Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

Rodney Howe, Kristine Larsen, Co-Chairs
c/o AAVSO, 49 Bay State Rd
Cambridge, MA 02138 USA

Web: http://www.aavso.org/solar-bulletin
Email: solar@aavso.org
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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. Section 1 gives contributions by our members. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Compare the AAVSO Ra index with SIDC R index for 13 Carrington Rotation moving averages.

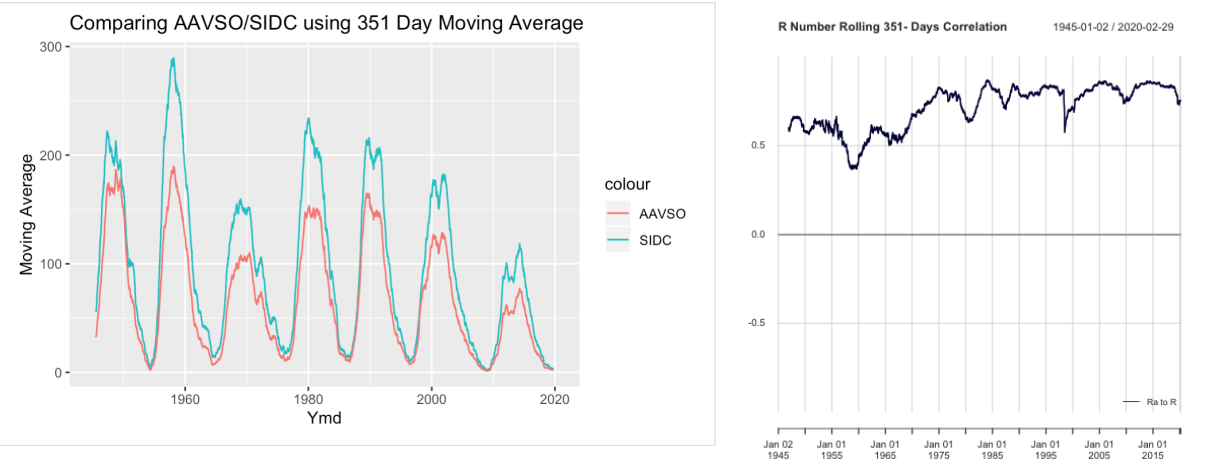

Figure 1: (left) AAVSO Ra and SIDC R index (all visual observations) numbers from 1945-2020, (right) shows a 13 * 27 (351) day Rolling Correlation of the Ra and R indices.

The AAVSO Ra index (from all visual observers' calculated Wolf numbers), from daily data showing 7 solar cycles, 1945-2020 (`https://www.aavso.org/sites/default/files/solar/NOAAfiles/daily.csv`), is compared to the SIDC R (ISN) index for the same time frame.

The Rolling Correlation graph shows how in the early 3 cycles the correlations are not as good as correlations of the later cycles, where there are overall higher data correlations for recent solar cycles (`http://www.sidc.be/silso/datafiles`).

Further reading: `https://en.wikipedia.org/wiki/Solar_rotation#Carrington_rotation`, and look at the Endnotes for Kim Hay and Micheal Deconinck's composition!

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

March 2020 (Figure 2): There were no SID events recorded here in Fort Collins, Colorado for the month of March, nor on the 17th of March, as one A.9 class solar flare was recorded during the day. (Please note the y-axis values in these SID graphs are non-dimensional.)

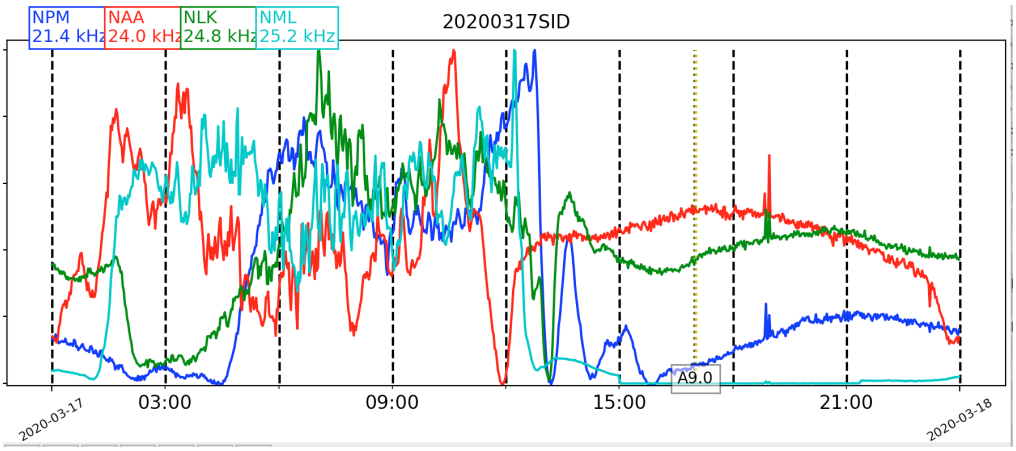

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In March 2020 we had 15 AAVSO SID observers who submitted VLF data as listed in Table 1. There were no observers who recorded SID events this month, which matched to GOES-15 XRA and FLA events.

Table 1: 202003 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO GBZ
J Godet	A119	GBZ
B Terrill	A120	NWC
F Adamson	A122	NWC
S Oatney	A125	NML NLK NAA
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
G Silvis	A141	HWU NAU
R Rogge	A143	GQD
K Menzies	A146	NAA
R Russel	A147	NPM
L Ferreira	A149	NWC

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-15 Data

In March 2020, there were four A-class and one B-class flares recorded from GOES-15. Slightly more flaring this month compared to last. There were 26 days this month with no GOES-15 reports of flares (see Figure 4).

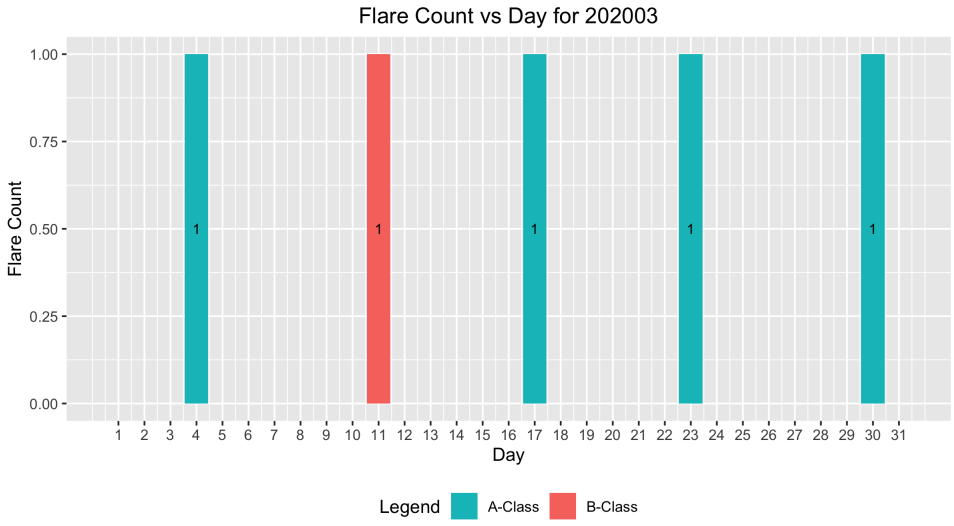

Figure 4: GOES - 15 XRA flares

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 an 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 March 2020. 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.

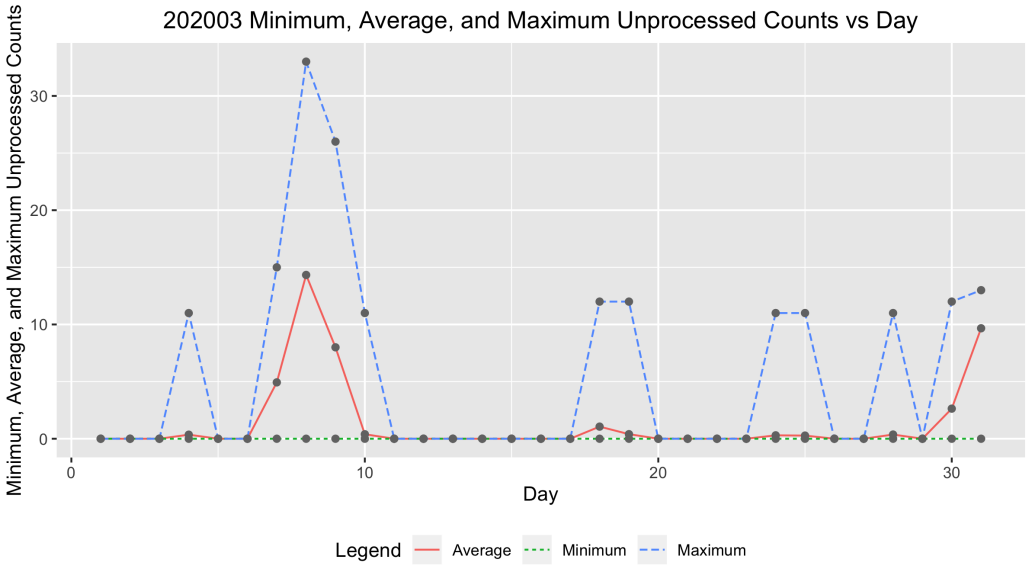

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

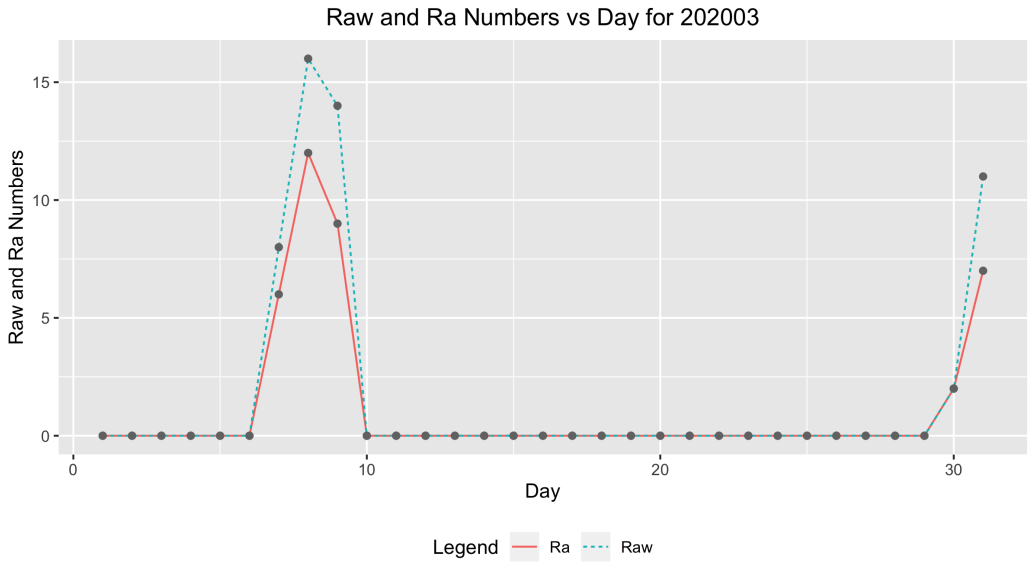

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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 Observations (column 2), the raw Wolf number (column 3), and the Shapley Correction (R_a) (column 4).

Table 2: 202003 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	35	0	0
2	31	0	0
3	32	0	0
4	31	0	0
5	33	0	0
6	36	0	0
7	44	8	6
8	39	16	12
9	36	14	9
10	28	0	0
11	37	0	0
12	39	0	0
13	38	0	0
14	38	0	0

Continued

Table 2: 202003 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	38	0	0
16	33	0	0
17	39	0	0
18	33	0	0
19	30	0	0
20	33	0	0
21	43	0	0
22	34	0	0
23	31	0	0
24	37	0	0
25	40	0	0
26	34	0	0
27	42	0	0
28	30	0	0
29	35	0	0
30	30	2	2
31	33	11	7
Averages	35.2	1.6	1.2

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for March 2020, and the Observer Name (column 3). The final rows of the table give the total number of observers who submitted sunspot counts and the total number of observations submitted. The final rows of the table give the total number of observers who submitted sunspot counts (64), and the total number of observations submitted (1092).

Table 3: 202003 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
AAX	26	Alexandre Amorim
AJV	19	J. Alonso
ARAG	31	Gema Araujo
ASA	16	Salvador Aguirre
ATE	21	Teofilo Arranz Heras
BARH	14	Howard Barnes
BERJ	26	Jose Alberto Berdejo
BMF	20	Michael Boschat
BRAD	28	David Branchett
BRAF	9	Raffaello Braga
BROB	20	Robert Brown

Continued

Table 3: 202003 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
BSAB	26	Santanu Basu
CHAG	29	German Morales Chavez
CIOA	5	Ioannis Chouinavas
CKB	14	Brian Cudnik
CNT	22	Dean Chantiles
DEMF	6	Frank Dempsey
DIVA	17	Ivo Demeulenaere
DJOB	15	Jorge del Rosario
DMIB	20	Michel Deconinck
DROB	1	Bob Dudley
DUBF	26	Franky Dubois
EHOA	15	Howard Eskildsen
ERB	21	Bob Eramia
FERJ	14	Javier Ruiz Fernandez
FLET	22	Tom Fleming
FUJK	23	K. Fujimori
HAYK	15	Kim Hay
HMQ	17	Mark Harris
HOWR	23	Rodney Howe
HRUT	23	Timothy Hrutkay
JDAC	6	David Jackson
JENS	8	Simon Jenner
JGE	1	Gerardo Jimenez Lopez
KAND	11	Kandilli Observatory
KAPJ	17	John Kaplan
KNJS	31	James & Shirley Knight
LGEC	17	Georgios Lekkas
LKR	2	Kristine Larsen
MARC	16	Arnaud Mengus
MARE	6	Enrico Mariani
MCE	22	Etsuiku Mochizuki
MGAR	3	Gary Myers
MILJ	14	Jay Miller
MJAF	29	Juan Antonio Moreno Quesada
MJHA	27	John McCammon
MUDG	11	George Mudry
MWU	22	Walter Maluf
OAAA	21	Al Sadeem Astronomy Observatory
ONJ	21	John O'Neill
PEKT	3	Riza Pektas
SDOH	31	Solar Dynamics Obs - HMI
SMNA	3	Michael Stephanou
SNE	7	Neil Simmons

Continued

Table 3: 202003 Number of observations by observer.

Observer Code	Number of Observers	Observer Name
STAB	28	Brian Gordon-States
SUZM	23	Miyoshi Suzuki
TESD	26	David Teske
TPJB	3	Patrick Thibault
TST	9	Steven Toothman
URBP	23	Piotr Urbanski
VARG	28	A. Gonzalo Vargas
VIDD	21	Daniel Vidican
WGI	7	Guido Wollenhaupt
WILW	11	William M. Wilson
Totals	1092	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 a paper (GLMM06) on http://www.spesi.org/?page_id=65 of the sunspot counts research page. The paper title is *A Generalized Linear Mixed Model for Enumerated Sunspots*.

Figure 7 shows the monthly GLMM R_a numbers for the 24th solar cycle to date. 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 confidence band uses the large sample approximation based on the Gaussian distribution. 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.

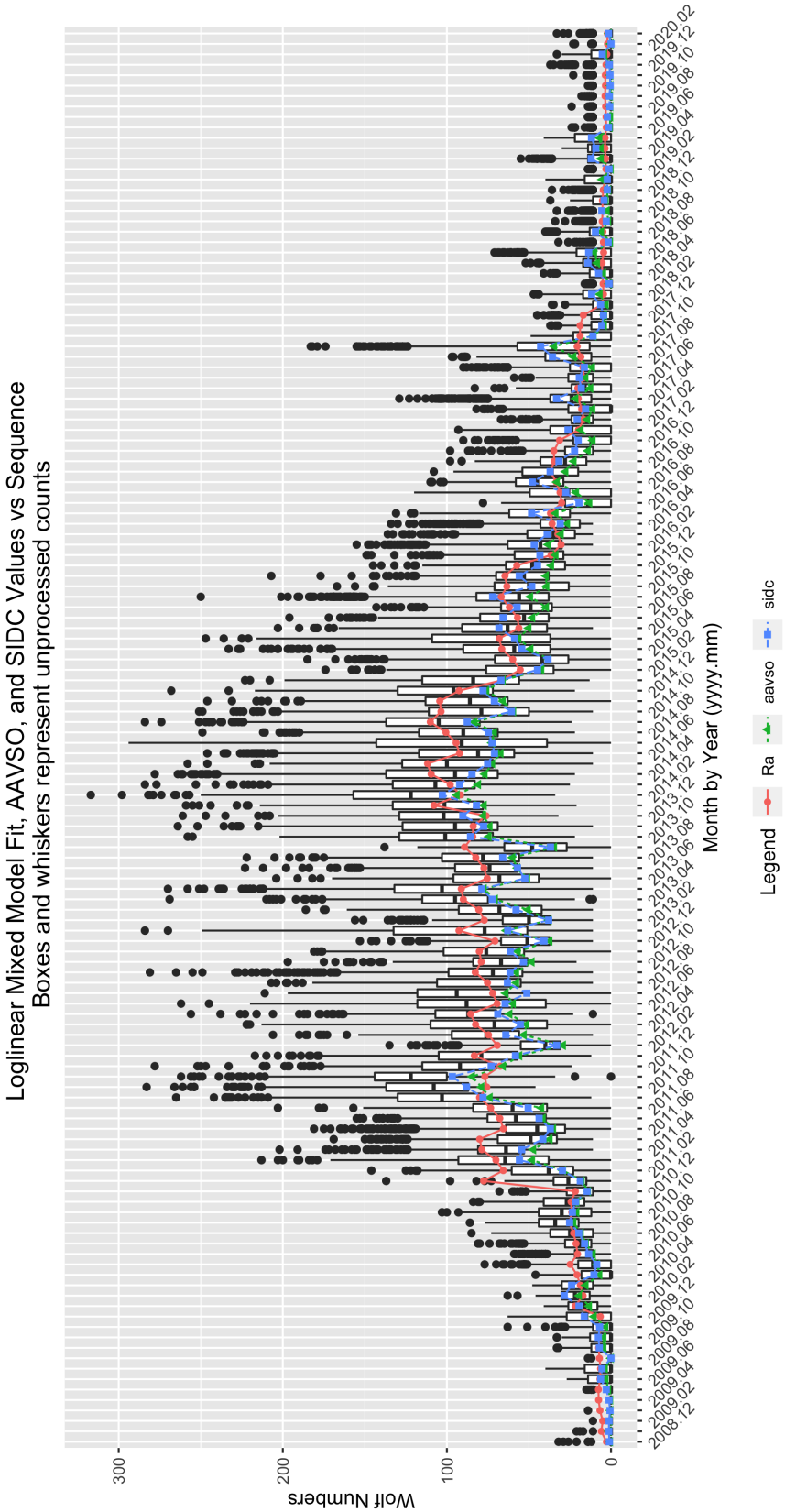

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

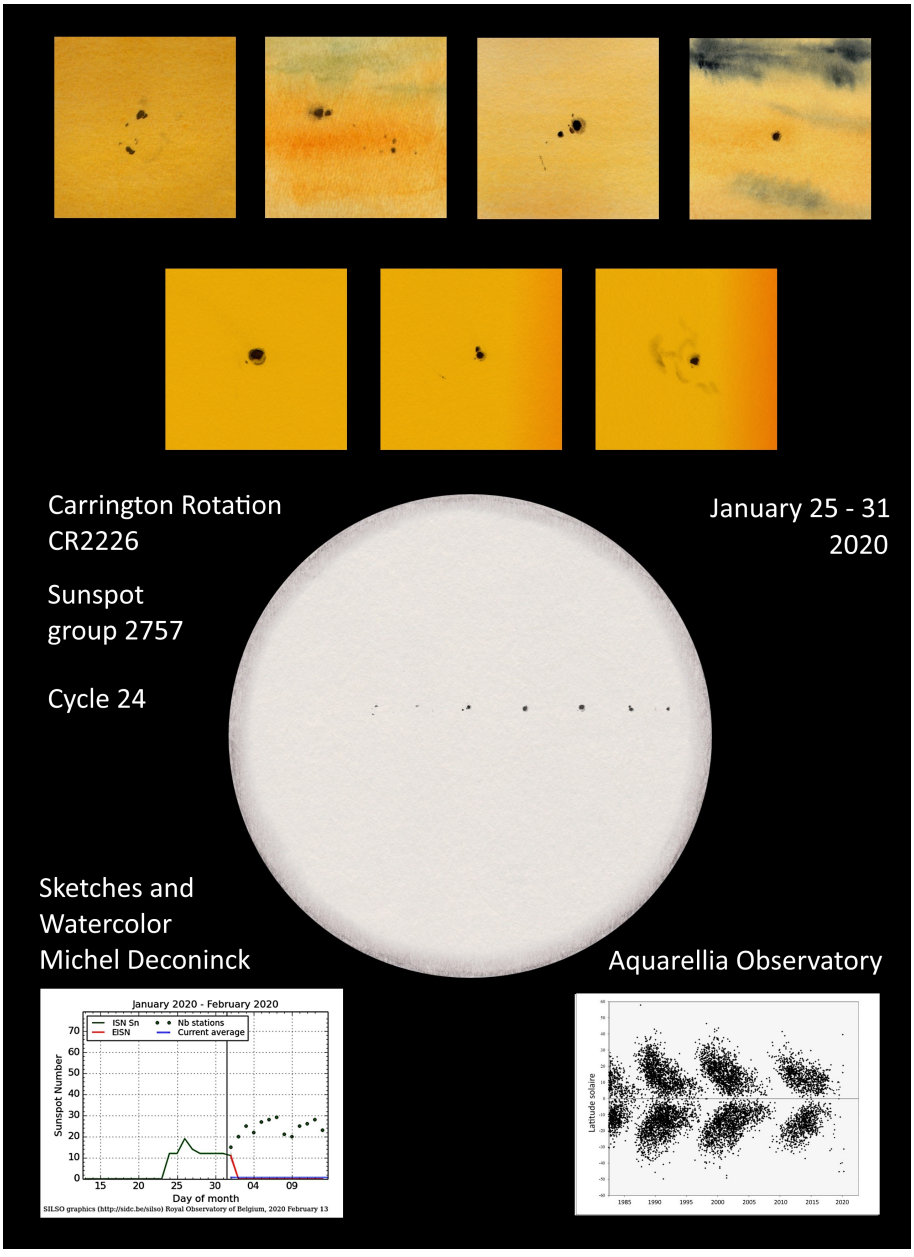

Figure 8: Kim Hay made this composition with water colors, along with Michael Deconinck showing Carrington Rotation 2226.