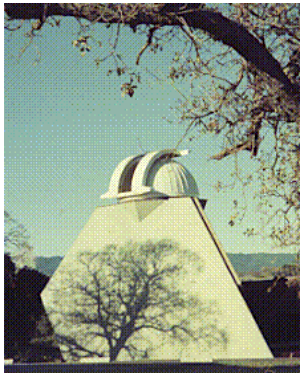


Validation of the Group Sunspot Number Series

Leif Svalgaard

Stanford University

Jan. 2020

2020 Sun-Climate Symposium, Tucson, AZ

"Il est, dans la carrière des Sciences comme ailleurs, certains fantômes, qui semblent d'abord vouloir arrêter nos pas, & dont il suffit de s'approcher pour reconnôitre & dissiper leur illusion". *J.D. De Cassini* (1791)

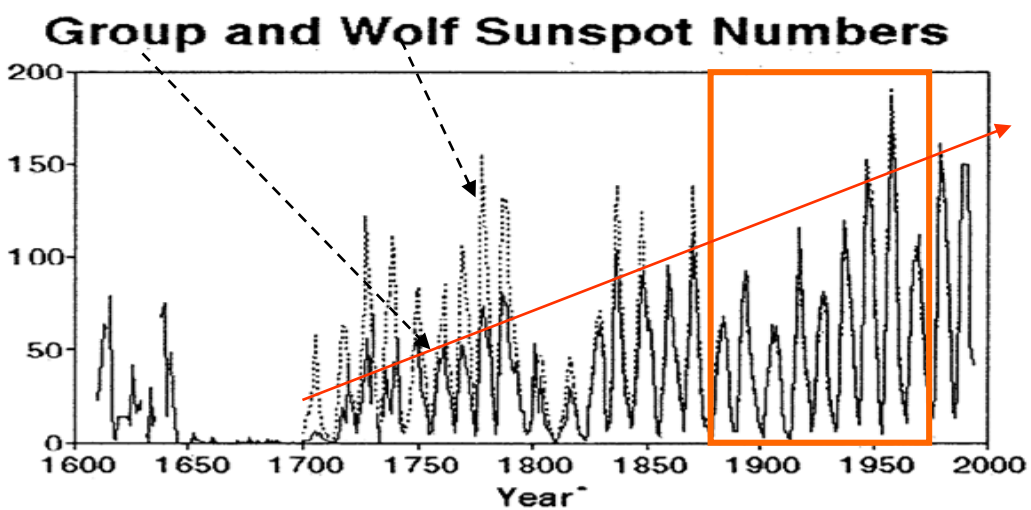
The H&S Papers That Started it All

Hoyt, Douglas V.; Schatten, Kenneth H.; Nesme-Ribes, Elizabeth: The one hundredth year of Rudolf Wolf's death: **Do we have the correct reconstruction of solar activity?** *Geophysical Research Letters, Volume 21, Issue 18, p. 2067-2070, 1994*

Hoyt, Douglas V.; Schatten, Kenneth H.: Group Sunspot Numbers: a new solar activity reconstruction. *Sol. Phys. 179, 189–219, 1998*. [HS98 in what follows]

"In this paper, we construct a time series known as the Group Sunspot Number. […] The generation and preliminary analysis of the Group Sunspot Numbers allow us to make several conclusions: (1) **Solar activity before 1882 is lower than generally assumed** and consequently **solar activity in the last few decades is higher than it has been for several centuries.**" [Other researchers have claimed for more than ≈10,000 years]

The Problem: Two Very Different 'Sunspot Series'. Which One to Use?



Original Wolf Number: Wo = Groups + 1/10 Spots. ('1/10 Spots' was assumed to be a measure of the area of the group). W = k 10 Wo

H&S GSN = 12 G where the '12' was chosen to make the GSN = W for the interval 1874-1976

I proposed a solution for reconciliation: The SSN Workshops (Utterly Failed the Goal)

http://ssnworkshop.wikia.com/wiki/Home


Sunspot, NM, 2011


Brussels, BE, 2012


Sunspot, NM, 2012


Tucson, AZ, 2013


Locarno, CH, 2014


Brussels, BE, 2015

Goal: a community-vetted and agreed-upon solar activity series;
Failure: we now have over half a dozen dissenting and different series…

The Principal Issue is Still Unresolved

A second attempt has recently been made to resolve the problem: **ISSI Team 417 (2017):** "This ISSI Team aims to resolve the uncertainties related to the sunspot series and to produce a consensus new-generation series, based on the modern methods and knowledge of physical processes leading to sunspot variability. The ultimate **goal is to provide a consensus "best" sunspot number** including accurate estimates of the uncertainties, for use by the whole scientific community (Meetings 2018 and 2019)

We now have basically two classes of reconstructions:

1: A set of series that closely resemble the original H&S reconstruction

2: A set of series that closely resemble the 'official' Sunspot series (both V1and V2; V2 is essentially just V1/0.6)

The main difference is (as pointed out by H&S) a discontinuity around 1880-1885 with up to 40% discrepancy between the two classes.

Instead of resolving the issue, opinions and claims have become more polarized and new reconstructions have marred the discourse with no end in sight

As the SSN workshops, this new effort also looks like a failure

Some of the new 'Modern' Series… Breakthroughs or Hype?

T. Willamo, I.G. Usoskin, and G. A. Kovaltsov, 2017, [WEA]
Updated sunspot group number reconstruction for 1749–1996 using the active day fraction method, Astronomy & Astrophysics manuscript no. 29839JN˙C:
[…] The new reconstruction reflects the centennial variability of solar activity as evaluated using the singular spectrum analysis method. **It depicts a highly significant feature of the modern grand maximum of solar activity in the second half of the 20th century, being a factor 1.33–1.77 higher than during the 18 and 19th centuries.**

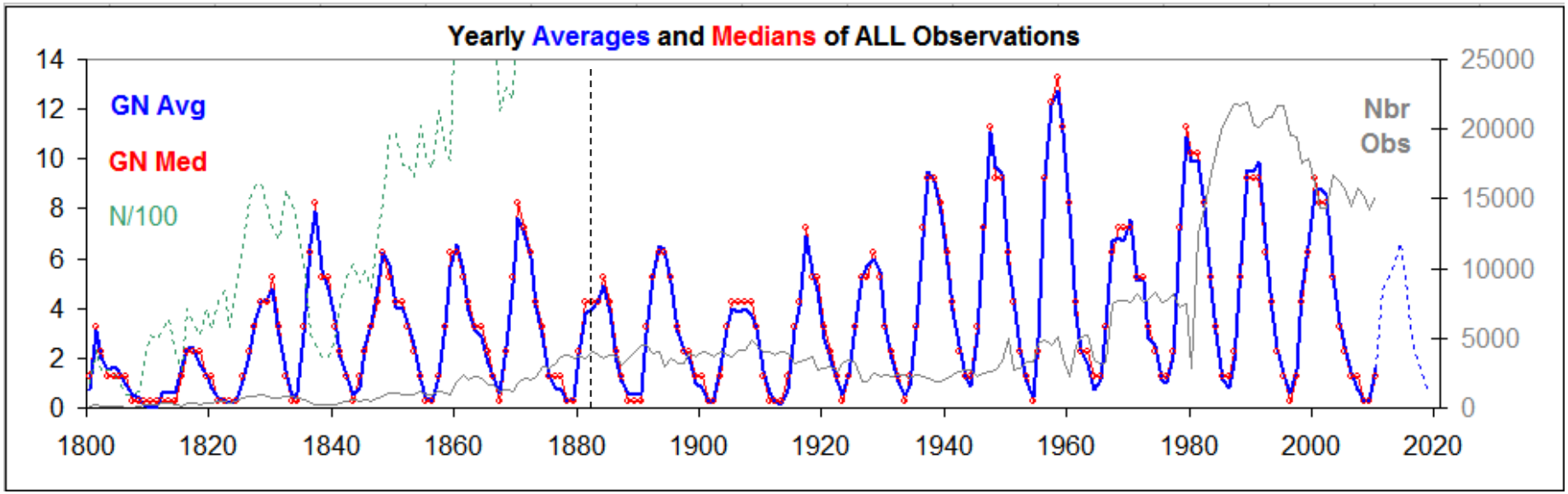
Theodosios Chatzistergos, Ilya G. Usoskin, Gennady A. Kovaltsov, Natalie A. Krivova, and Sami K. Solanki, New reconstruction of the sunspot group numbers since 1739 using direct calibration and "backbone" methods, *A&A 602, A69 (2017):* [CEA]
[…]This series suggests moderate activity during the 18th and 19th century, which is significantly lower than the high level of solar activity predicted by other recent reconstructions applying linear regressions. The new series […] confirms **the existence of the modern Grand Maximum of solar activity in the second half of the 20th century**.

Thierry Dudok de Wit & Ed W. Cliver, *Space Climate 7, 2019* (Abstract): [DC19]
[…] Here we present a new approach that **bypasses the need for intercalibration** and in addition avoids the artificial introduction of backbone observers for stitching records together. […] Thanks to this method no specification of backbones or daily-chaining is required.

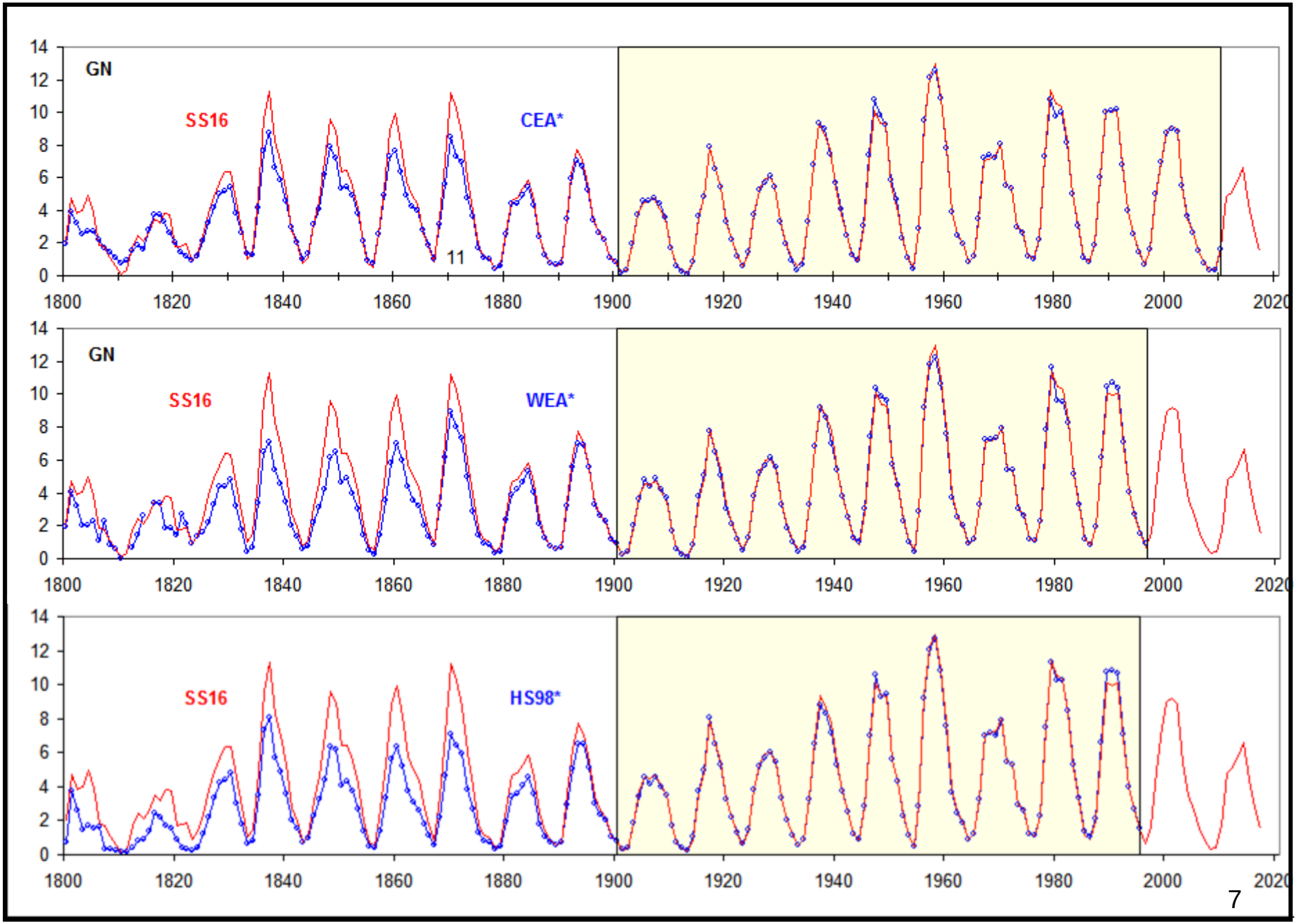
Common assumption: the observational data are accurate

Vox Populi (The Wisdom of Crowds), F. Galton, *Nature* 1907

If the Group Number data collected by Wolf, by H&S, and since 1981 by SILSO are indeed accurate and represent actual counts of what the observers and the rapporteurs believed to be Sunspot Groups, then these 'Modern' Reconstructions of solar activity given by the Group Numbers must closely resemble the historical record shown below. If not, it must be explained *why* not.



As we shall see, they generally do, conforming to Galton's insight


GN
SS16
CEA*
11
GN
SS16
WEA*
SS16
HS98*
0
2
4
6
8
10
12
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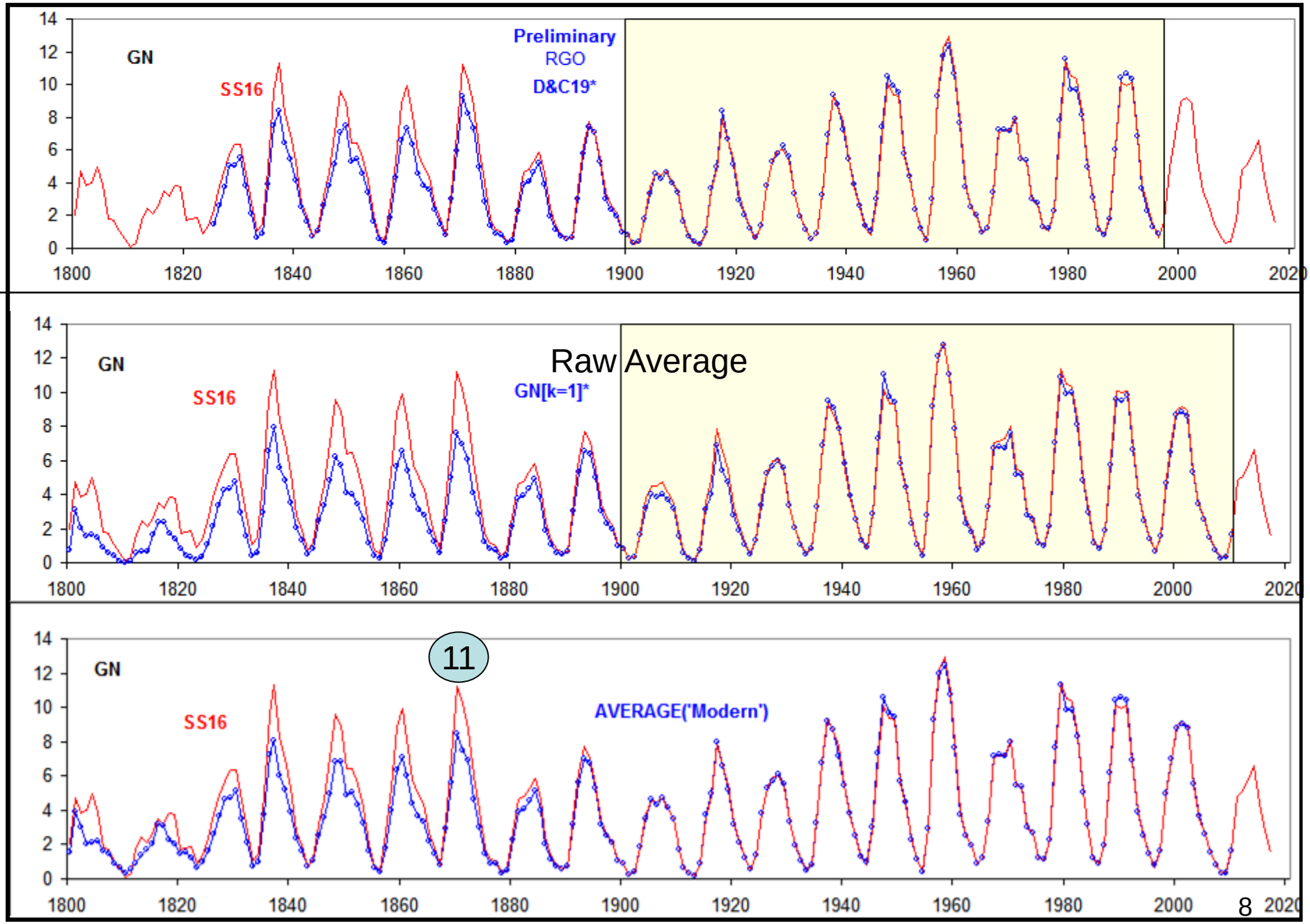
1860
1880
1900
1920
1940
1960
1980
2000
2020


GN
SS16
Preliminary
RGO
D&C19*
GN
SS16
Raw Average
GN[k=1]*
GN
SS16
11
AVERAGE('Modern')
0
2
4
6
8
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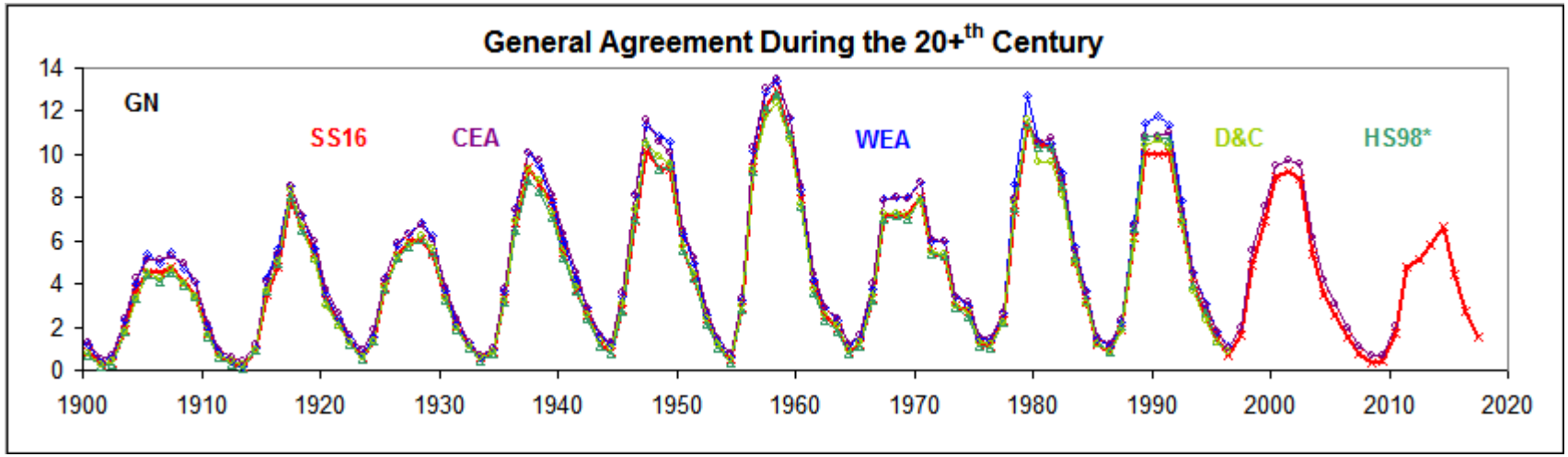
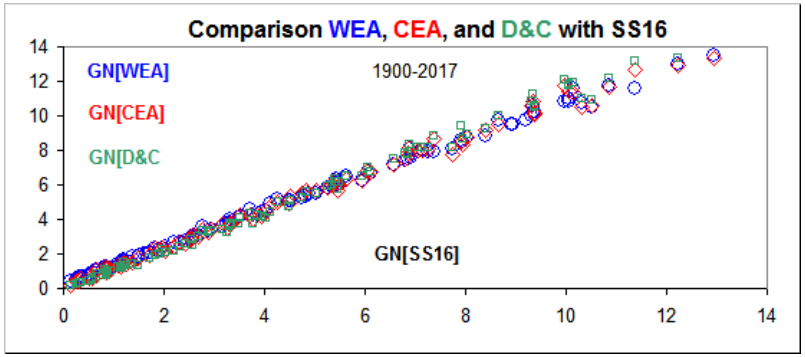
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020

Everybody Agrees About 20th Century



This suggests that the [very] different methods [apart from minor details and scaling matching] basically work and that therefore it is **not productive to argue which is 'better'** or which has severe errors or uses 'unsound procedures'. So, in spite of all the objections, hand wringing, gnashing of teeth, and general acrimony, all methods give the same results within ±3% when the underlying data are good and belong to the same population.



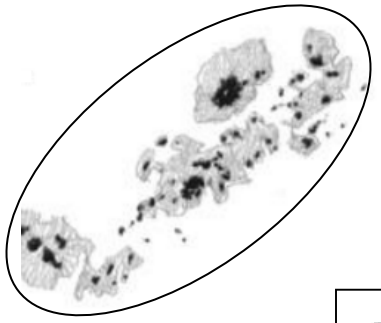
When analyzing yearly values, the regression lines are remarkably linear (even proportional), belying claims that they are not.

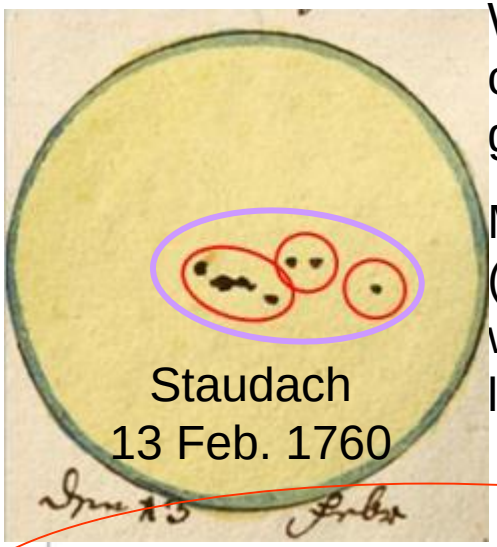
A New Paradigm (Different Populations)

- We shall therefore argue that the set of the new dissenting Group Number series resembling the H&S series actually accurately represents the archived raw observational data (assembled first by Wolf and later by H&S and today curated by Vaquero et al.)
- And that the secular increase (from one population to the next) in archived Group Numbers is due to evolving technology and [more importantly] to understanding of what makes a group, rather than to errors and mistakes committed by the researchers
- And that the true evolution of solar activity can only be validated by agreement with other manifestations of said activity (often derisively called ‘proxies’) of which there are many

Fundamental Issue: What Is a Group?

Definition has changed over time

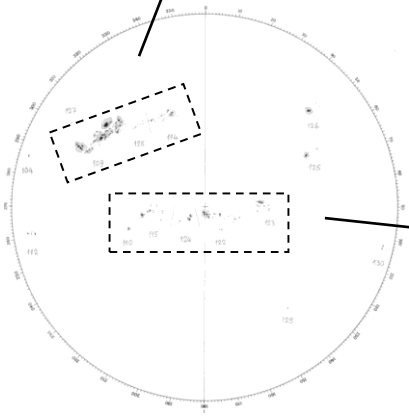




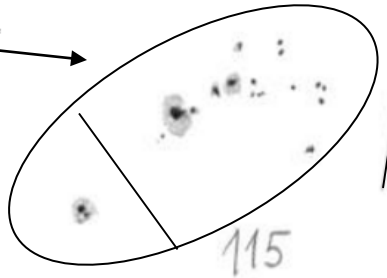
Wolf (1857) counted only one group on that day.

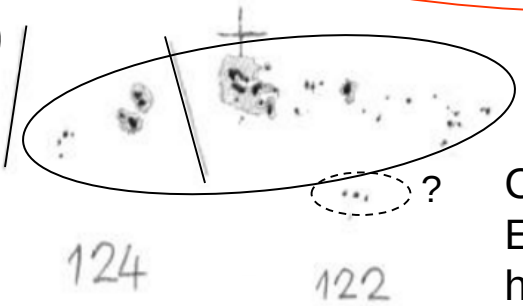
Modern observers (Cortesi, even me) would count at least three groups.

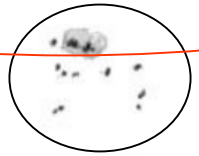
Contrary to common belief, counting spots is easy, counting groups is **hard**



Locarno







Cortesi counted 8 groups. Early observers would likely have counted only 5 groups

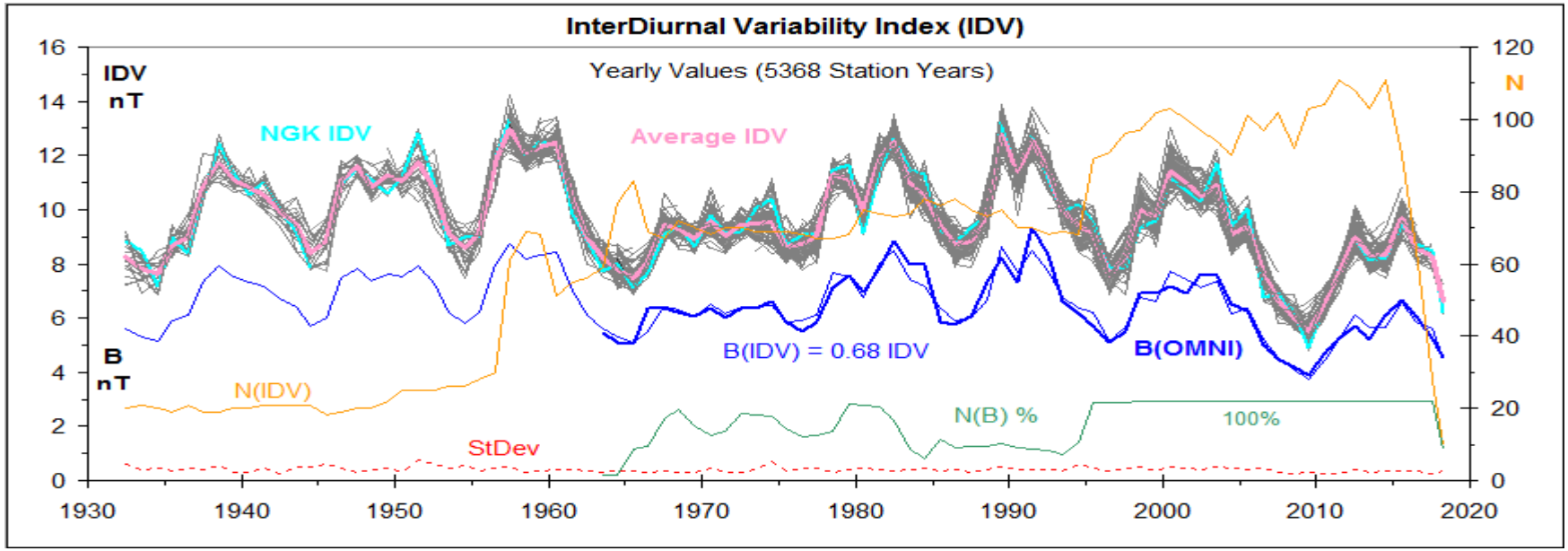
Some Major Proxies for Solar Activity

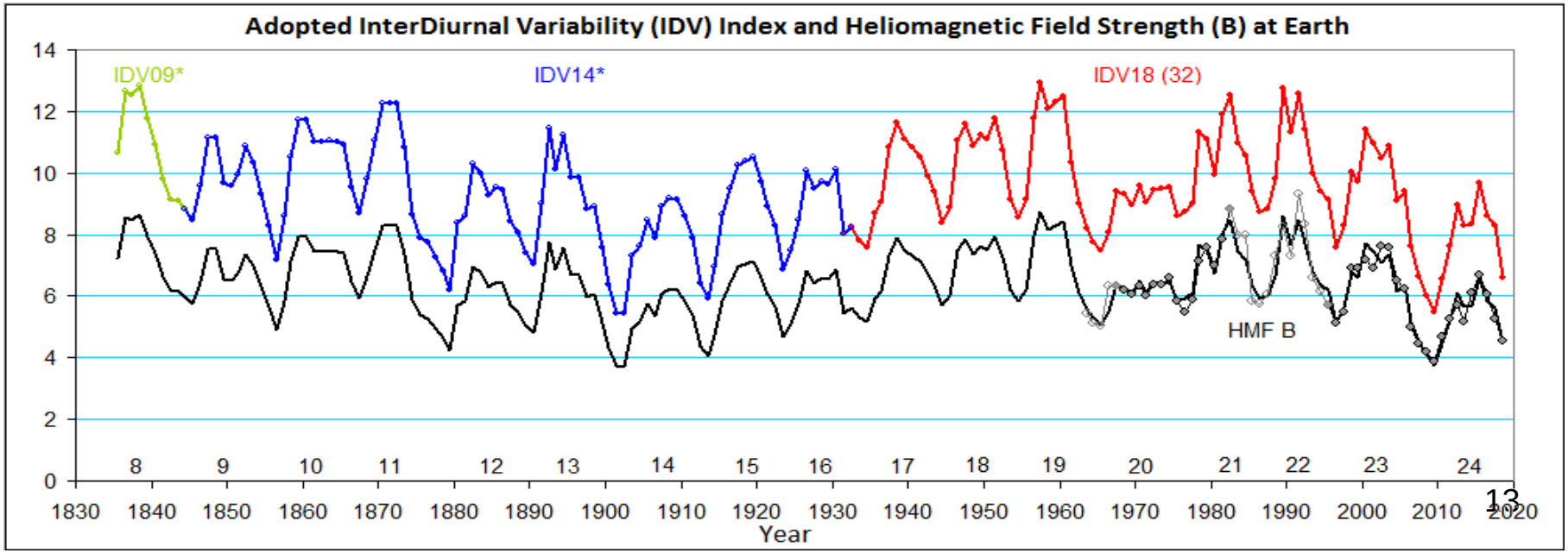
Wolfer (1893) introduced an improved method of counting sunspots and insisted on counting all spots [and groups] that could be seen, not omitting small and fleeting spots and corrected for the previous undercounts [the infamous correction factor of 0.6]. **So the classical Relative Sunspot Number already incorporates the effect of the New Paradigm**. The recent revision (Version 2) made needed small corrections [e.g. for the Waldmeier jump in 1947]. There is a strong correlation between the Relative Sunspot Number SN and the Group Number GN, so **SN is a good proxy for GN**.

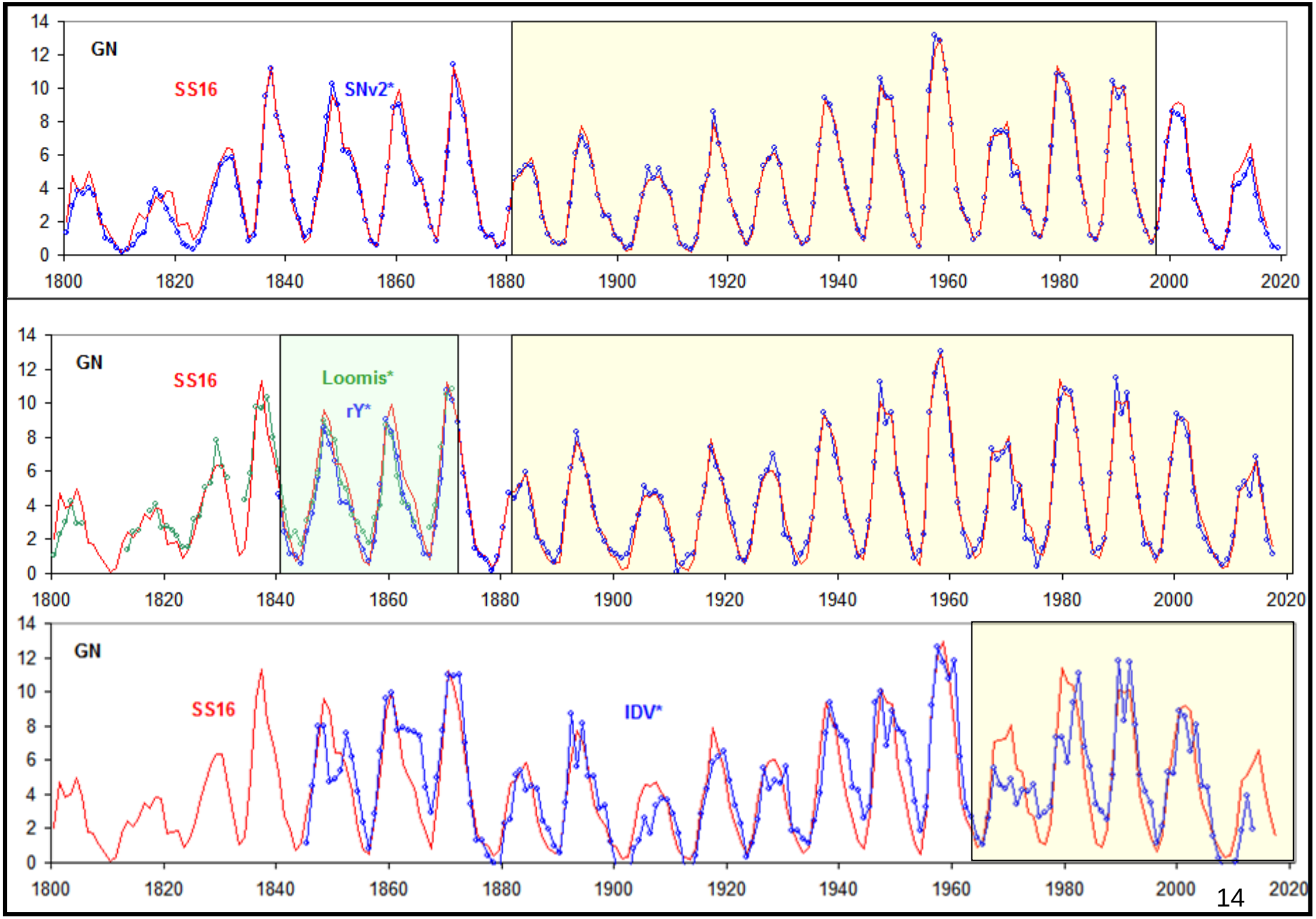
Solar EUV creates the ionospheric E-region. Dynamo induced electric currents have a magnetic effect observed as diurnal variations (e.g. rY) at geomagnetic observatories for centuries. Already Julius Bartels (1941, 1946) emphasized the importance of the diurnal variation: The correlations between the Sunspot Number and the diurnal variations… "are the **closest found so far between solar and terrestrial phenomena**", so rY is also an excellent proxy for GN.

The geomagnetic IDV-index is a measure of the energy in the Magnetospheric Ring Current [Van Allen Belts] and has been found to be a **strong proxy for the Hemispheric Magnetic field** [B at Earth] which in turn is related to the Solar Wind 'Open' Magnetic flux, and thus also a proxy for the Solar Magnetic Field and the GN.

IDV is a Good Proxy for the Heliospheric Magnetic Field






GN
SS16
SNv2*
Loomis*
rY*
IDV*
0
2
4
6
8
10
12
14
1800
1820
1840
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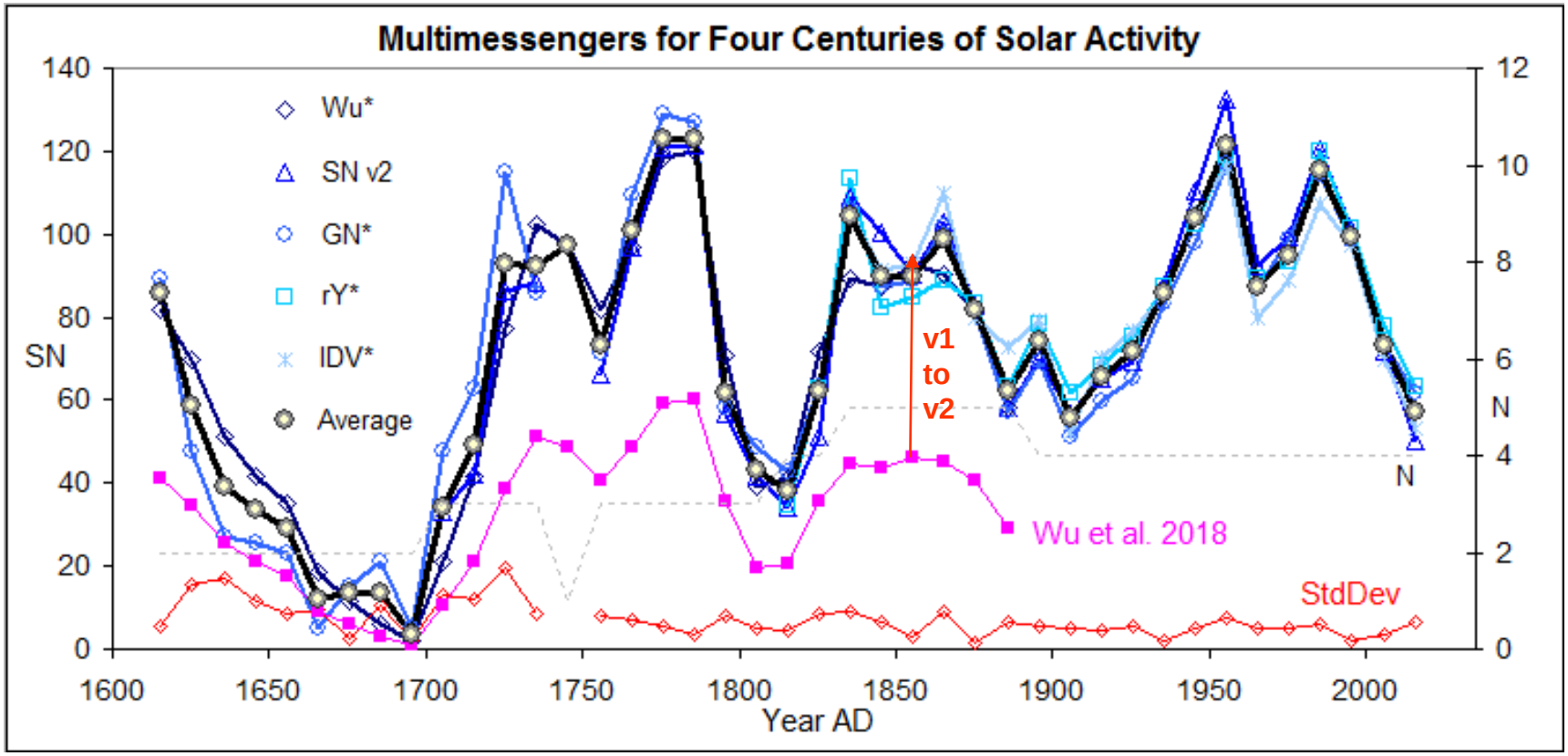
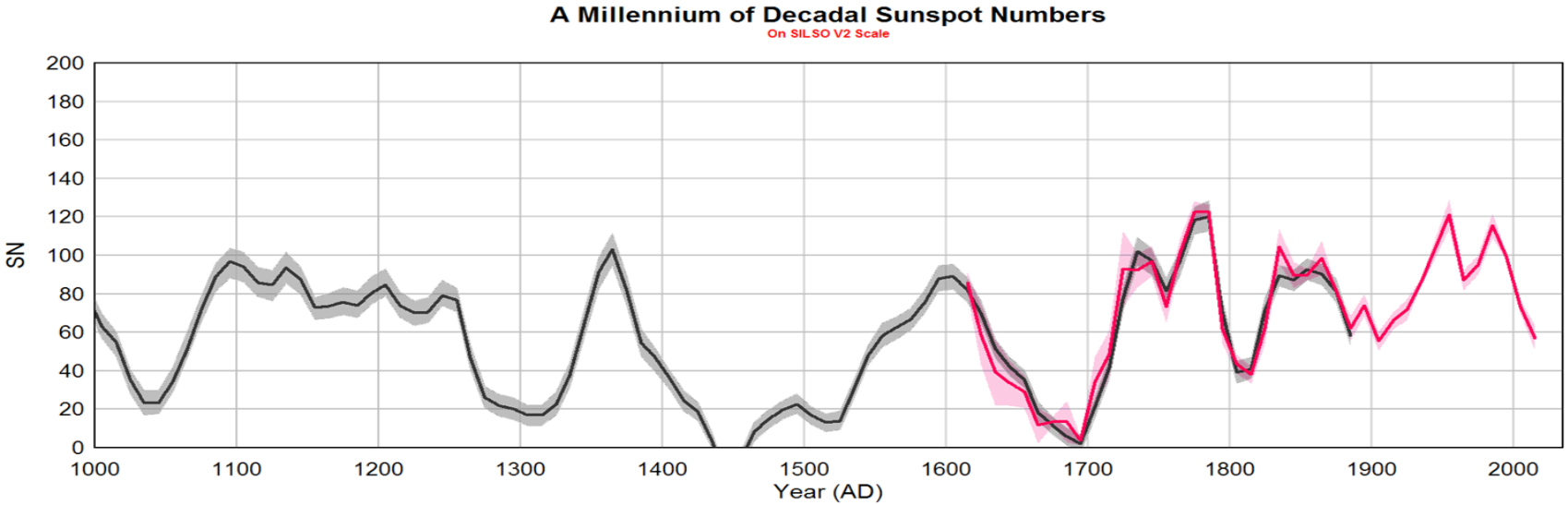
2000
2020

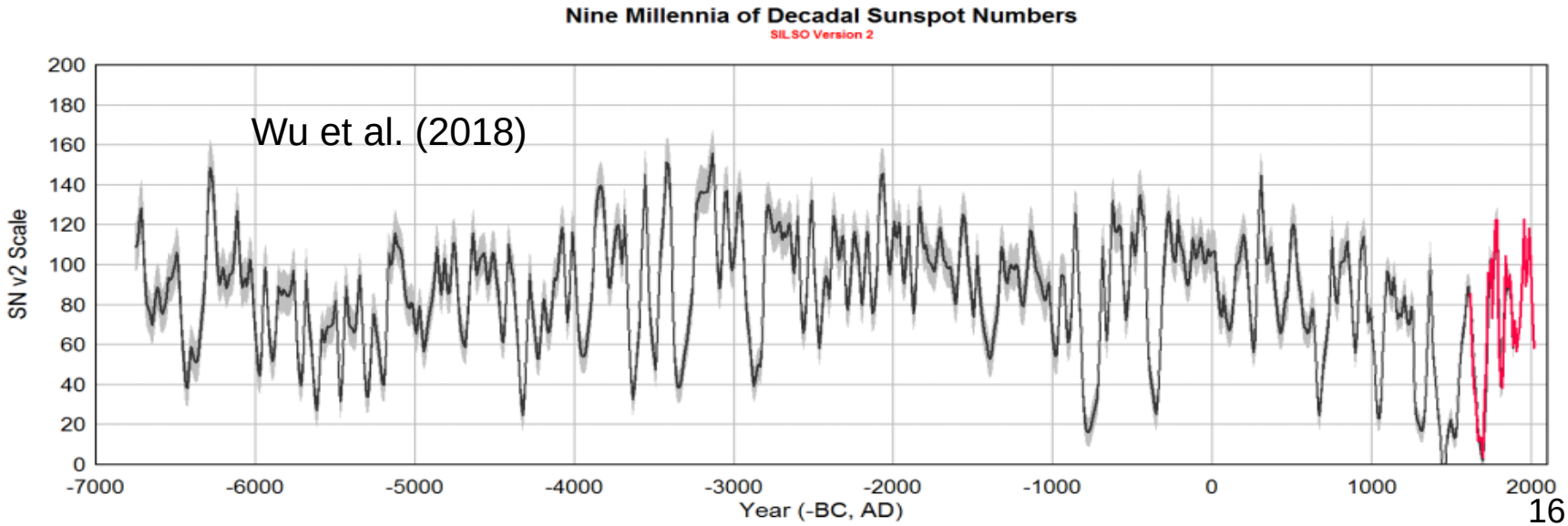
SN, GN, rY, GCR, IDV



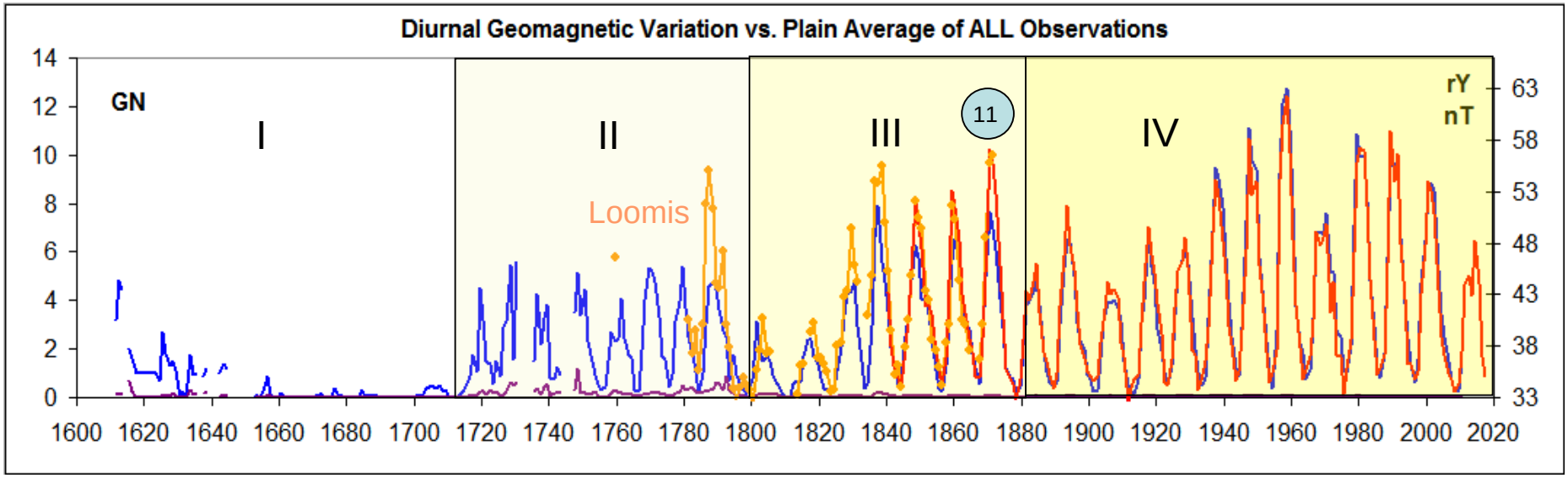
To convert the Decadal Averaged Cosmic Ray (GCR)-based reconstruction by Wu et al. (2018) from SNv1 to SNv2, one has to multiply by a factor of 2.

The longer view: Nine millennia





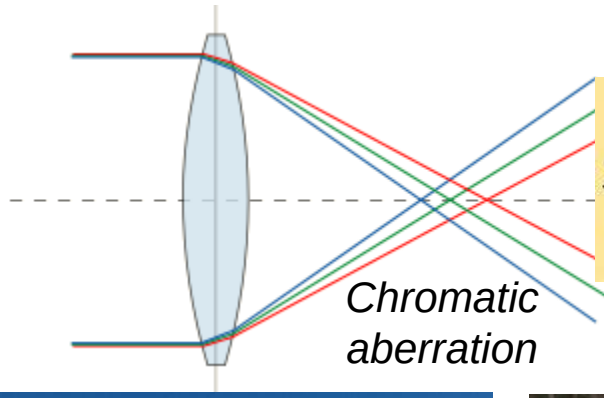
Four Speculative Populations of GNs



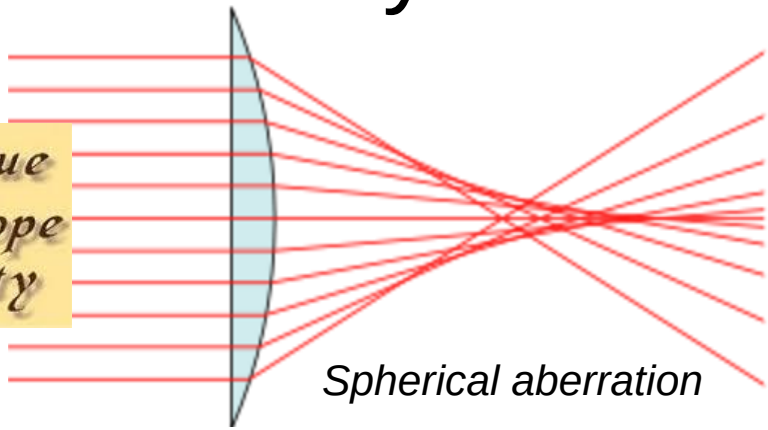
The different populations are the result both of evolving technology, e.g achromatic lenses, and of improved understanding of the definition of a group (blue curve). The diurnal variation (reddish curves) of the East component of the geomagnetic field relies primarily on measurements of an angle [the Declination] and as such does not require calibration and thus does not evolve with time. We speculatively identify four populations as shown above. Note the different sizes of cycle 11 in pop. III and IV.

Because of the evolving populations, the backbones themselves [no matter how constructed] must be normalized to a common standard [Wolfer's].

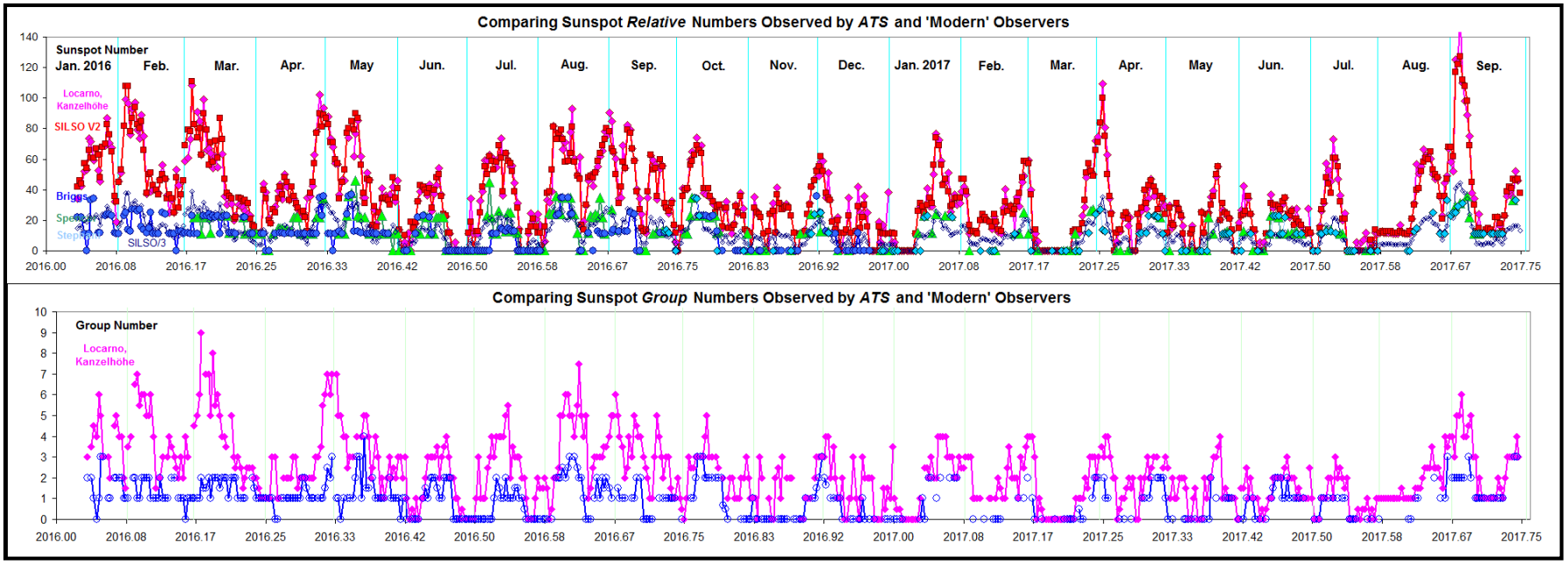
Construct Telescopes with the Same Flaws as Typical 18th Century Ones

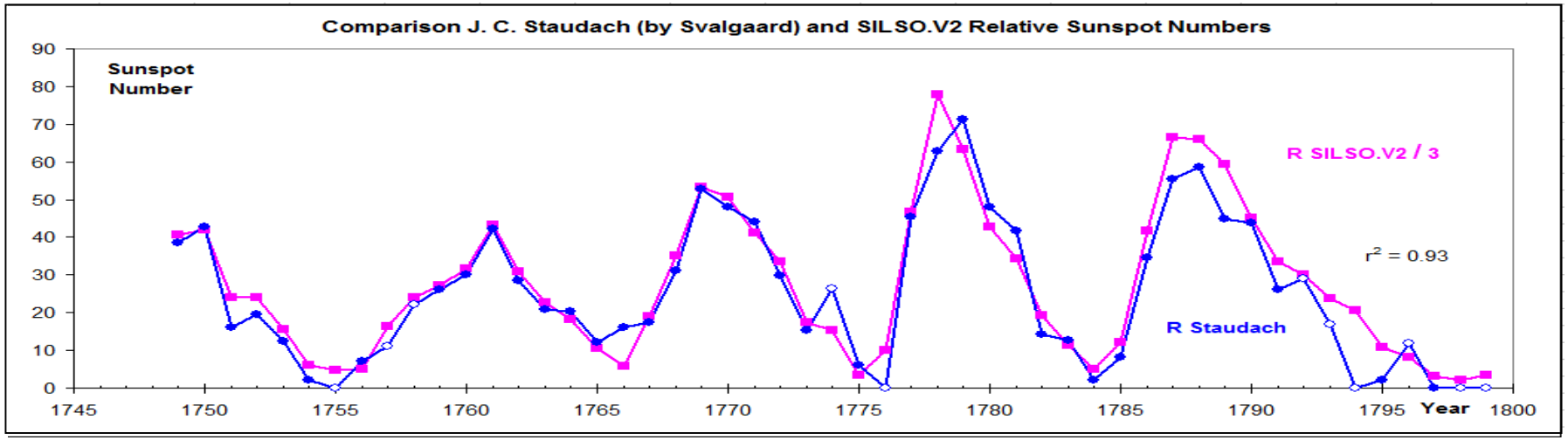


the Antique Telescope Society



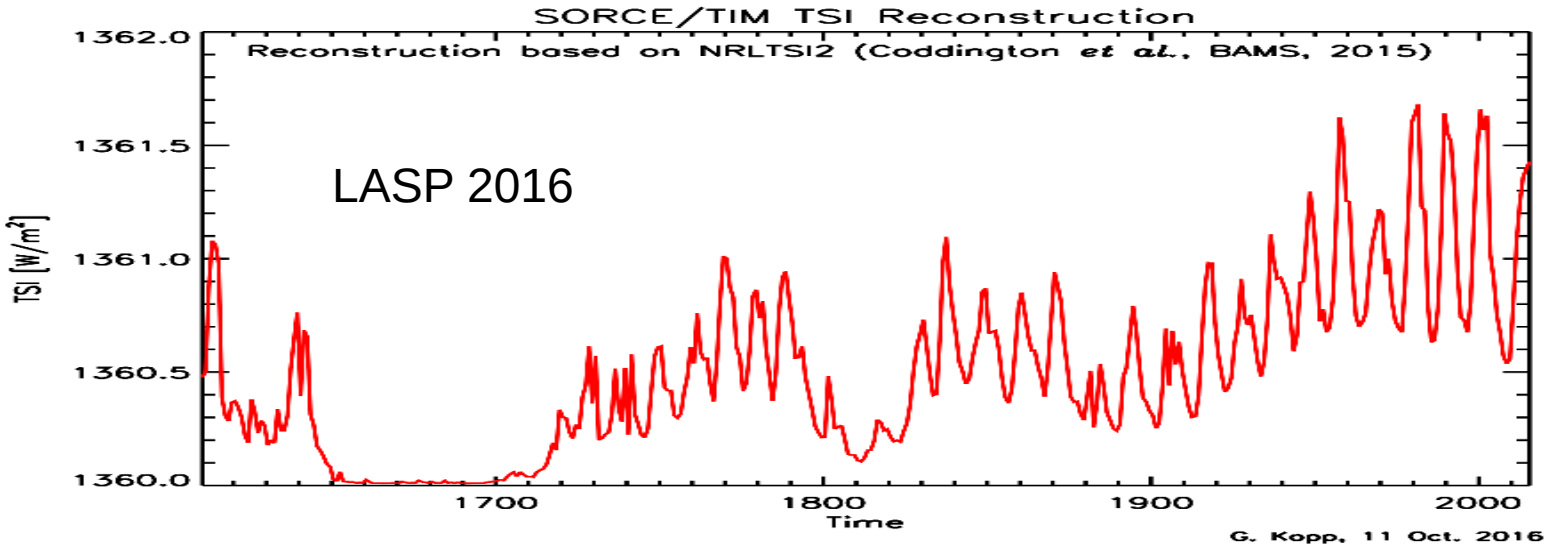
Modern Observers See (*Two*)Three Times as Many (*Groups*)Spots as The Old Telescopes Show

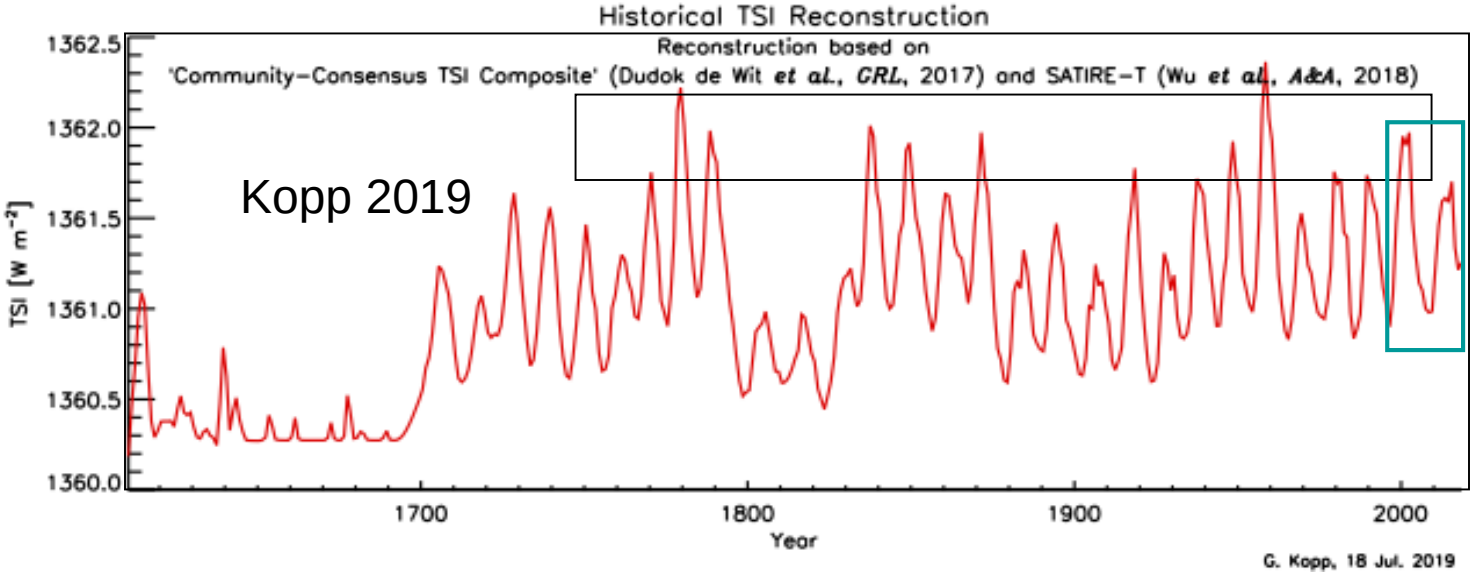




What a Difference a Corrected Solar Activity Record Makes

The Total Solar Irradiance [TSI] record is important for the terrestrial climate variation





Still some issues…

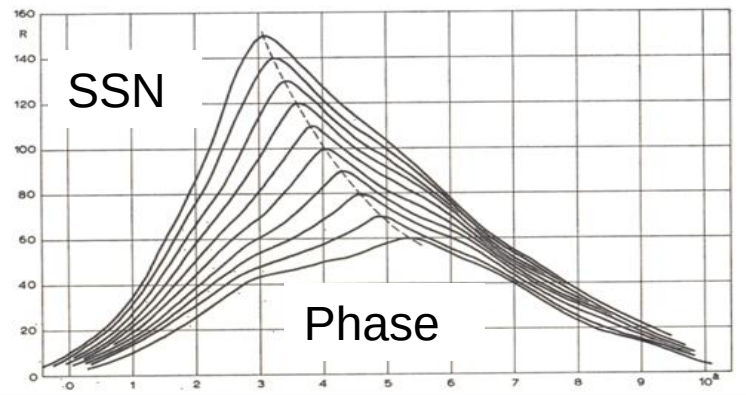
But we'll take whatever progress we can get…

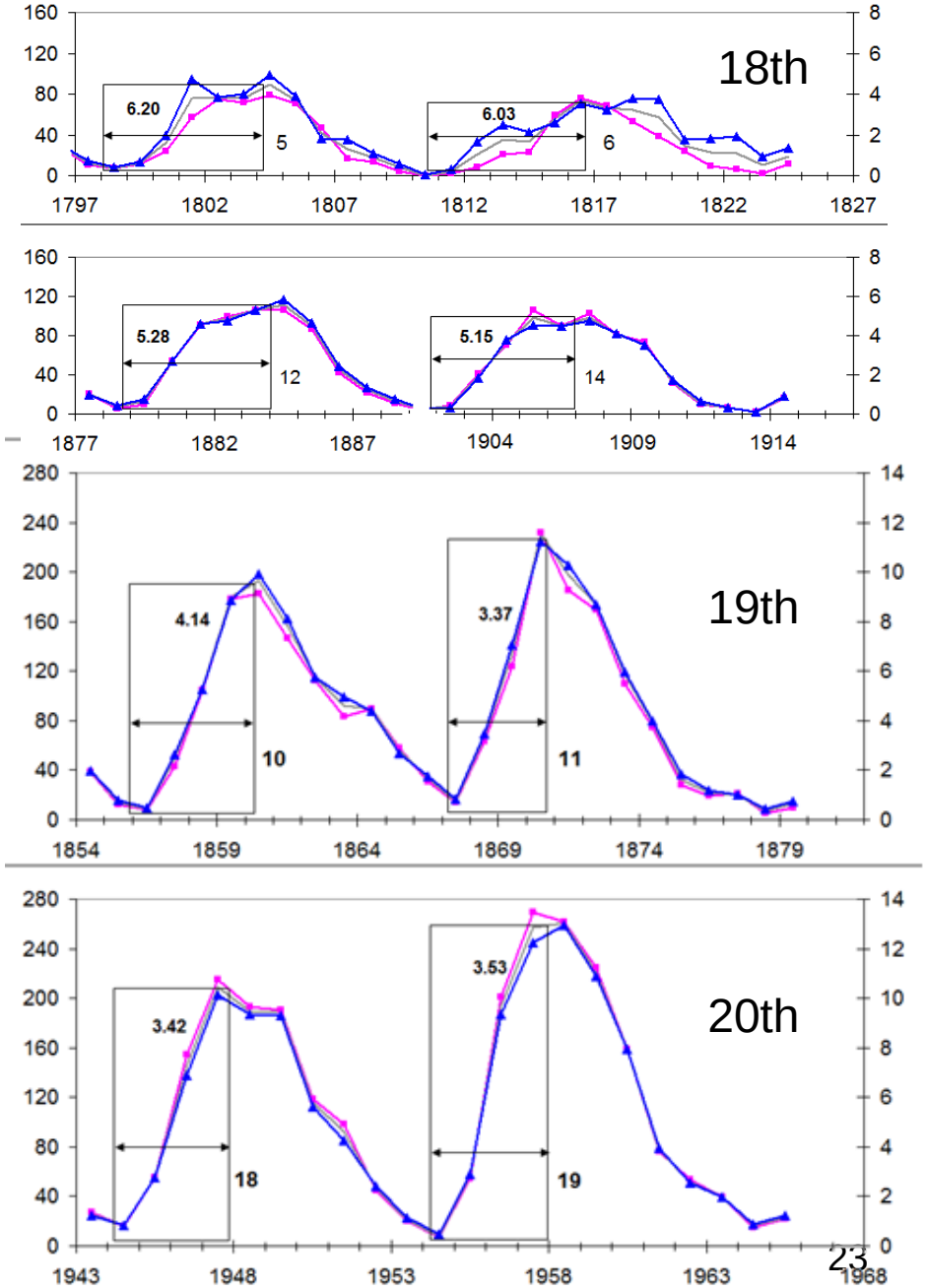
Conclusions

- From the fact that all reconstructions agree for the 20th century one must conclude that the different methods basically work and that therefore it is not productive to argue which is 'better' or which has severe errors or uses 'unsound procedures'.
- The Revised Sunspot Number (v2) and the [scaled] Svalgaard & Schatten (2016) Group Numbers agree well and vary as several solar-activity proxies do for at least the last 300 years,
- supporting the New Paradigm that there are at **least** two different 'populations' of observed Group Numbers [with a dividing year in the 1880s]. Not taking this into account produces ≈40% artificially lower numbers for most of the 19th century and beyond.
- So, it is time to embrace and to use the revised sunspot number [and group number] record instead of clinging to the old H&S reconstruction.

Extra Slides

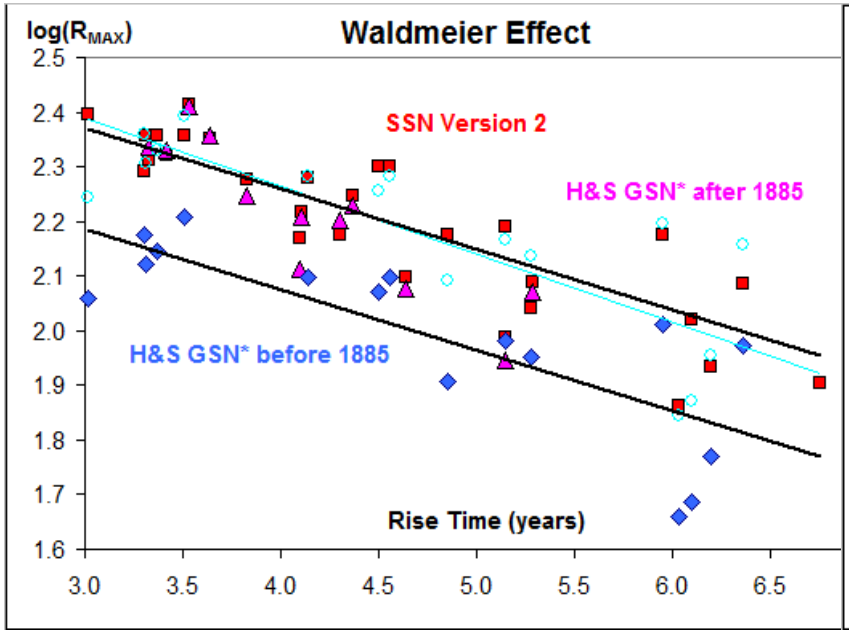
The Waldmeier Effect

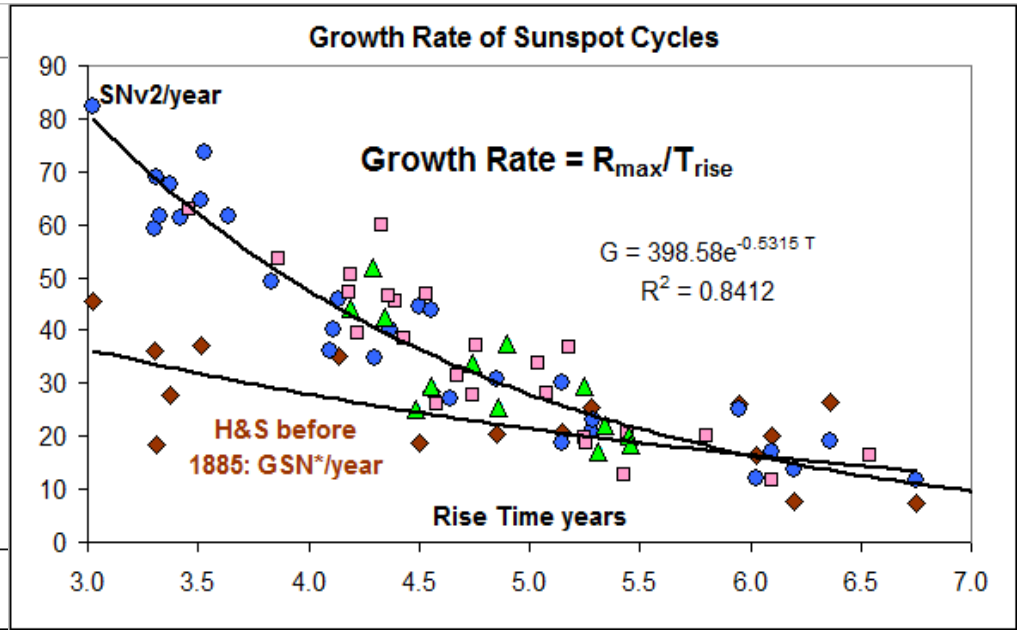


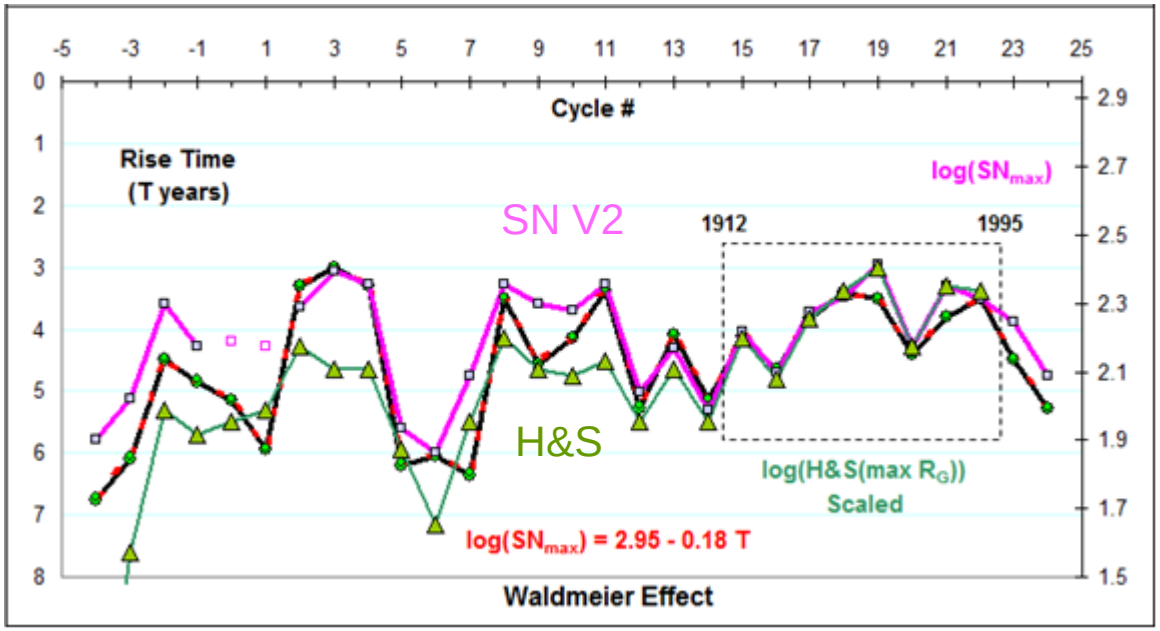


There is a relationship between the rise time T (in years) from minimum to maximum and the maximum smoothed monthly sunspot number. The times of the extrema can be determined without knowledge of the reduction (or scale) factors. "**Since this relationship also holds for the years from 1750 to 1848 we can be assured that the scale value of the relative sunspot number over the last more than 200 years has stayed constant** or has only been subject to insignificant variations". Waldmeier (1978).

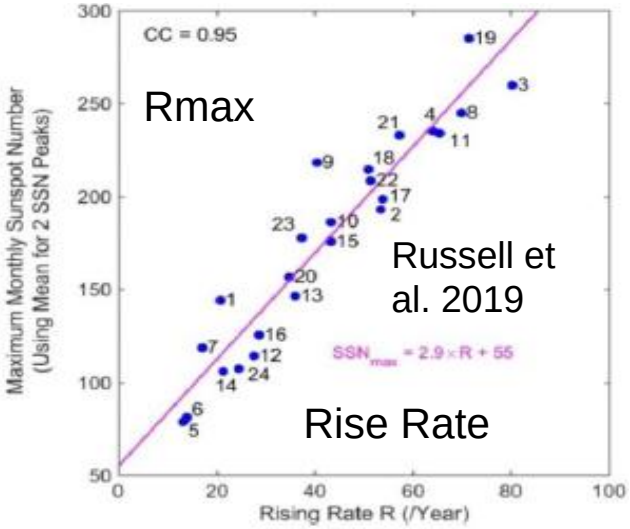
Later cycles have confirmed that the scale has stayed constant more than 250 years







More Waldmeier Effect



The H&S GSN fits the Waldmeier Effect after ≈1885, but not before (is too low).

Abstract

Solar activity e.g. as measured by the number of active regions (sunspot groups) on the disk at any time varies on time scales ranging from solar rotation to centuries. Solar activity (telescopically observed for four centuries) manifests itself both by variations of wave radiation (e.g., EUV flux and TSI) and of particle emission (e.g., solar wind and energetic particles). These variations influence the Earth's environment (e.g., the ionosphere and the Van Allen Belts) with consequences that are observable on the ground as variations in the geomagnetic field. Two centuries of systematic (and an additional earlier century of more sporadic) observations serve as direct measurements of solar activity influence and can reliably be employed to reconstruct said activity for centuries past. These reconstructions validate the recent revisions of the (difficult to calibrate) telescopic observations (the Sunspot and the Group Numbers) that show no significant long-term trend over the past three hundred years. This is particularly important for historical reconstructions of total solar irradiance, such as the recently released Climate Data Record which shows a trend not compatible with the neither the geomagnetic record nor with the revised sunspot records.