On the ratio between the sunspot number and the sunspot group number

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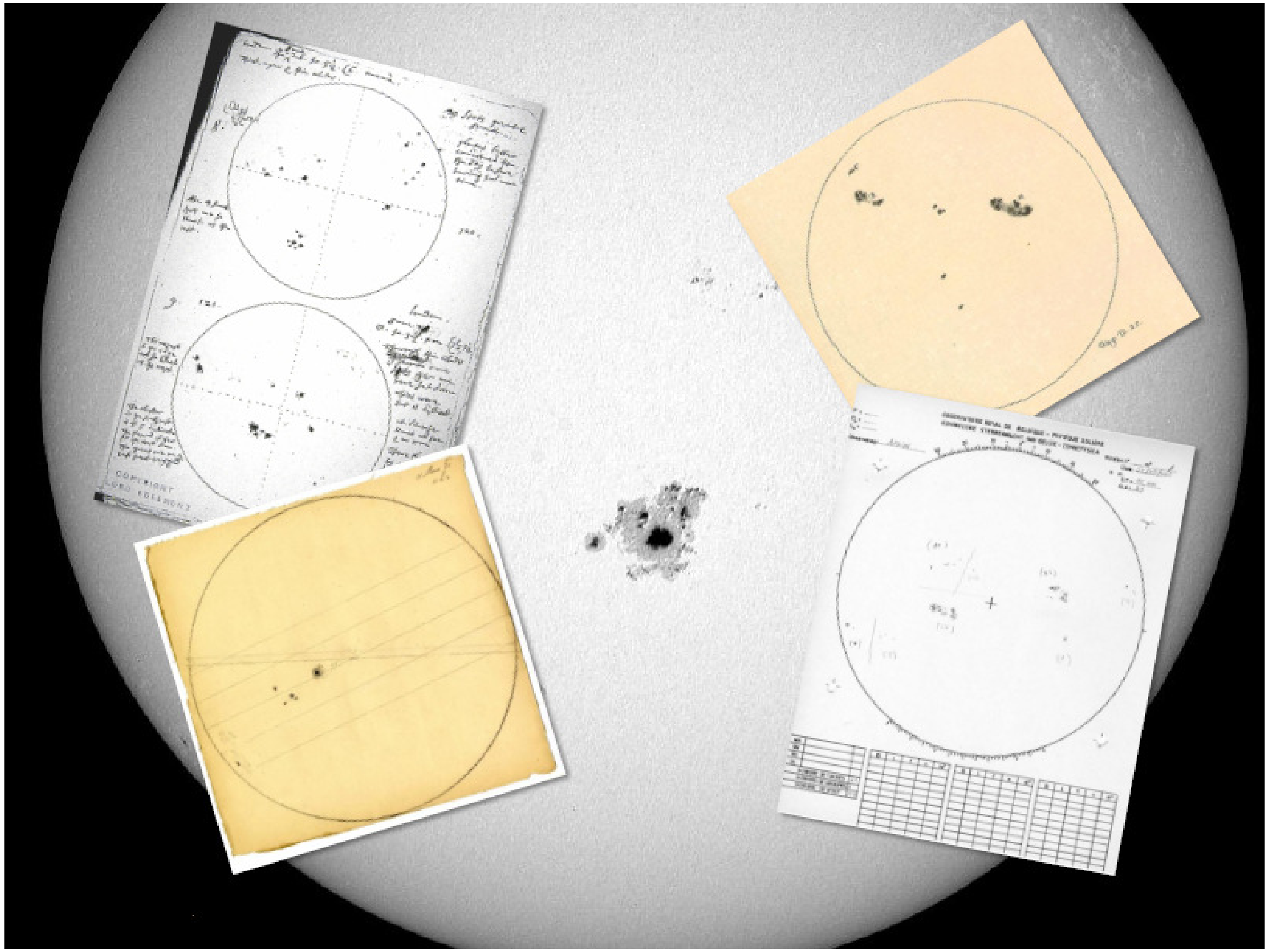
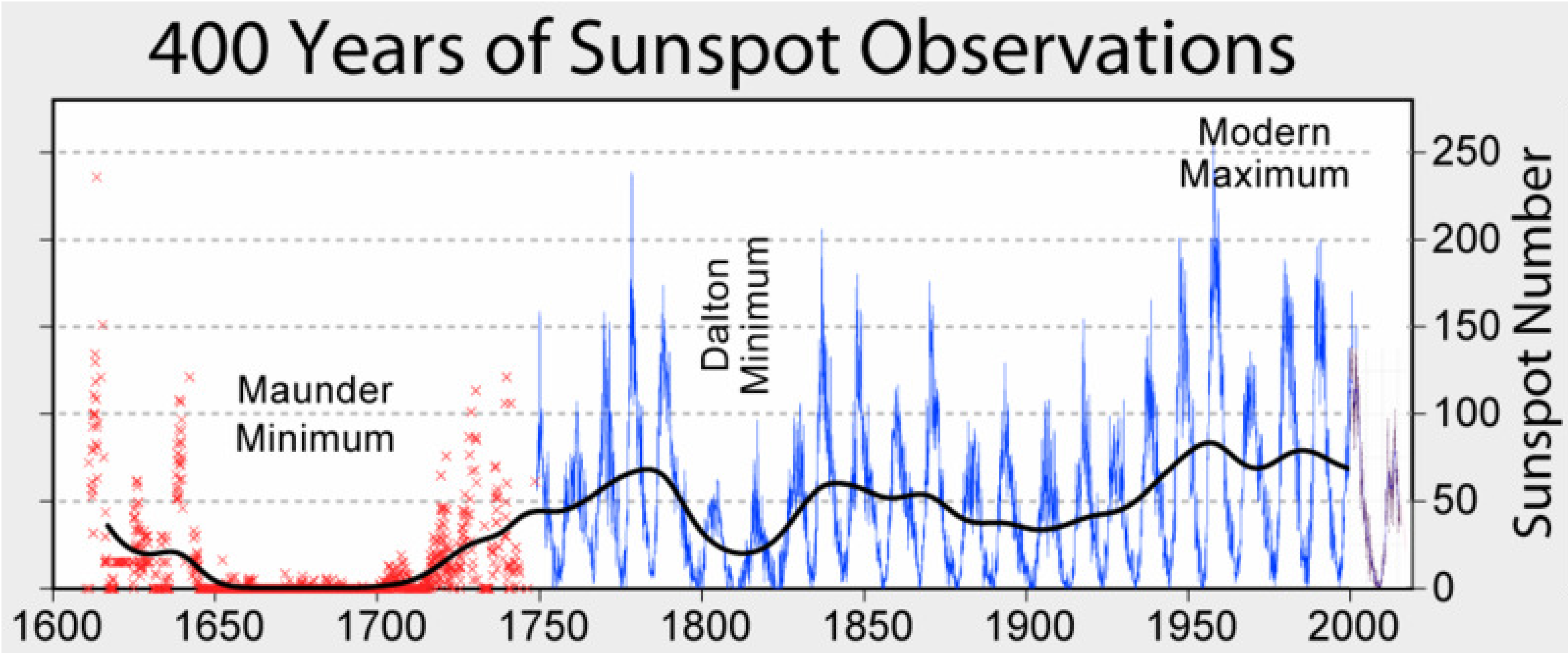
Sunspots are the most visible manifestation of solar activity



The number of sunspots is the longest instrumental data series of solar activity

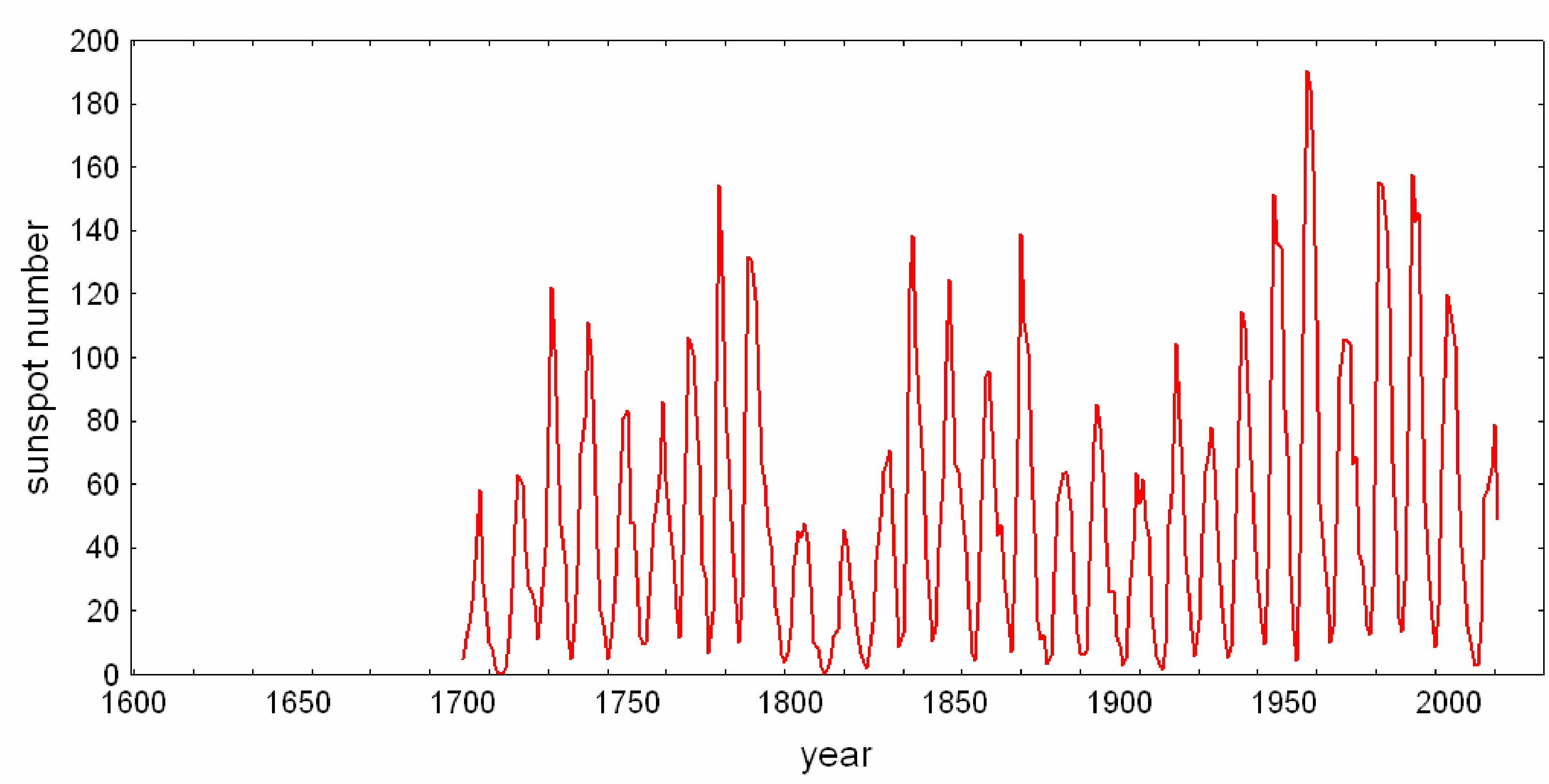


Widely used for the study of:

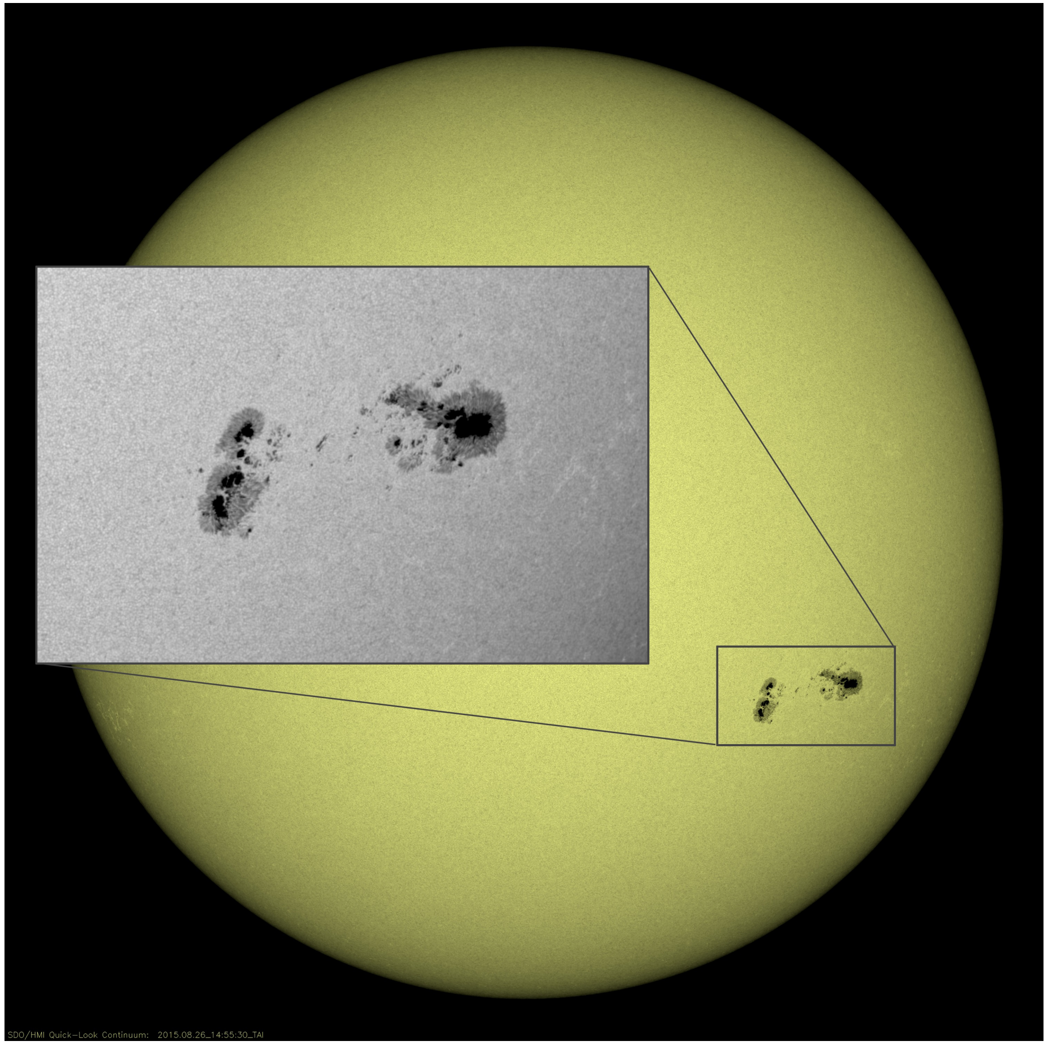
- the Sun (and other stars)
- the Sun's influence on the terrestrial system

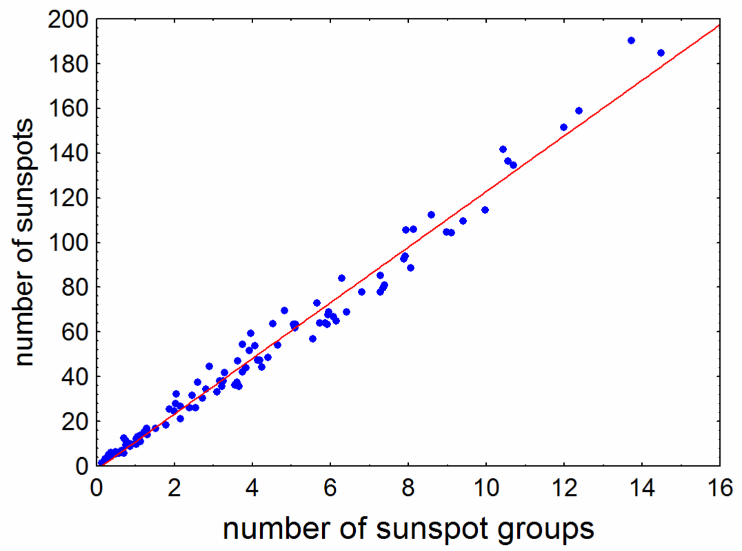
The original “relative sunspot number”, known also as “Wolf number” or “Zurich international sunspot number”, was defined by Wolf as

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



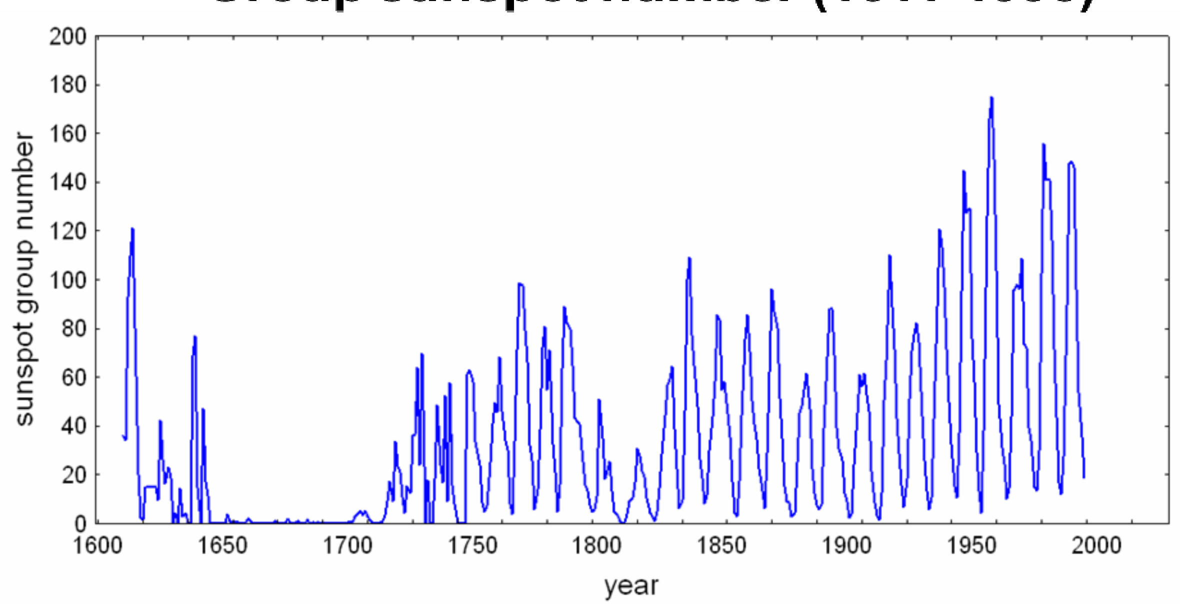
More reliable to count the number of sunspot groups





Linear relationship between the number of sunspot groups and the number of sunspots

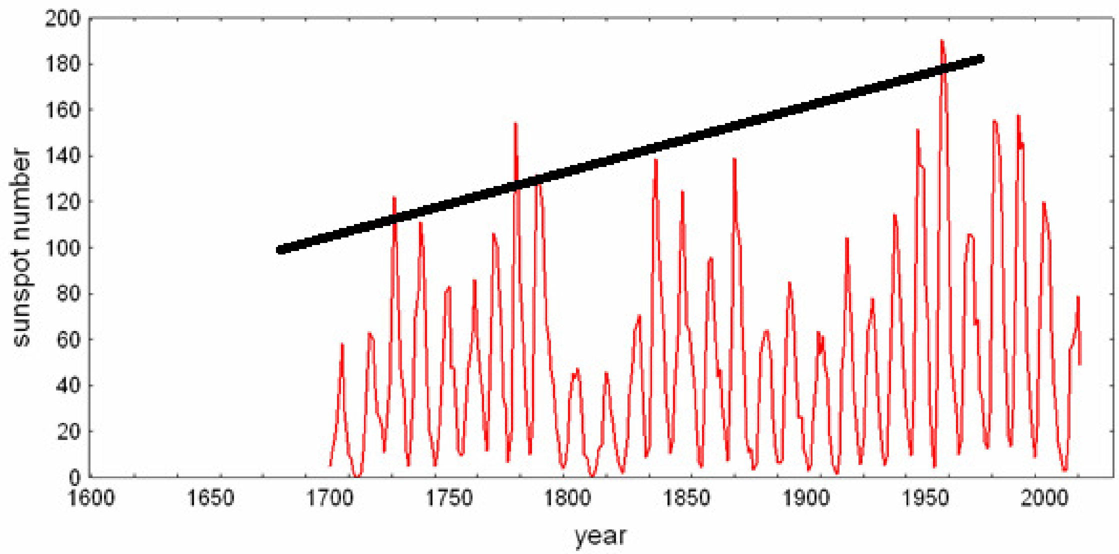
Group sunspot number (1611-1998)

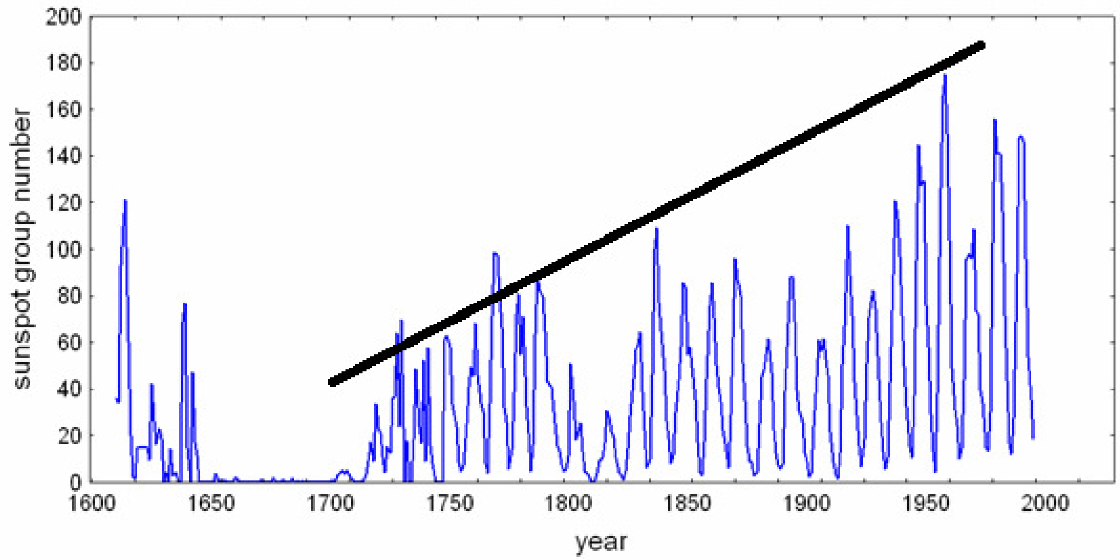


$R_G = 12.08\ G$

Hoyt and Schatten (1998)

However, RZ and RG are not identical the main difference – the long-term trends





Two data series

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)

Given the importance of the reconstructed time series, the coexistence of two conflicting series is a highly unsatisfactory situation that should now be actively addressed. **Clette et al. (2015)**

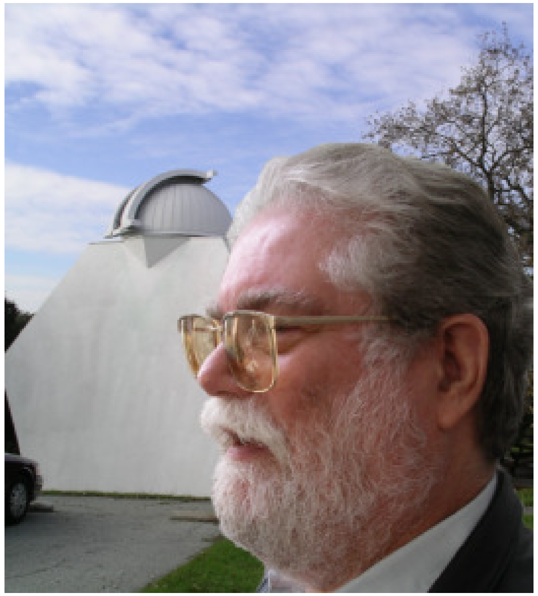
Sunspot number workshop 19-22 September 2011

Sunspot (National Solar Observatory, Sacramento Peak , New Mexico)

Ed Cliver

National Solar Observatory

US Air Force Research Lab



Leif Svalgaard

Stanford University

Frederic Clette

Royal Observatory of Belgium

Goals of this workshop

Rectify discrepancy between G & I SSN series during 19th century

Publish a vetted and agreed upon single SSN time series

Followed by several other sunspot number workshops

SSN1 – September 2011

SSN2 – May 2012

Mini SSN Workshop
September 2012

SSN3 – January 2013

SSN4 – January 2014

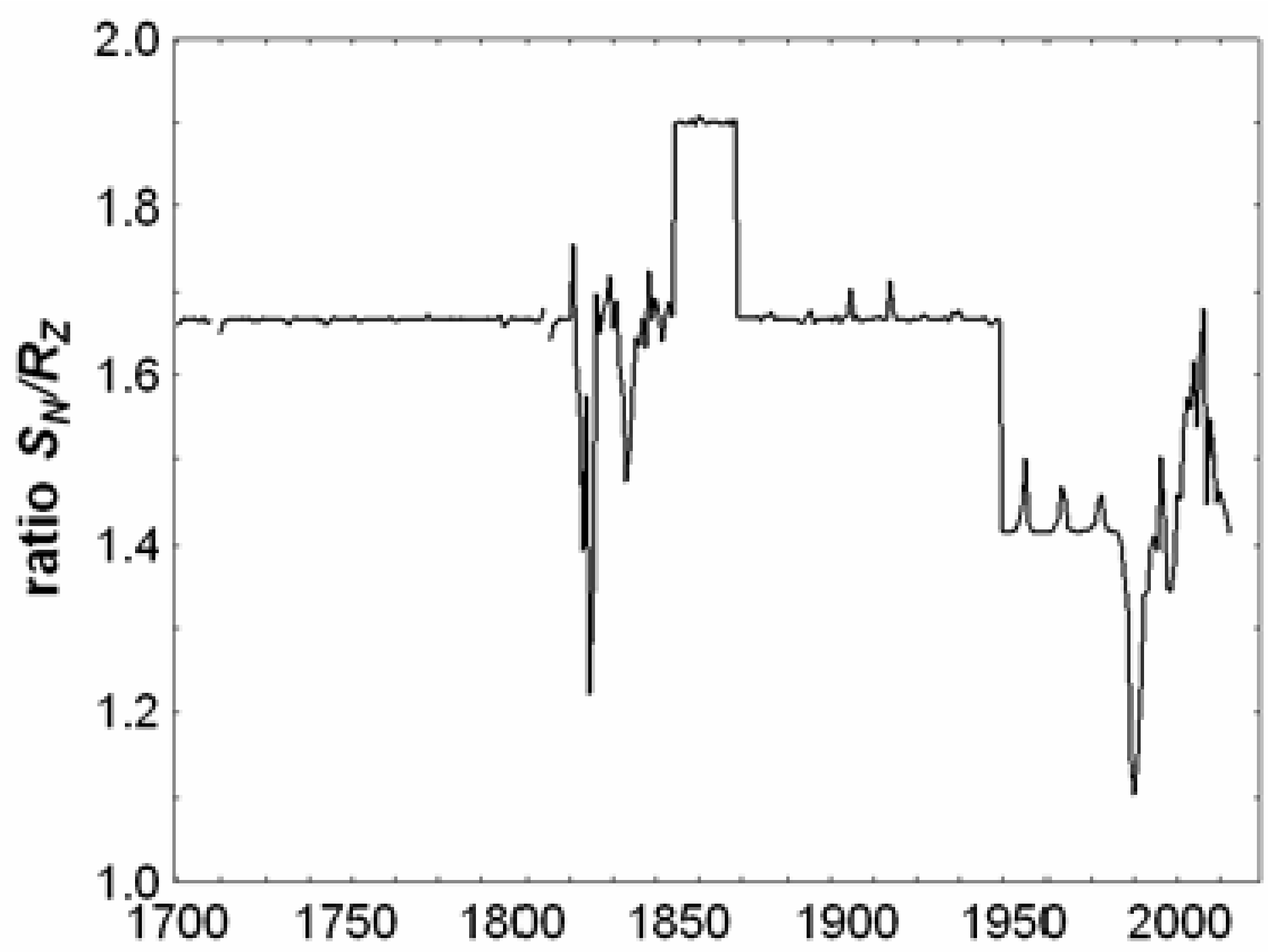
SIDC (Solar Influences Data analysis Center)

created in 1980 in the Royal Observatory of Belgium as a World Data Center with the task to continue the International relative sunspot number record after the decision of the new director of the Swiss Federal Institute of Technology J.O. Stenflo to terminate the 130-year-long Zürich sunspot number observational program initiated by R. Wolf

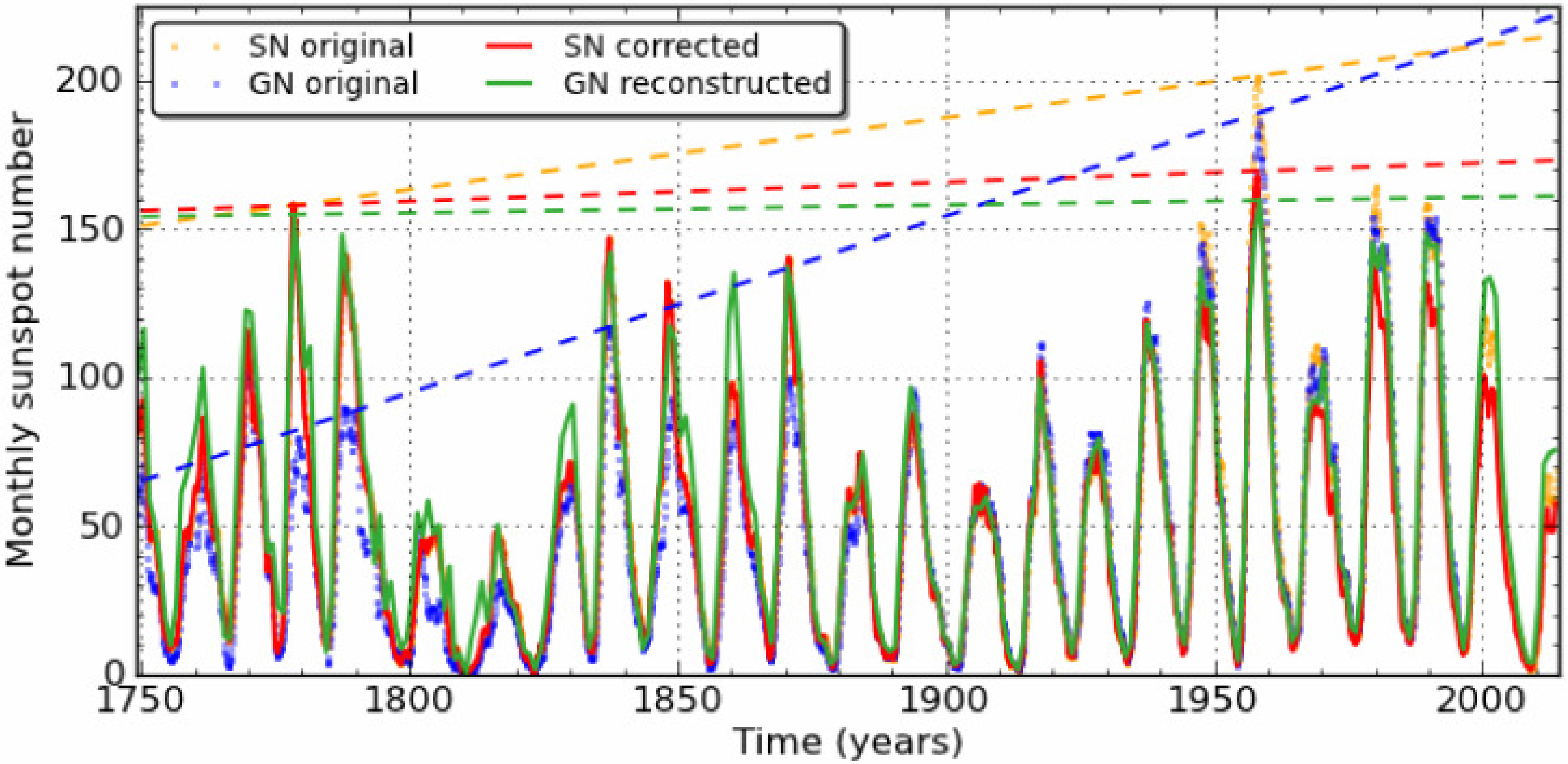
“Since July 1st 2015, the original Sunspot number data are replaced by a new entirely revised data series.”

Sunspot Index and Long-term Solar Observations

The transformation of the R_Z into the new series S_N



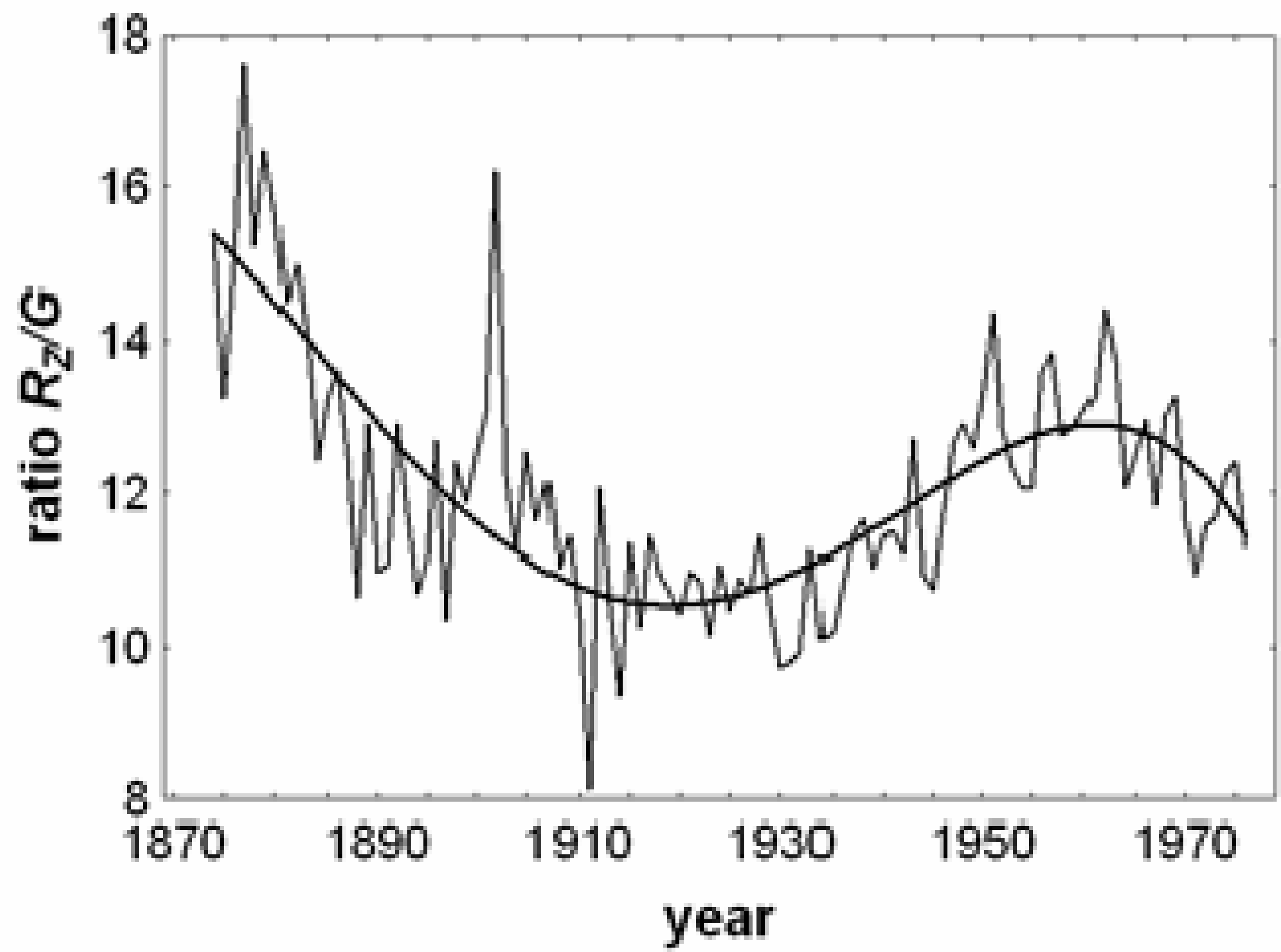
In the meantime, the Group sunspot number was also "recalibrated"

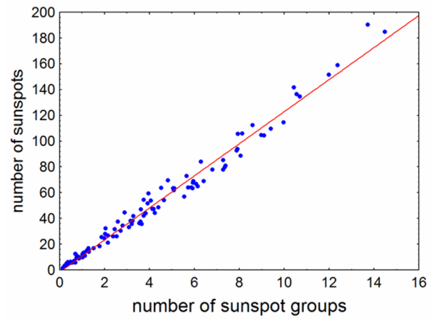


The two new series match very well, and both have no long-term trend

A press briefing during the IAU XXIX General Assembly in 2015:
"the corrected sunspot history suggests that "rising global temperatures since the industrial revolution cannot be attributed to increased solar activity"
(https://www.iau.org/news/pressreleases/detail/iau1508/).

Is it justified to try to "reconcile" the two data series?





Rg = 12.08G

A constant number of sunspots per sunspot group

Possible sources of uncertainties

- changes of observers during the more than four centuries over which the measurements were collected
- changes of pilot observatories
- changes of instruments
- changes of observational routines
- changes of calculation schemes
- etc., etc.

We use 3 observatories with continuous and homogeneous (though much shorter) data records

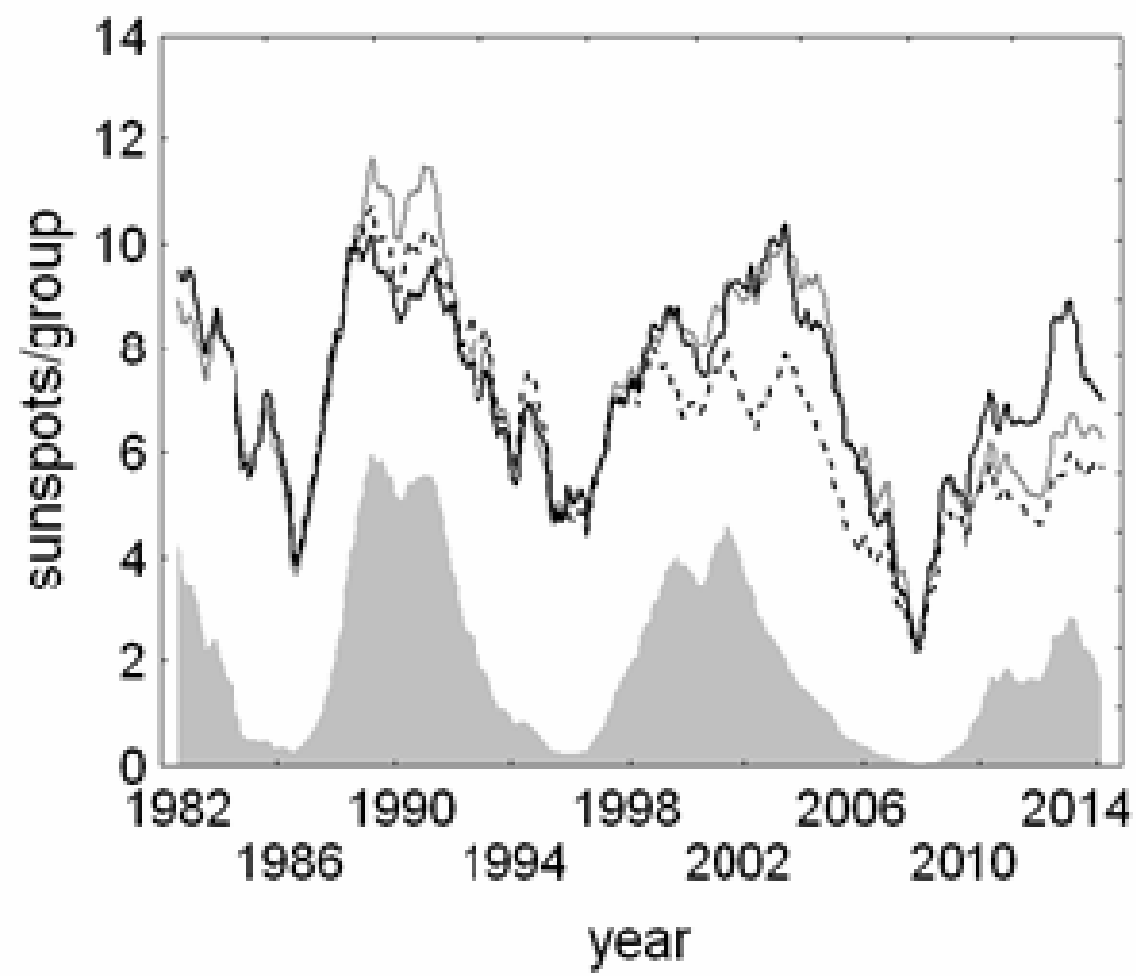
Learmonth (LEAR) from January 1982 to December 2015
Holloman (HOLL) from January 1982 to December 2015
San Vito (SVTO) from January 1986 to December 2015

the observations cover descending branch of cycle 21 (1982–1986), cycles 22 (1986–1996) and 23 (1996–2008), and the first half of cycle 24.

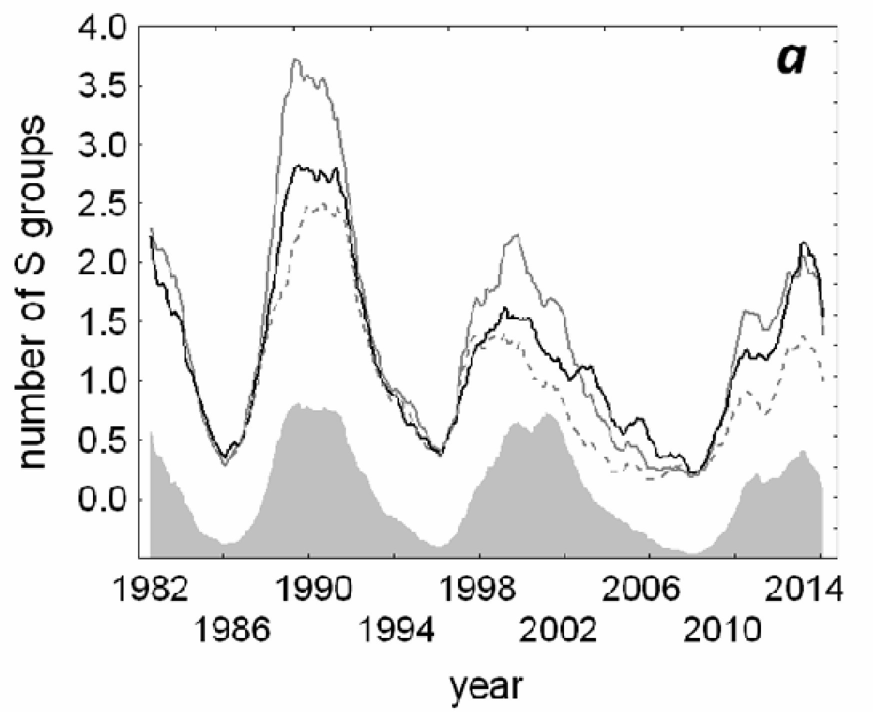
Separation of active regions into four types, based on the size of the sunspot group and the sunspot evolution, Kilcik et al. (2014)

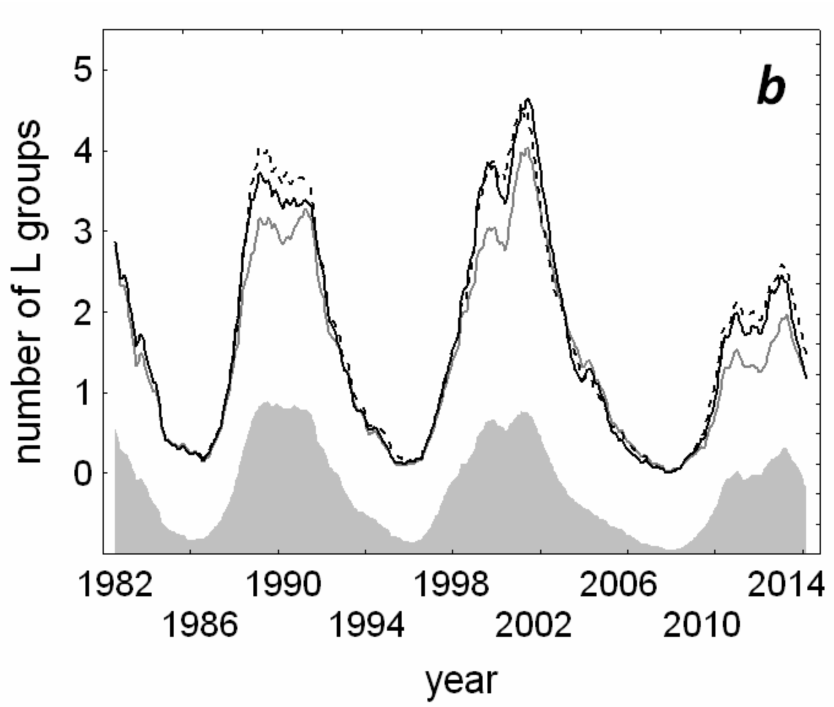
- S – simple groups (Zurich classes A and B), in the early stage of their evolution with tiny spots which do not have penumbrae.
- M – medium (class C); in the middle of their group evolution with two or more spots which demonstrate bipolarity and have a penumbra at one end of the group.
- L – large (classes D, E, and F); well developed groups spreading from 10 to over 15 degrees of solar longitude, with two or more bipolar spots, with penumbrae at both sides of the group.
- F – final (class H) types; the decayed remnants of M and L groups, containing a single spot group with penumbra occasionally accompanied by a few small spots.

The number of sunspots per sunspot group has solar cycle variations

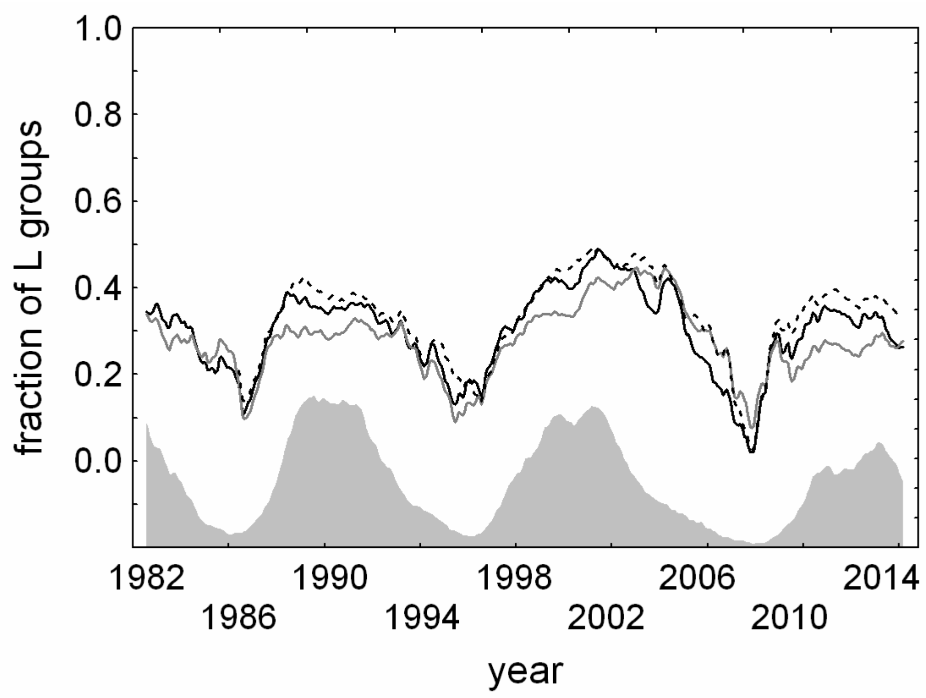


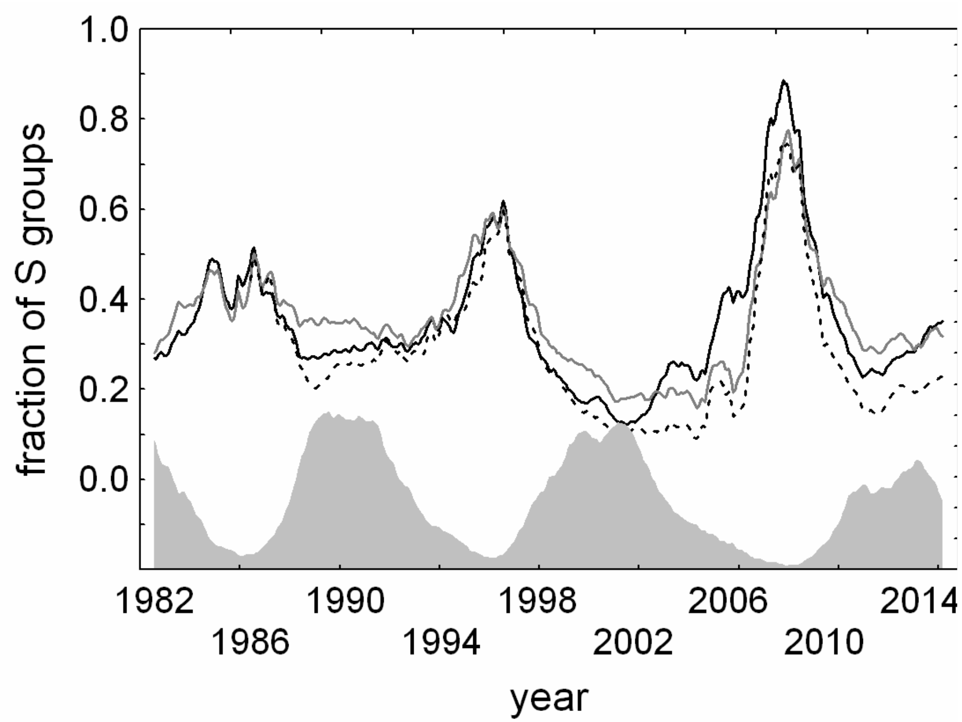
LEAR (black solid line), HOLL (grey solid line), SVTO (black dotted line), During the solar cycle, as well as from cycle to cycle, the relative number of the sunspot groups in the different categories varies



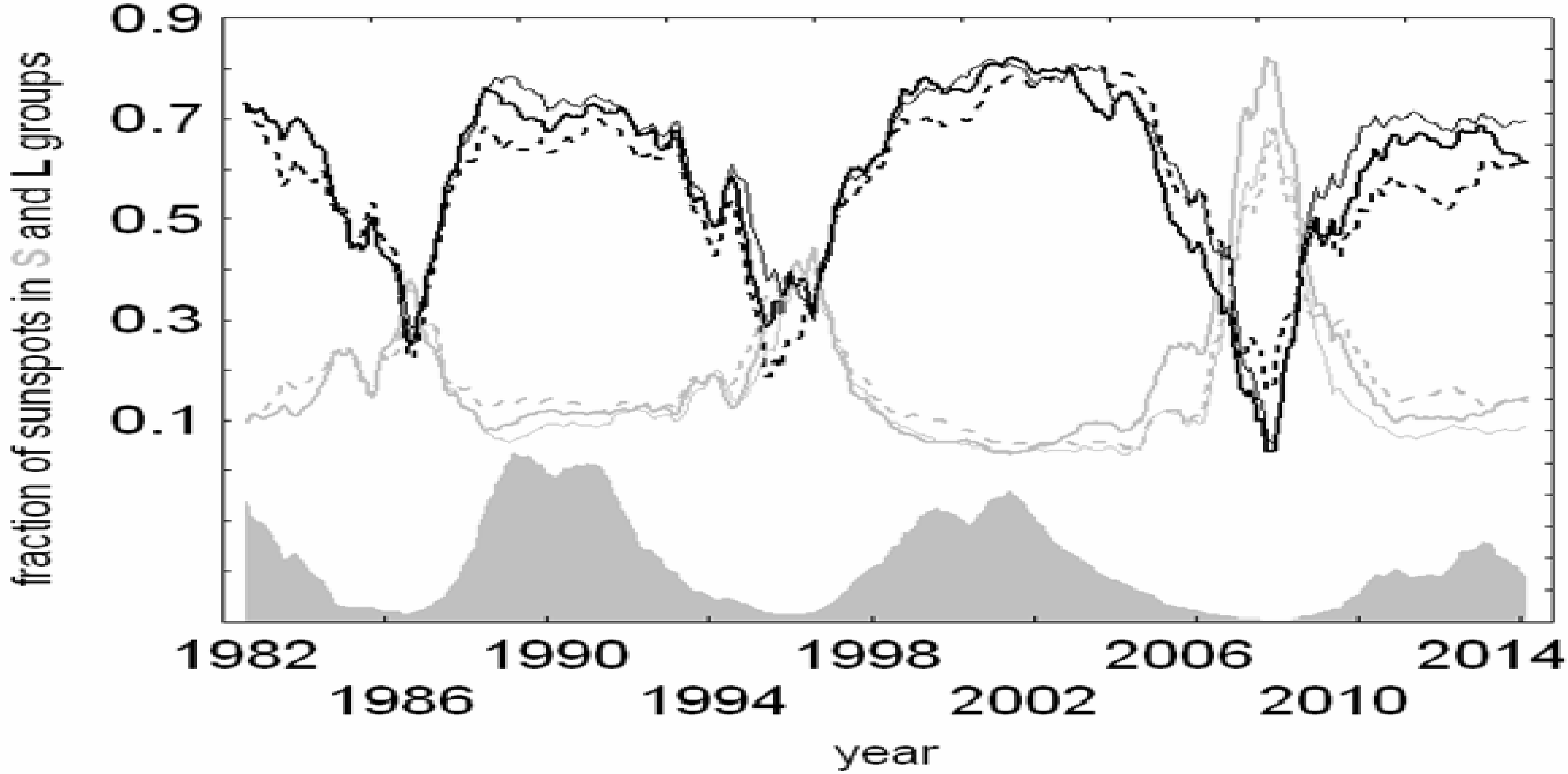


fraction of S and L groups





fraction of sunspots contained in different groups



Around sunspot maximum, ~80% of the sunspots in L groups, ~10% in S groups
Around sunspot minima the contribution of sunspots in S groups increases
In the minimum 23/24 sunspots in S groups 7 - 8 times more than sunspots in L groups.

Tlatov (2012) from Kislovodsk station

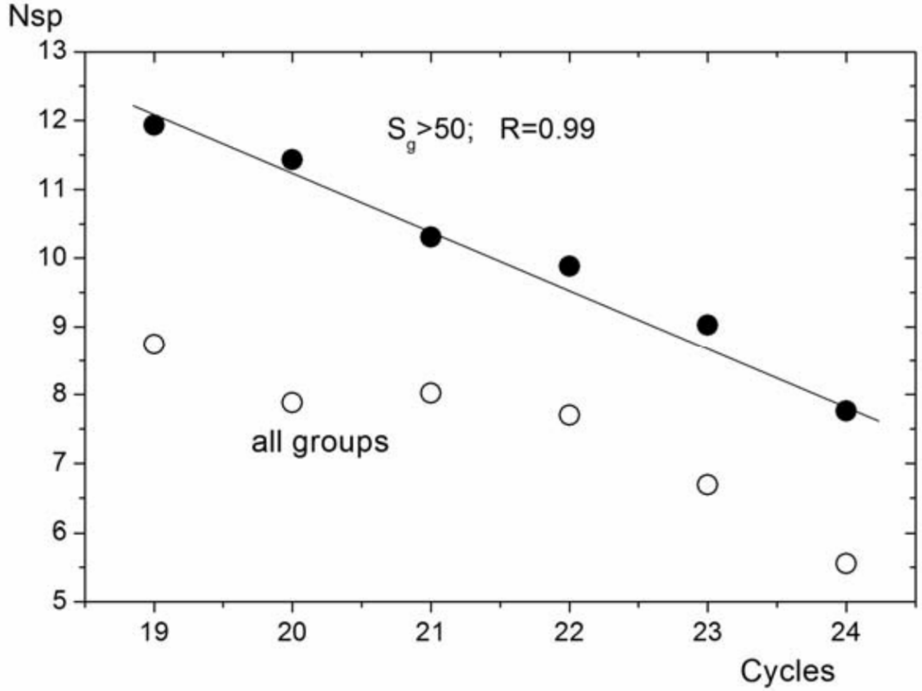
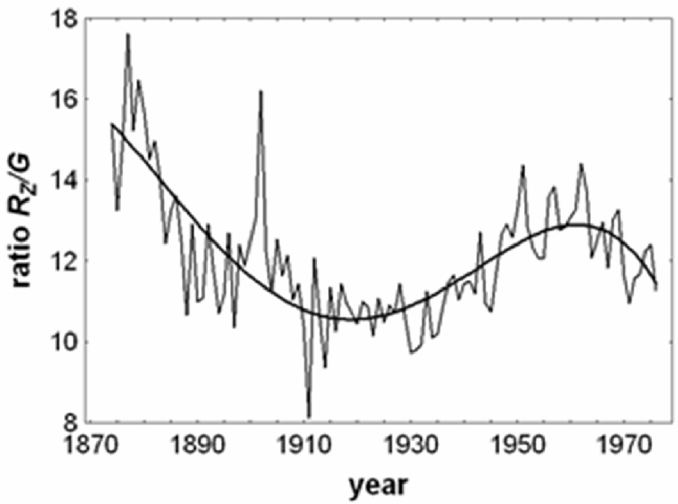
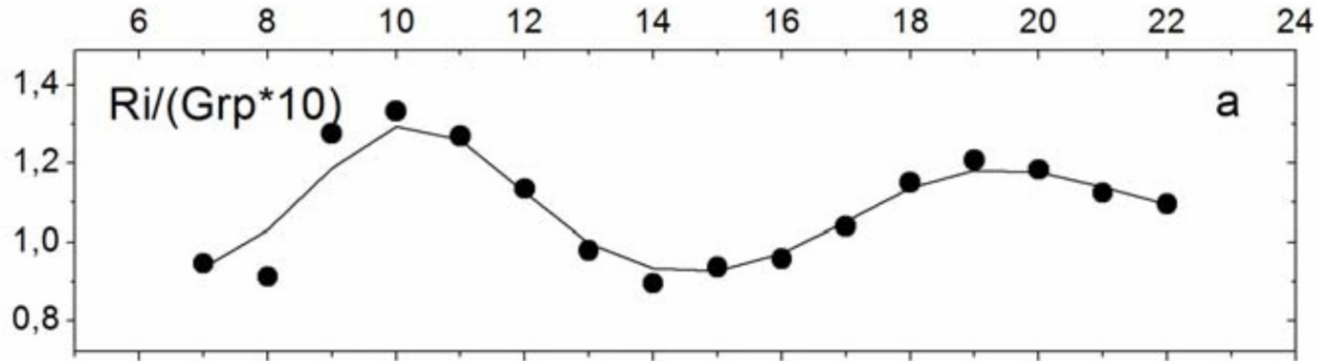
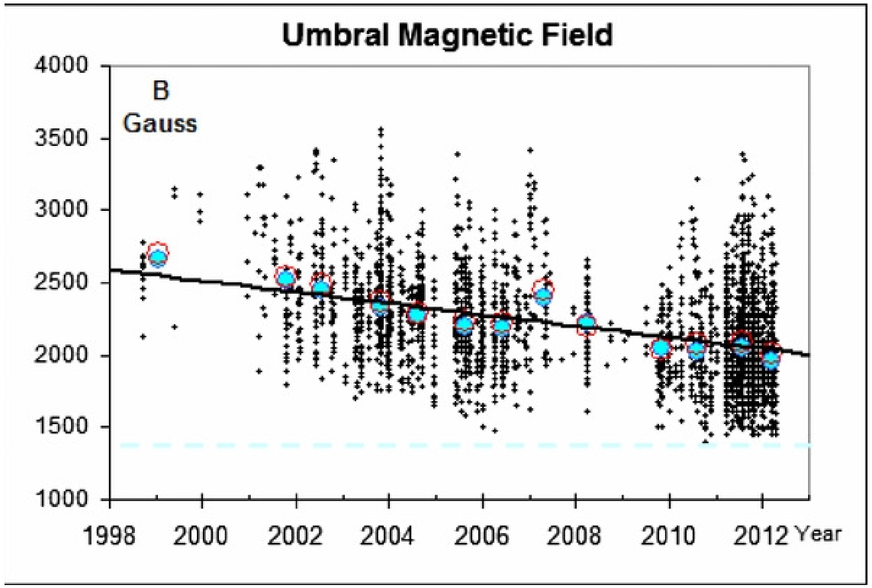


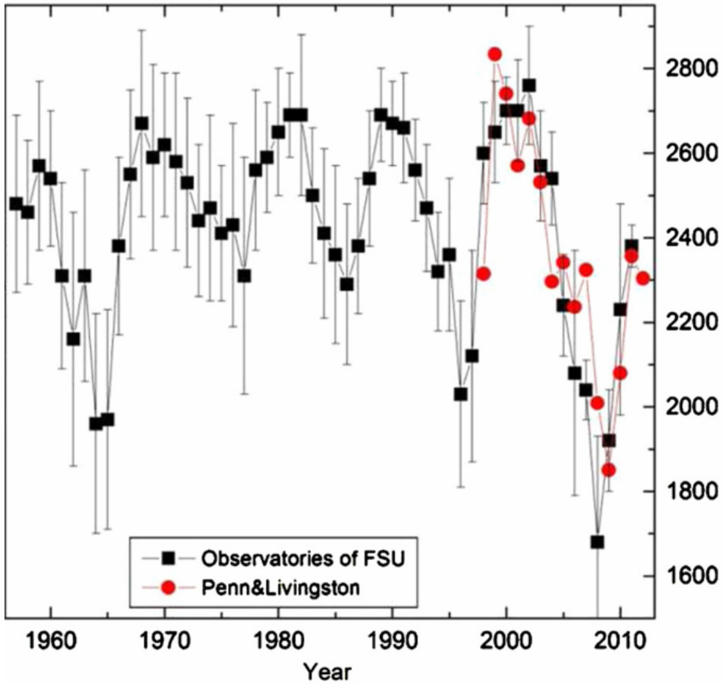
Fig. 2. Variation in the average sunspot number in a group during a cycle.





Sheeley (1966): the complexity of a sunspot group (=number of sunspots) increases with its magnetic field

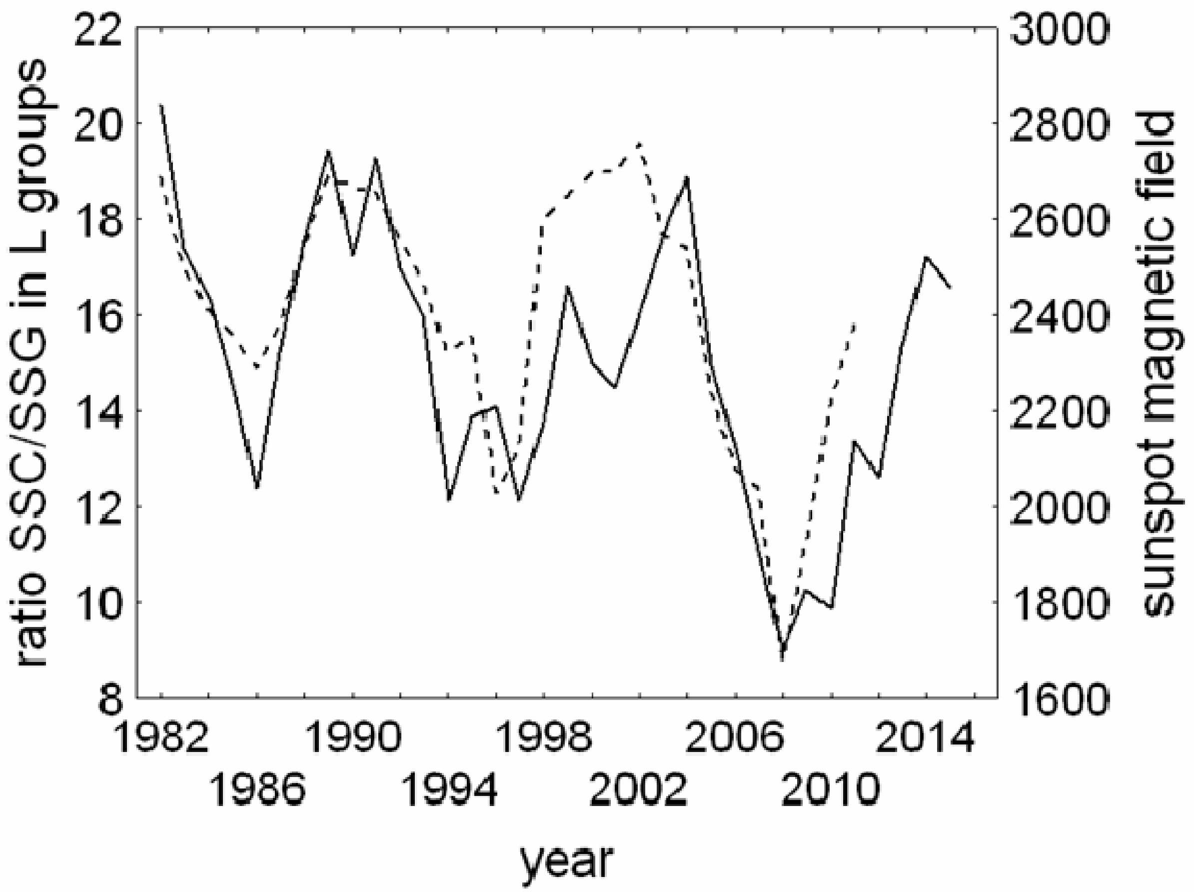




Penn and Livingston (2012)

Nagovitsyn et al. (2012)

The average number of sunspots in sunspot groups depends on the solar magnetic field



conclusion

- The changing ratio between R_Z and R_G is a real feature reflecting the evolution of solar magnetic fields
- The attempts to “rectify the discrepancy” between these two indices are not physically justified and lead to losing important information about the Sun’s evolution
- The new sunspot indices are not correct.