	5	Mois Carlo
CNT	20	Dean Chantiles
CVJ	19	Jose Carvajal

Continued

Table 3: 202207 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DARB	10	Aritra Das
DFR	12	Frank Dempsey
DJOB	12	Jorge del Rosario
DUBF	30	Franky Dubois
EHOA	12	Howard Eskildsen
ERB	27	Bob Eramia
FERA	25	Eric Fabrigat
FLET	30	Tom Fleming
GIGA	28	Igor Grageda Mendez
HALB	26	Brian Halls
HKY	27	Kim Hay
HMQ	1	Mark Harris
HOWR	22	Rodney Howe
HRUT	11	Timothy Hrutkay
IEWA	23	Ernest W. Iverson
ILUB	8	Luigi Iapichino
JDAC	5	David Jackson
JGE	6	Gerardo Jimenez Lopez
JSI	5	Simon Jenner
KAND	30	Kandilli Observatory
KAPJ	12	John Kaplan
KNJS	24	James & Shirley Knight
LEVM	7	Monty Leventhal
LKR	6	Kristine Larsen
MARC	8	Arnaud Mengus
MARE	2	Enrico Mariani
MCE	22	Etsuiku Mochizuki
MJAF	30	Juan Antonio Moreno Quesada
MJHA	27	John McCammon
MLL	13	Jay Miller
MMAE	1	Aaron McNeely
MMAY	31	Max Surlaroute
MMI	31	Michael Moeller
MSS	12	Sandy Mesics
MUDG	8	George Mudry
MWU	24	Walter Maluf
OAAA	14	Al Sadeem Astronomy Obs.
ONJ	19	John O'Neill
PLUD	26	Ludovic Perbet
RJUB	12	Justus Randolph
RJV	24	Javier Ruiz Fernandez
SDOH	31	Solar Dynamics Obs - HMI
SNE	5	Neil Simmons

Continued

Table 3: 202207 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SRIE	19	Rick St. Hilaire
TDE	30	David Teske
TST	17	Steven Toothman
URBP	26	Piotr Urbanski
VIDD	17	Dan Vidican
WGI	2	Guido Wollenhaupt
WND	19	Denis Wallian
WWM	29	William M. Wilson
Totals	1272	69

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. For more details, see *A Generalized Linear Mixed Model for Enumerated Sunspots* ('GLMM06' in the sunspot counts research page at http://www.spesi.org/?page id=65).

Figure 7 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 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.

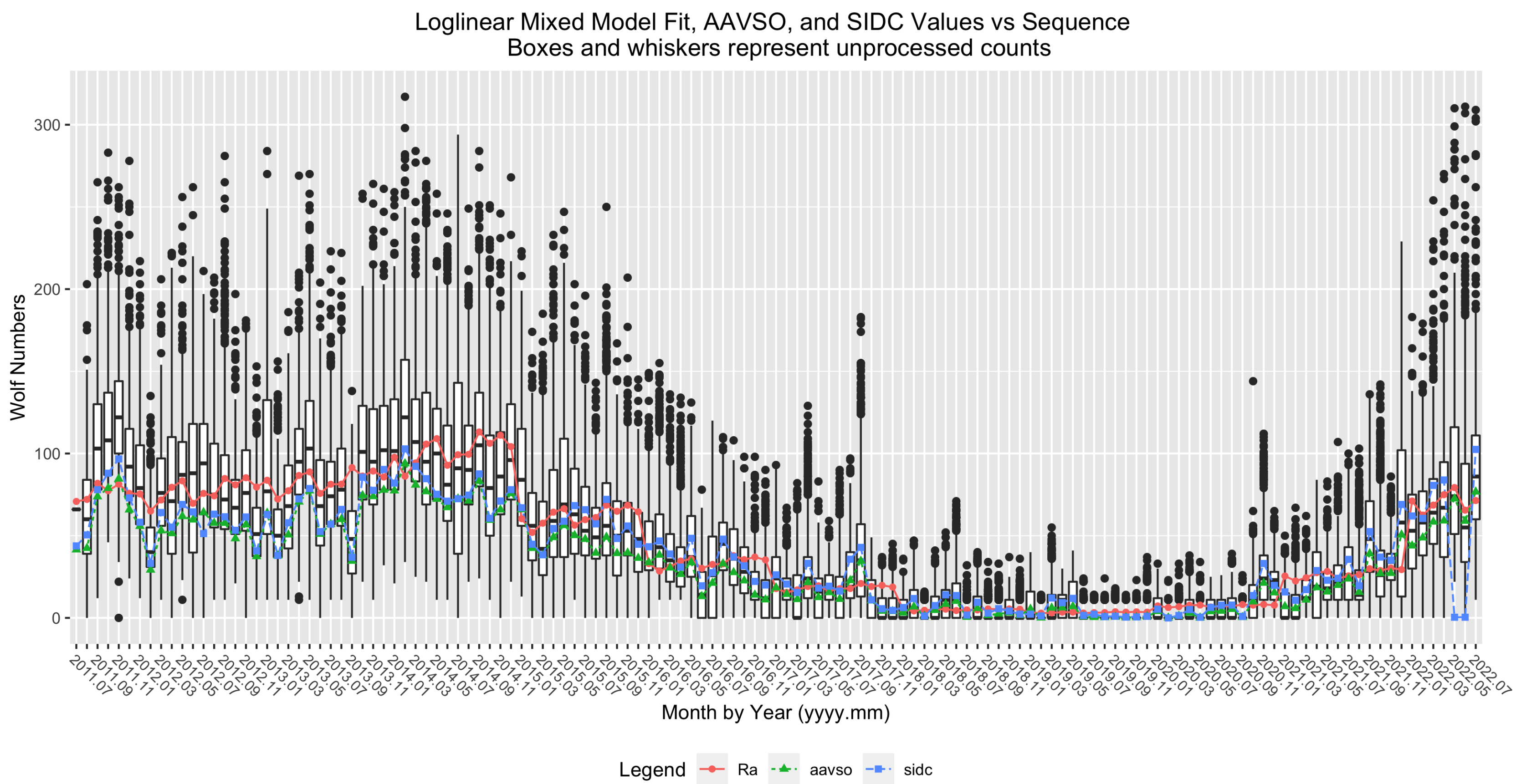

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

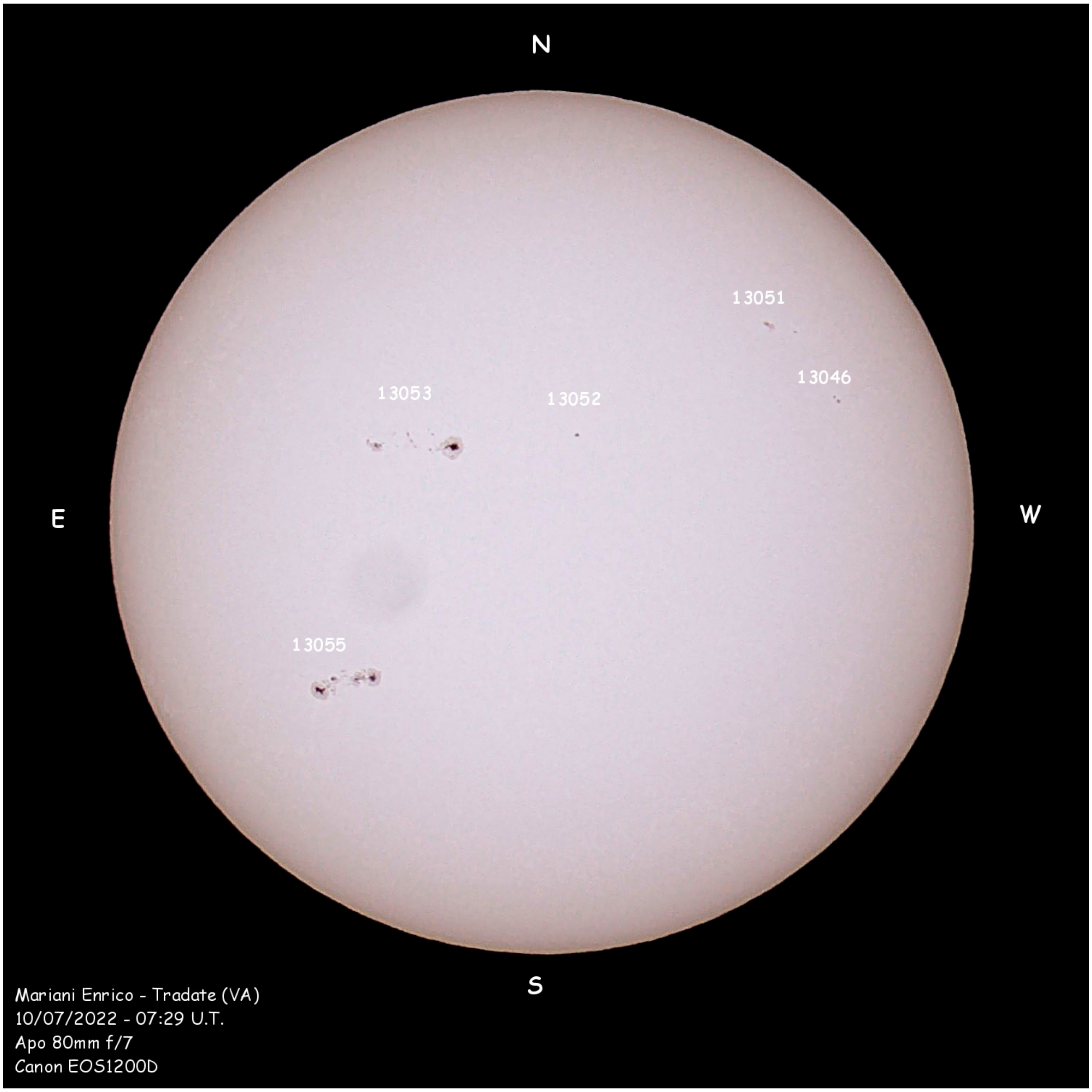

Figure 8: "Good morning, here is a photo of the surface of the Sun on 2022-07-10. I took it from my house in Tradate, Italy at 07:29 U.T. with a Canon EOS1200D at primary focus of my APO 80mm refactor, which I use for solar observations."--Enrico Mariani (MARE)

5 References

Letham, B. (2017). Seasonality, holiday effects, and regressors. [Machine Learning]. Facebook GitHub. Retrieved August 13, 2022, from https://facebook.github.io/prophet/docs/seasonality,_holiday_effects,_and_regressors.html#specifying-custom-seasonalities

SILSO, World Data Center - Sunspot Number and Long-term Solar Observations. (2022). Sunspot number catalogue, 1850-2022 [data set]. Royal Observatory of Belgium. https://www.sidc.be/silso/datafiles

Acknowledgement: Help with the R code from David Jackson (AAVSO observer code JDAC)