AGU PUBLICATIONS

Space Weather

NEWS ARTICLE

10.1002/2015SW001264

Citation:
Clette, F., E. W. Cliver, L. Lefèvre, L. Svalgaard, and J. M. Vaquero (2015), Revision of the Sunspot Number(s), *Space Weather*, *13*, doi:10.1002/2015SW001264.

Accepted article online 5 AUG 2015

Revision of the Sunspot Number(s)

F. Clette, E. W. Cliver, L. Lefèvre, L. Svalgaard, and J. M. Vaquero

The sunspot number is "arguably the most intensively studied time series in astrophysics" [*Charbonneau*, 2010]. There is a problem with the sunspot number, however. There are two of them, and they differ widely before about 1885 (Figure 1a). The international sunspot number, designated R_I, was developed by Rudolf Wolf during the second half of the nineteenth century. It has the formula

$$R_I = (10 \times G) + S$$

where G is the number of sunspot groups and S is the number of individual spots. During the 1990s, *Hoyt and Schatten* [1998a, 1998b] developed the group sunspot number (R_G) which is based only on group counts, in part because this was all that was available for many early observations. As a result they were able to extend R_G back to the first telescopic sunspot observations in 1610 and encompass the Maunder Minimum. Hoyt and Schatten scaled their group counts to R_I for the interval from 1874 to 1976 to produce R_G.

No consensus has developed on which of the two sunspot numbers to use and, as a result, the sunspot number has become a soft parameter, with R_I or R_G able to provide support or underpinning for quite different conclusions. To address this undesirable situation, we organized a series of four community-wide sunspot number workshops from 2011 to 2014 to recalibrate the sunspot numbers [*Cliver et al.*, 2013, 2015].

This recalibration effort has now been completed and the two revised time series, designated S_N and G_N to indicate the break from the past, are posted on the Sunspot Index and Long-term Solar Observations website (http://sidc.oma.be/silso/). During the last 4 years we found that both R_I and R_G contained inhomogeneities

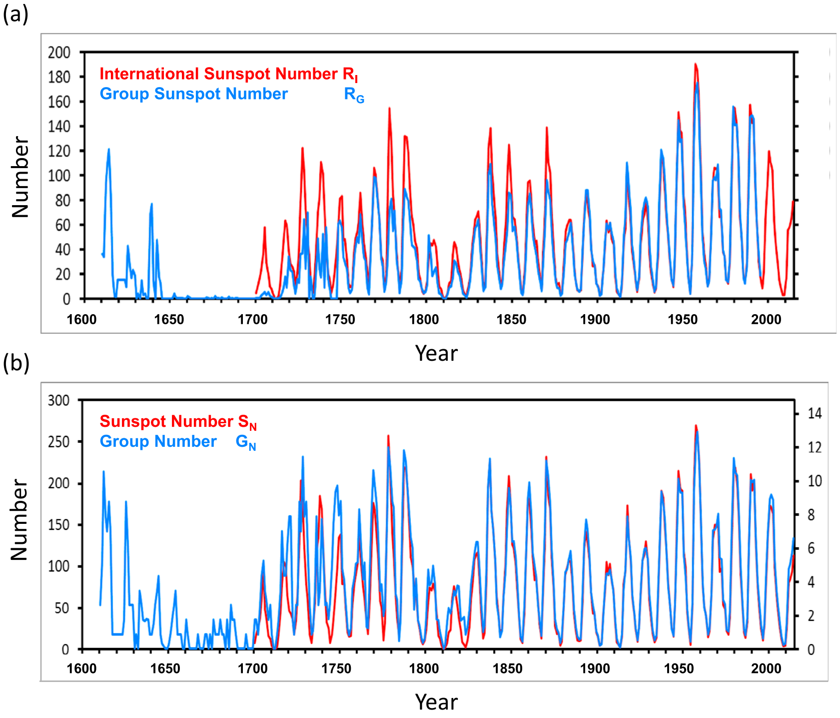

Figure 1. (a) Comparison of the international (R_I) and group (R_G) sunspot number time series (reprinted from *Cliver et al.* [2015] by permission of *Central European Astrophysical Bulletin*). (b) Comparison of the successor S_N and G_N time series. The scaling difference between the time series in Figures 1a and 1b is primarily due to removal of an artifact in R_I that stemmed from differences in telescope aperture and spot counting procedure between Wolf and his successor Wolfer. The right-hand scale in Figure 1b gives the group count (G_N).

and artifacts. Figure 1b shows that correction of these flaws results in two series (S_N and G_N) that track each other much more closely than their predecessors, although both more closely resemble R_I than R_G. Just as R_I and R_G were not perfect, we anticipate possible future revisions of S_N and G_N as new historical data are uncovered and we gain better understanding of the sunspot number.

The revised sunspot time series have implications, yet to be explored, for the solar dynamo, space climate, and terrestrial climate change. They provide a surer bridge to the millennia of the solar activity record written in cosmogenic nuclide concentrations in ice cores and tree rings.

Details of the sunspot number recalibration are given in *Svalgaard* [2013], *Clette et al*. [2014], F. Clette et al. (A fully updated sunspot number: Assembling all corrections, submitted to *Solar Physics*, 2015), and *Svalgaard and Schatten* [2015]. The two 2015 papers will appear with related work in a forthcoming Topical Issue of Solar Physics.

Acknowledgments
We acknowledge support from the Royal Observatory of Belgium, the Belgian Solar-Terrestrial Center of Excellence, the National Solar Observatory, the U.S. Air Force Research Laboratory, Stanford University, Universidad de Extremadura, Specola Solare Ticinese, and Istituto Ricerche Solari Locarno. Data on which Figure 1a is based can be found at http://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-indices/sunspot-numbers/group/ and http://www.sidc.be/silso/versionarchive.

References

Charbonneau, P. (2010), Dynamo models of the solar cycle, *Living Rev. Solar Phys.*, *7*, 3, doi:10.12942/lrsp-2010-3.

Clette, F., L. Svalgaard, J. M. Vaquero, and E. W. Cliver (2014), Revisiting the sunspot number: A 400-year perspective on the solar cycle, *Space Sci. Rev.*, *16*, 35–103, doi:10.1007/s11214-014-0074-2.

Cliver, E. W., F. Clette, and L. Svalgaard (2013), Recalibrating the sunspot number (SSN): The SSN workshops, *Central Eur. Astrophys. Bull.*, *37*, 401–416.

Cliver, E. W., F. Clette, L. Svalgaard, and J. M. Vaquero (2015), Recalibrating the sunspot number (SN): The 3rd and 4th SN workshops, *Central Eur. Astrophys. Bull.*, in press.

Hoyt, D. V., and K. H. Schatten (1998a), Group sunspot numbers: A new solar activity reconstruction, *Solar Phys.*, *179*, 189–219, doi:10.1023/A:1005007527816.

Hoyt, D. V., and K. H. Schatten (1998b), Group sunspot numbers: A new solar activity reconstruction, *Solar Phys.*, *181*, 491–512, doi:10.1023/A:1005056326158.

Svalgaard, L. (2013), Solar activity—Past, present, future, *J. Space Weather Space Clim.*, *3*, A24, doi:10.1051/swsc/2013046.

Svalgaard, L., and K. H. Schatten (2015), Reconstruction of the sunspot group number: The backbone method, *Solar Phys.*, in press.

Frédéric Clette *is a Work Leader at the Royal Observatory of Belgium in Brussels. After participating for many years to solar space missions, since 2011, he is the Director of the World Data Center "Sunspot Index and Long-term Solar Observations", a member organization of the International Council for Science World Data System.*
E-mail: frederic.clette@oma.be.

Edward W. Cliver *is an Emeritus Astronomer at the National Solar Observatory in Sunspot, New Mexico.*
E-mail: ecliver@nso.edu.

Laure Lefèvre *is a researcher at the Royal Observatory of Belgium in Brussels since 2009, where she joined forces with the World Data Center-Sunspot Index and Long-term Solar Observations. She has a background in engineering and specializes in advanced time series and statistical analyses.*
E-mail: laure.lefevre@oma.be.

Leif Svalgaard *is a Senior Research Scientist at Stanford University and a member of a past NOAA/NASA panel for prediction of the solar cycle.*
Email: leif@leif.org.

José M. Vaquero *is an Associate Professor at the Universidad de Extremadura in Mérida (Badajoz), Spain.*
E-mail: jvaquero@unex.es.