Recalibration of the sunspot indices: justification and consequences

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The sunspots are the most visible manifestation of solar activity, and with the longest record.

Therefore, the long-term variations of solar activity are traditionally quantified by indices based on sunspot records.
The original “Wolf number” known also as “Zurich sunspot number” or “International sunspot number” $R_Z$, was defined by Wolf as

$$R_Z = k (10G + N)$$

Where: $G =$ number of observed sunspot groups, $N =$ number of individual sunspots, $k =$ observer’s correction factor
A linear relationship between the number of sunspots and the number of sunspot groups in the period 1874 to 1976.

The Group sunspot number series: based on only the number of sunspot groups $G$ in Wolf’s formula

$$R_Z = k (10G + N)$$

$$R_G = 12.08 G$$
In spite of the good correlation between them, $R_Z$ and $R_G$ are not identical.

The main difference: the long-term trends

$R_Z$ calculated for the period 1700-2015

$R_G$ calculated for the period 1610-1995

(Hoyt and Schatten, 1998)
\( R_z \) provided by observations in:

- **Zürich Observatory** during 131 years, from 1849 to 1980 (Waldmeier, 1961)

- **SIDC (Solar Influences Data analysis Center)** created in 1980 in the Royal Observatory of Belgium as a World Data Center with the task to continue the \( R_z \) record

- Since July 1, 2015, **SIDC**, renamed in the meantime to **SILSO (Sunspot Index and Long-term Solar Observations)**, terminated the production of the original Sunspot number \( R_z \), and replaced it by a new entirely revised data series, \( S_N \).
Justification for the need to revise the sunspot record presented at the first Sunspot Number Workshop

Sunspot Number Workshop at Sunspot
19-22 September 2011

Why the Sunspot Number Needs Re-examination

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Integrity ★ Service ★ Excellence
It’s used for important applications

- Climate change
- Solar dynamo modeling
- Long-term solar variability

We have two sunspot numbers

With no consensus on which is more accurate

- Vieira et al. (2011) $G$ (1610-1700); $I$ (1700-present)
- Dikpati et al. (2006) $I$ (1750-1880)
- Solanki et al. (2004) $G$ (1610-present)
The use of two SSNs might be acceptable if the differences between the two time series were insignificant. Figure 1 shows that that is not the case. The choice of which sunspot time series to use can have a substantial difference on the conclusions drawn. For example, the report that we have just experienced the most active period of solar activity in the last ~8,000 years (Solanki et al., 2004; cf., Usoskin et al., 2006) is based on the use of the Group SSN.

To address the problem of the two discordant sunspot numbers, we have, with the sponsorship of the US National Solar Observatory (NSO), the Royal Observatory of Belgium (ROB), and the US Air Force, initiated a series of SSN Workshops.
The series of sunspot number workshops

SSN1
September 2011

SSN2
May 2012

Mini SSN Workshop
September 2012

SSN3
January 2013

SSN4
January 2014

ISSI SSN Meeting
January 2018
Motivation of the SSN workshops:

“Given the importance of the sunspot time series, the co-existence of two conflicting series is a highly unsatisfactory situation that should now be actively addressed”

(Clette et al., 2014).

The mail goals of the SSN workshops:

- “to rectify the discrepancies” between $R_Z$ and $R_G$;
- “to publish a single consensus sunspot data series”

(Cliver, Clette and Svalgaard, 2013; Cliver et al., 2015).
GROUP NUMBER CORRECTIONS

- Original Group Number
- New Group Number

- Staudach (1749-1826)
- "Backbone" reconstruction (1820-2015)
- "Greenwich" trend (1885-1915)
Long term trends … gone

Difference between the two series … gone
Is the goal “to rectify the discrepancies” between $R_Z$ and $R_G$ justified?

The number of sunspots per sunspot group has solar cycle and cycle-to-cycle variations.

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Tlatov A., Geomagnetism and Aeronomy, 2013, vol.53, Mo.8, pp.953-956
The complexity of a sunspot group (= the number of spots per group) depends on the magnetic field in sunspot groups (Sheeley, 1966).

⇒ The sunspot cycle and cycle-to-cycle variations in the ratio between $R_Z$ and $R_G$ are due to sunspot cycle and cycle-to-cycle variations of the sunspot magnetic fields.

The discrepancy between $R_Z$ and $R_G$ is a real feature and the attempts to rectify it are not justified!
Was the goal “to publish a single consensus sunspot data series” achieved? Not at all!

A part of the newly proposed sunspot number and group number series after the “recalibrated” Version 2 series were published. For a more complete list, refer to Cliver E.D., Solar Phys. 291, 2891-2916, 2016
No consensus between any two series

- Researchers studying solar variability and its terrestrial impacts totally at loss about the reliable quantitative measures of solar variability
- Recent studies based on the new series incomparable and incompatible to the enormous mass of studies based on the original series
Other consequences: differences in sunspot based models

An example: total solar irradiance reconstructed by two models using original and new sunspot and group sunspot data series.

Conclusions

• In the process of bringing RZ and RG to agreement, some errors have been identified and removed. However, the goal to “rectify the discrepancies” between the two data series is not physically justified, and bringing them to agreement and to no long-term trends has caused more problems that it has solved.

• The Version 2 new sunspot and group sunspot series were not accepted by consensus. On the contrary, their publication triggered a number of alternative series, none of them accepted by consensus.

• This makes results based on different recent series, and based on recent and original series incomparable and incompatible.
The way out

• The more than 300/400-year long sunspot number and sunspot group number data series should be continued while other reconstructions can be proposed and discussed.

• One or more observatories with long sunspot number and sunspot group number data records should be identify, matching best the original $R_Z$ and $R_G$ series, and they should be officially charged to continue the data series.

• The differences between them should be used to study the long-term variations of the operation of solar dynamo.