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 SDO data for the solar polar fields

The Solar Dynamics Observatory (SDO) data are stored in a database at Stanford University, California. Here is what these data show for the solar polar magnetic fields for the last decade. These are the mean radial field strengths in Gauss flux. Notice how the polar fields crossed at the peak of the last cycle 24, and are likely to cross back over around the peak of cycle 25 (`https://nbviewer.org/github/mbobra/plotting-polar-field/blob/master/plot_polarfield_d3.ipynb`). See the Endnotes section for more detail.

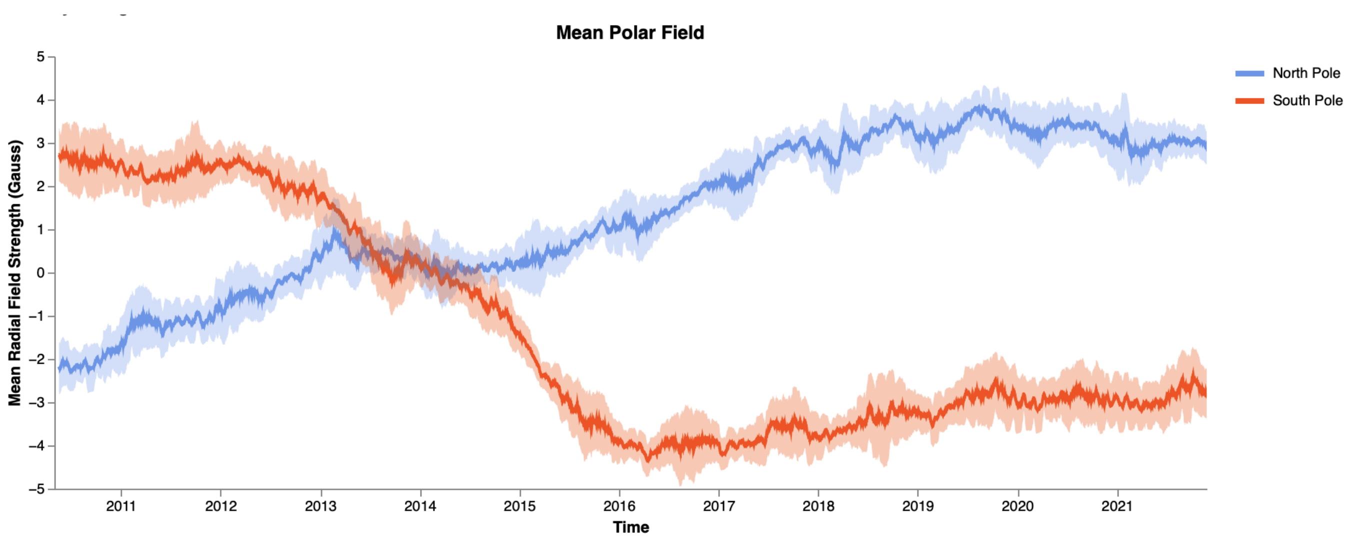

Figure 1: North and South solar polar magnetic fields over the last decade.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

November 2021 (Figure 2) a large SID Event from a M2.0 flare recorded here at Fort Collins, Colorado with the peak at 17:02 UT seen best from the NAA transmitter at Cutler, Maine.

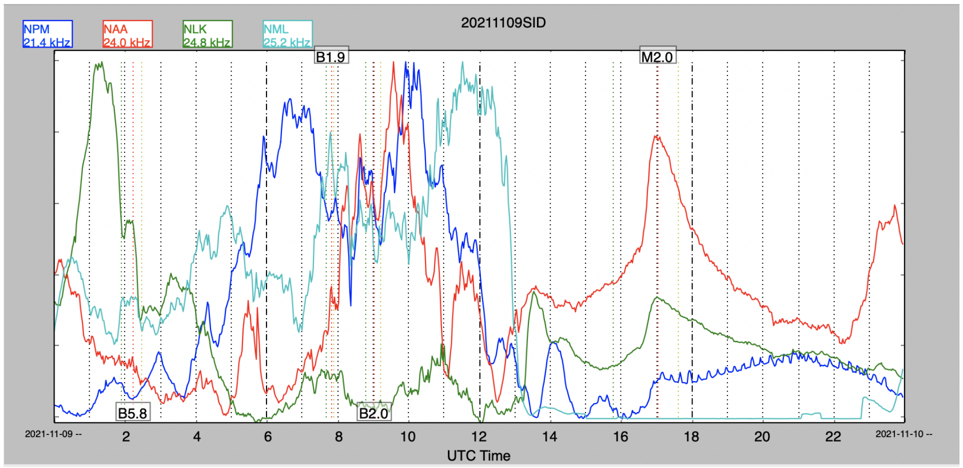

Figure 2: VLF recording on the 9th of November.

2.2 SID Observers

In November 2021, 17 AAVSO SID observers submitted VLF data as listed in Table 1.

Table 1: 202111 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD
B Terrill	A120	NWC
F Adamson	A122	NWC
J Karlovsky	A131	FTA
R Green	A134	NWC
R Mrllak	A136	DHO
S Aguirre	A138	NPM
G Silvis	A141	NAA NLK
K Menzies	A146	NAA
L Pina	A148	NAA NLK
L Ferreira	A149	NWC
J Wendler	A150	NAA
H Krumnow	A152	FTA GBZ
J DeVries	A153	NLK

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.

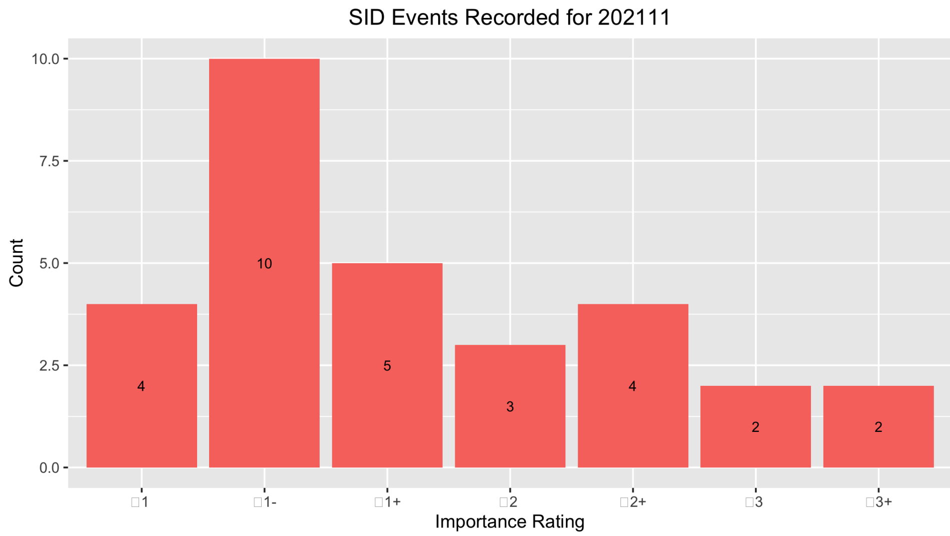

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In November 2021, there were 178 GOES-16 XRA flares for November, 2021: three M-Class, 17 C-Class, and 158 B-Class flares. Far less flaring this month compared to last month, with three days of no flares (see Figure 4).

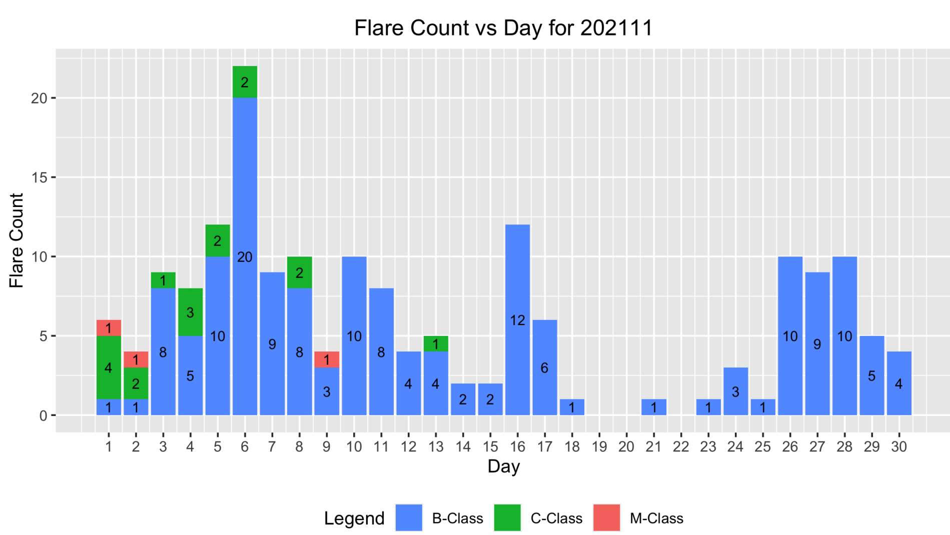

Figure 4: GOES-16 XRA flares.

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 November 2021. 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.

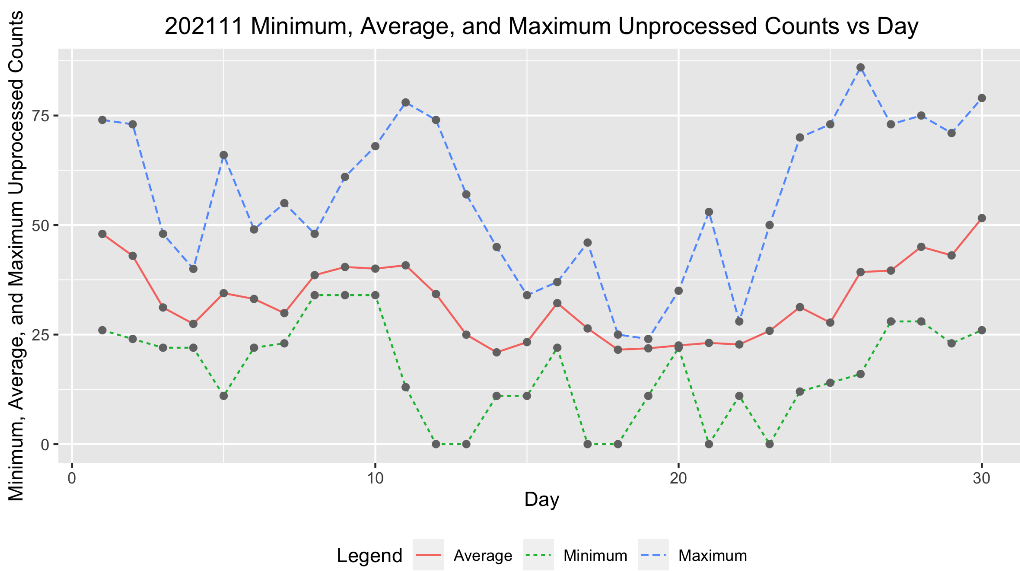

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

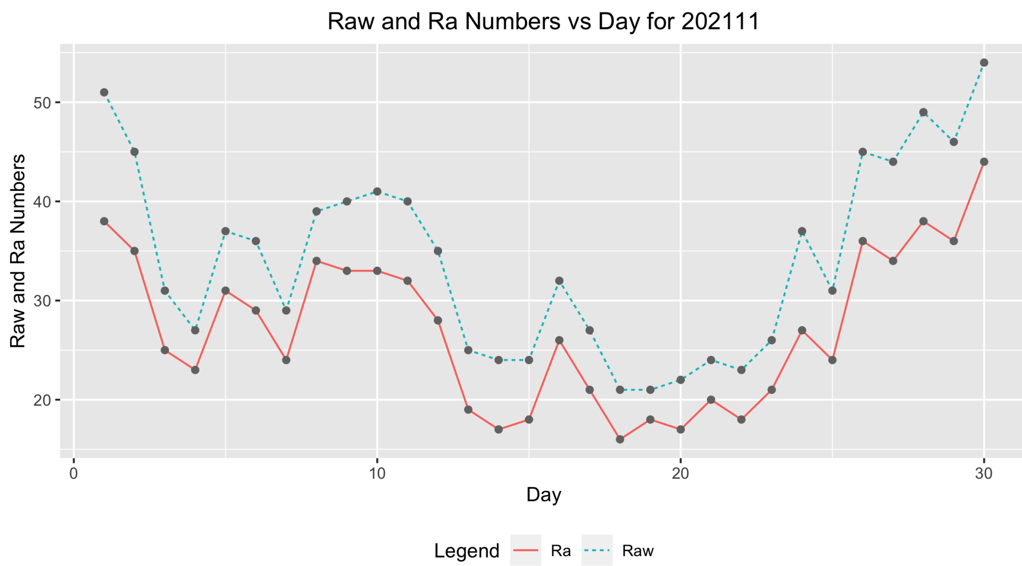

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 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: 202111 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	41	51	38
2	43	45	35
3	38	31	25
4	36	27	23
5	44	37	31
6	43	36	29
7	42	29	24
8	39	39	34
9	37	40	33
10	38	41	33
11	37	40	32
12	42	35	28
13	41	25	19
14	36	24	17

Continued

Table 2: 202111 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	29	24	18
16	37	32	26
17	42	27	21
18	38	21	16
19	37	21	18
20	41	22	17
21	31	24	20
22	32	23	18
23	35	26	21
24	34	37	27
25	31	31	24
26	30	45	36
27	39	44	34
28	31	49	38
29	39	46	36
30	41	54	44
Averages	37.5	34.2	27.2

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for November 2021, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (67), and total number of observations submitted (1124).

Table 3: 202111 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	18	Alexandre Amorim
AJV	18	J. Alonso
ARAG	30	Gema Araujo
ASA	27	Salvador Aguirre
ATE	27	Teofilo Arranz Heras
BARH	8	Howard Barnes
BATR	4	Roberto Battaiola
BKL	5	John A. Blackwell
BMF	18	Michael Boschat
BMIG	17	Michel Besson
BRAF	2	Raffaello Braga
BROB	27	Robert Brown
BXZ	23	Jose Alberto Berdejo
BZX	26	A. Gonzalo Vargas

Continued

Table 3: 202111 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CKB	23	Brian Cudnik
CMOD	4	Mois Carlo
CNT	28	Dean Chantiles
CVJ	8	Jose Carvajal
DARB	17	Aritra Das
DJOB	7	Jorge del Rosario
DMIB	16	Michel Deconinck
DROB	8	Bob Dudley
DUBF	17	Franky Dubois
EHOA	16	Howard Eskildsen
ERB	8	Bob Eramia
FDAE	2	David Fox
FLET	26	Tom Fleming
GIGA	27	Igor Grageda Mendez
HALB	9	Brian Halls
HKY	16	Kim Hay
HOWR	20	Rodney Howe
HRUT	27	Timothy Hrutkay
IEWA	24	Ernest W. Iverson
JDAC	13	David Jackson
JGE	3	Gerardo Jimenez Lopez
JSI	2	Simon Jenner
KAMB	30	Amoli Kakkar
KAND	19	Kandilli Observatory
KAPJ	12	John Kaplan
KNJS	30	James & Shirley Knight
KZAD	20	Zachary Knoles
LEVM	10	Monty Leventhal
LKR	9	Kristine Larsen
LRRA	23	Robert Little
MARC	6	Arnaud Mengus
MCE	25	Etsuiku Mochizuki
MJHA	27	John McCammon
MLL	14	Jay Miller
MMAY	30	Max Surlaroute
MMI	30	Michael Moeller
MUDG	6	George Mudry
MWU	21	Walter Maluf
OAAA	21	Al Sadeem Astronomy Obs.
ONJ	18	John O'Neill
PLUD	18	Ludovic Perbet
RFDA	19	Filipp Romanov
RJV	10	Javier Ruiz Fernandez

Continued

Table 3: 202111 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SATH	6	Andries Son
SDOH	30	Solar Dynamics Obs - HMI
SNE	2	Neil Simmons
SUZM	29	Miyoshi Suzuki
TDE	26	David Teske
TST	14	Steven Toothman
URBP	6	Piotr Urbanski
VIDD	10	Dan Vidican
VRUA	8	Ruben Verboven
WWM	24	William M. Wilson
Totals	1124	67

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: *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 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.

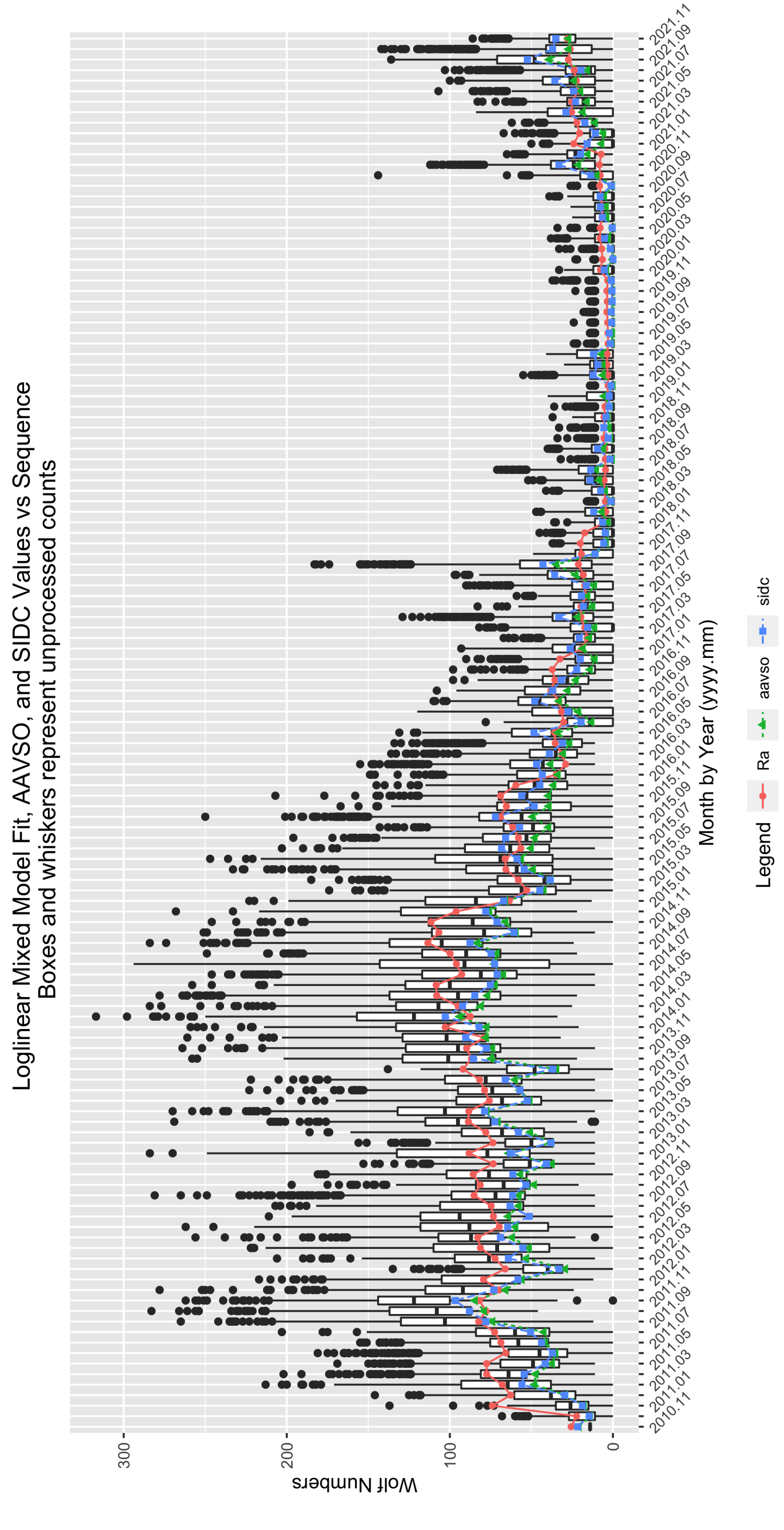

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

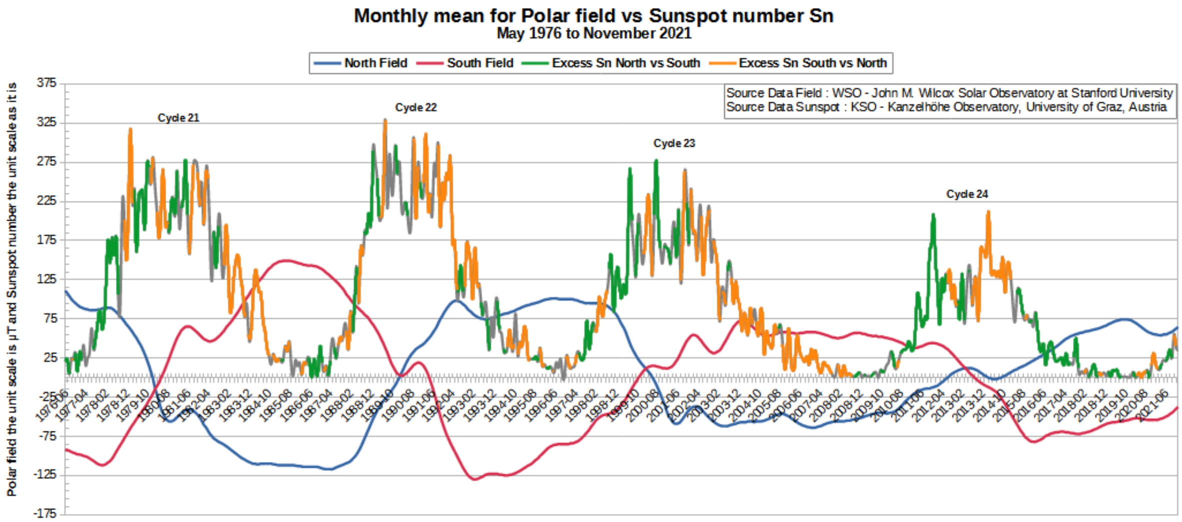

Figure 8: Max Surlaroute (MMAY) used data from Wilcox Solar Observatory (WSO) at Stanford for magnetic fields, as well as data from Kanzelhoe Solar Observatory (KSO), Austria for the number of North and South hemisphere sunspots.

This graph was created by Max Surlaroute (MMAY). Notice how the WSO polar field data and the KSO sunspot data have weakened over the last few solar cycles. Data for this graph come from `http://wso.stanford.edu/Polar.html` and `https://www.kso.ac.at/index_en.php`.

Max Surlaroute says, "My first observations are that indeed it seems that the intensity of the number of sunspots is accentuated more in the Southern Hemisphere than in the North. I also note that at first glance, this phenomenon is particularly more present when the cycle is in its period of decrease, at least for cycles 21, 22, and 23. Moreover, at first sight, when the North polar region becomes negative, the phenomena manifests itself more towards the second half of the decay of the cycle, whereas if the North polar region becomes positive, then the phenomenon manifests itself more in the first half of the decay of the cycle. This leads me to question: is this a systematic phenomenon with a periodicity on a different scale which can vary according to other solar variables, and particularly, those related to the magnetic activity of the sun in its different forms?”