Should We Try to Re-Construct the American Relative Sunspot Index (Ra)?

Howe R*

Editor, Chair, c/o AAVSO, 49 Bay State Rd, Cambridge, MA 02138 USA

*Corresponding author: Howe R, Editor, Chair, c/o AAVSO, 49 Bay State Rd, Cambridge, MA 02138, USA, E-Mail: ahowe@frii.com

Abstract

The new correction of the international sunspot number (ISN), called the Sunspot Number Version 2.0, led by Fredric Clette (Director of the World Data Centre [WDC]-SILSO), Ed Cliver (National Solar Observatory), and Leif Svalgaard (Stanford University), nullies the claim that there has been a Modern Grand Maximum. This comes from the International Astronomical Union (IAU) press release, August 2015 (http://www.iau.org/news/pressreleases/detail/ iau1508/). This ISN reconstruction raises some questions for the AAVSO: should we try to re-construct the American Relative Index (Ra) to go along with the ISN reconstruction (Clette et al)? Shapley's method with k-factors (http://iopscience.iop.org/article/10. 1086/126109/pdf) is a statistical model that agglomerates variation due to random effects such as observer and xed effects after seeing the condition. The raw Wolf averages and calculated Ra have used the Shapley method since 1949. If the AAVSO decides to re-construct the American Ra Index, then it is important to compare the newly digitize data back to 1947 and up to 2010 from two AAVSO observer's Herbert Luft and Thomas Cragg (Vaquero et al). These archives exist at AAVSO HQ in di erent formats of raw observations from these two observers over the past 70 years.

Keywords: American relative index; AAVSO solar observers; Rolling correlation; Rolling covariance

Introduction

In this paper we use two sets of daily data; one from those observers who submit their group and sunspot counts and calculated Wolf numbers; $W=(10g+s)$, to the AAVSO Solar Section [1]. The second data set comes from all AAVSO American Relative Index (R_a) which in the past has been submitted to NOAA/NGDC since period June 1947 through July 2016, and since then has been calculated from AAVSO observer's data every month, and is now on display at LASP Interactive Solar Irradiance Datacenter: http:// lasp.colorado.edu/lisird. The R_a index has been and will continue to be

calculated from Shapley 1949. Recently data have been digitized from two observers, Herbert Luft, and Thomas Cragg by Mike Saladyga, AAVSO: https://www.aavso.org/ herb-lufts-notebooks-new-science-aavso-archives. The intent in this paper will be to evaluate whether the AAVSO should re-construct the American Relative Index, based on these newly digitized data.

FIG. 1 depicts the difference of the Wolf number daily averages and R_a daily averages and the difference between the two (left panel) from the R_a splint (right panel) for April 1947 through September 2018. **FIG. 2** Gives an idea of these two data sets matches up to each other. And, **FIG. 3** showing the AAVSO Wolf averages and the R_a numbers as rolling correlation and Covariance. **FIG. 4** showing the R_a and AAVSO Wolf numbers where we compare how these two data sets covering the same period have different rolling correlations and covariances.
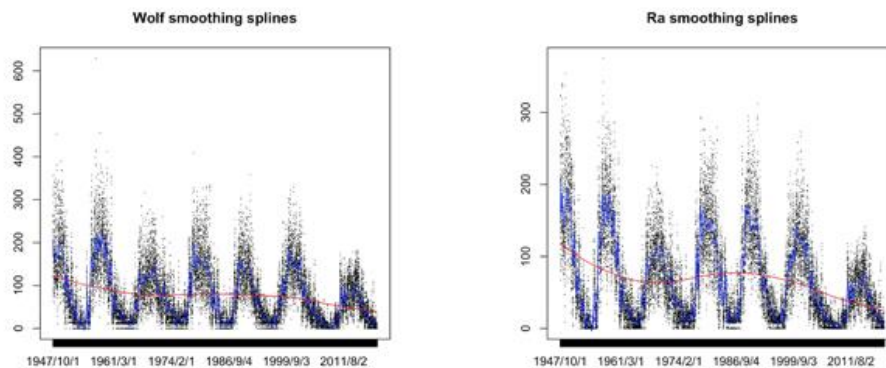

FIG. 1. **Wolf numbers from June 1947 through September 2018 with 5 degrees of freedom smoothing spline of Wolf numbers (left panel), and the R_a spline t with 5 degrees of freedom smoothing spline for the same time frame (right panel).**

Methods

Rolling correlation can be used to examine how correlative relationships between the two data set and how wolf numbers and R_a numbers change over time. A value of 1 means both data sets are synchronized with each other. A value of -1 means that if the Wolf numbers decline, the R_a numbers rise. A correlation of zero means no correlation relationship exists.

This period was chosen for analysis as there are no days for which Wolf numbers are missing in the AAVSO data set. The R_a matching data suggests solar cycles over the last 70 years have valued different than Wolf numbers for both Luft and Cragg digitized data.

The question for AAVSO is whether the correlation between the two data sets exists regardless of the apparent misalignment. Is there enough evidence in these negative correlations to requires a reconstruction the R_a? These statistical tests and graphs come from the R project: https: //cran.r-project.org and Dr. Jamie Riggs, Solar System Science Section Head, International Astrostatistics Association [2-5].
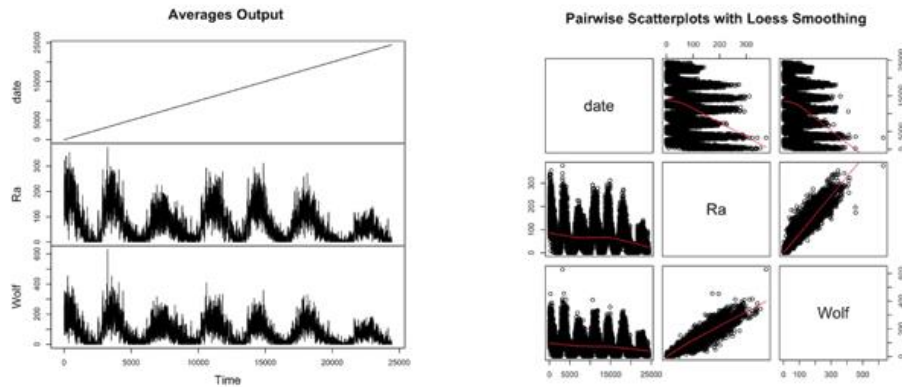
FIG. 2. **Shows how closely do the daily Wolf number averages (https://www.aavso.org/solar) match up to the daily American Relative Index (left panel). And how tightly these two data sets t on scatter plot of pairwise comparisons (right panel). Both sets of data contain 24,432 days of observations.**
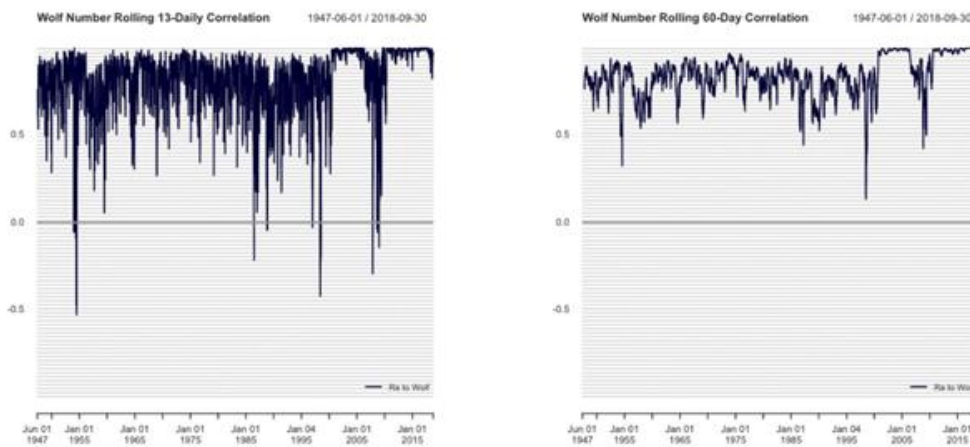

FIG. 3. **AAVSO R_a and Wolf numbers 13 day rolling correlation of both R_a and AAVSO data (left panel). And a 60 day Rolling Correlation plot of R_a and wolf numbers from June 1947 through September 2018 from the AAVSO Solar database (right panel).**
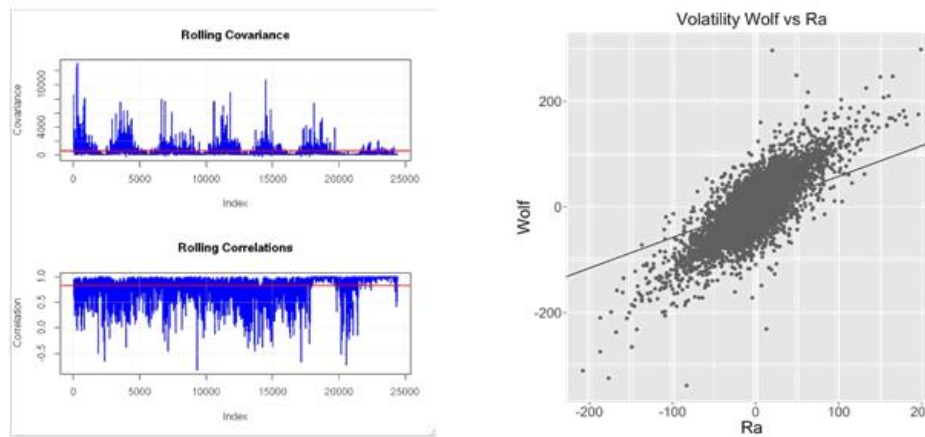
FIG. 4. **Rolling correlation and covariance plots of AAVSO R$_a$ and wolf numbers from June 1947 through September 2018 show the solar cycles (19 through 24) and what looks to be negative correlations between the AAVSO R$_a$ and Wolf numbers. The volatility graph is orthogonal to the covariance plot and shows symmetric or asymmetric slopes (having positive or negative slopes) for evaluating the variance of R$_a$ and Wolf, (right panel) showing asymmetric volatility.**

Results

What seems to be evident when we do the rolling correlations between the AAVSO Wolf numbers and the R$_a$ is a negative correlation for the newly digitized data. This would indicate that the long-standing R$_a$ is not matching the newly digitized Wolf numbers from Luft and Cragg from 1947 up to 2000.

Over the 7 cycles up to July 2018, the rolling correlation coefficient shows degrees of periodicity for the 13, 60 day windows. Increasing the time window of the rolling correlation increasingly smooths the correlation coefficients and highlight how the weak solar cycles show miss-match numbers between Wolf and R$_a$ daily data.

The average correlation coefficient over the portion of all cycles analyzed is (Intercept) -0.003516 Wolf 0.579737 (60 day) which is a negative correlation. If these data are assumed to be independent of each observation and independent of time, the static correlation coefficient is 0.8156. The slope of the regression line fitted to the R$_a$ versus Wolf numbers (**FIG. 4**, right panel) is 0.8156. The difference between the static correlation coefficient of the slope of the dotted line and the average rolling correlation coefficients is due to the regression accounting only for the differing variability of the two data sets and not accounting for time dependence.

Conclusions

To the best, we can determine through Rolling Correlations and Covariance analysis is that these two daily datasets have issues in matching their average number values. **FIG. 1 and 4**. However, increasing the daily rolling correlations from 13- to 60 day, **FIG. 3**, begin to smooth out the greater discrepancies between historically digitized data from two dedicated observers. None the less we will not try to reconstruct the American Relative Index R$_a$ given the current AAVSO database. y

REFERENCES

1. AAVSO Solar Section: https://www.aavso.org/solar.

2. Shapiro-Wilk normality test https://en.wikipedia.org/wiki/Shapiro R project: https: //cran.r-project.org and Dr. Jamie Riggs, Solar System Science Section Head, International Astrostatistics Association. http://www.spesi.org.

3. Clette F, Svalgaard L, José M. Vaquero, et al. Revisiting the sunspot number A 400-year perspective on the solar cycle. Space Science Reviews. 2014;186:35-103.

4. Vaquero JM, Svalgaard L, Carrasco VMS, et al., A revised collection of sunspot group numbers. Solar Physics. 2016;291:1-14.

5. Svalgaard L, Schatten KH. On the sunspot group number reconstruction: The backbone method revisited. 2017:1-53.