How Well Do We Know the Sunspot Number?

[And what we are doing to answer that question]

Leif Svalgaard
HEPL, Stanford University

Poster at ‘Solar in Sonoma (Petaluma)’, 30 Nov. 2012

http://www.leif.org/research/

The Sunspot Number(s) K-factors

Rudolf Wolf (1816-1893)
Observed 1849-1893

- Wolf Number = K_W (10*G + S)
- G = number of groups
- S = number of spots

- Group Number = 12 K_G G

Ken Schatten

Douglas Hoyt and Kenneth Schatten devised the *Group Sunspot Number* using just the group count (1993).

Unfortunately a K-factor was also necessary here, so the result really depends on how well the K-factor can be determined

Problems with the Sunspot Number(s)

- In the 1940s the observers in Zürich began to count larger spots more than once [weighting according to size], inflating the SSN by ~20% continuing until the present
- The Group Sunspot Number is about 50% too low prior to about 1885
- When the above problems are corrected there is no long-term trend over the past three hundred years, i.e. no Modern Grand Maximum

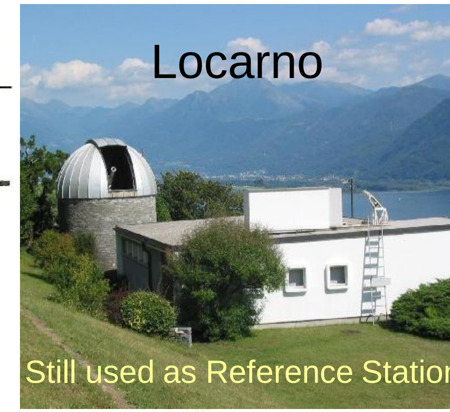
Waldmeier's Description of his [?] Sunspot Counting Method

Astronomische Mitteilungen der Eidgenössischen Sternwarte Zürich
Nr. 285

1968

Die Beziehung zwischen der Sonnenflecken-relativzahl und der Gruppenzahl

Von
M. Waldmeier

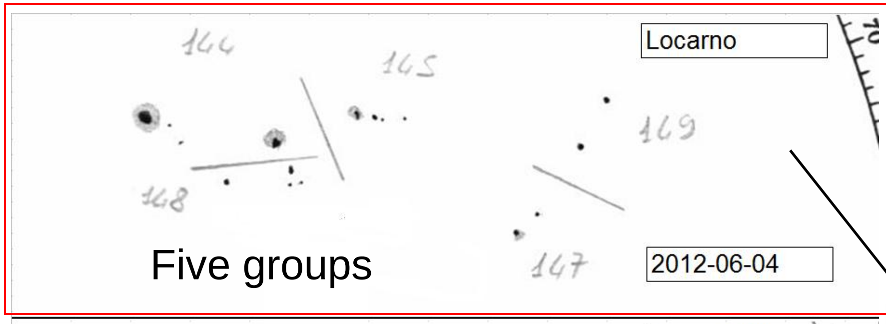


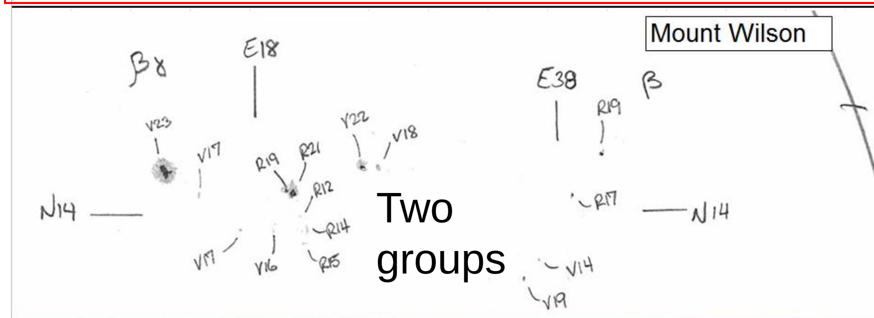
Später wurden den Flecken entsprechend ihrer Größe Gewichte erteilt: Ein punktförmiger Fleck wird einfach gezählt, ein größerer, jedoch nicht mit Penumbra versehener Fleck erhält das statistische Gewicht 2, ein kleiner Hoffleck 3, ein größerer 5.

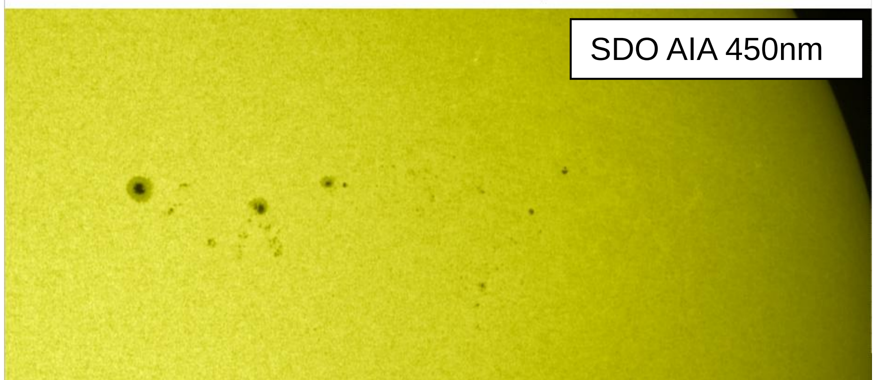
"A spot like a fine point is counted as one spot; a larger spot, but still without penumbra, gets the statistical weight 2, a smallish spot with penumbra gets 3, and a larger one gets 5." Presumably there would be spots with weight 4, too.

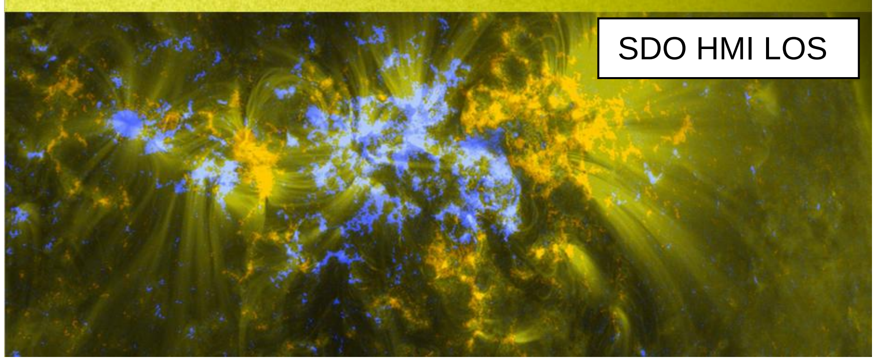
This very important piece of metadata was strongly downplayed and is not generally known

Combined Effect of Weighting and More Groups is an Inflation of the Relative Sunspot Number by 20+%









No Weight

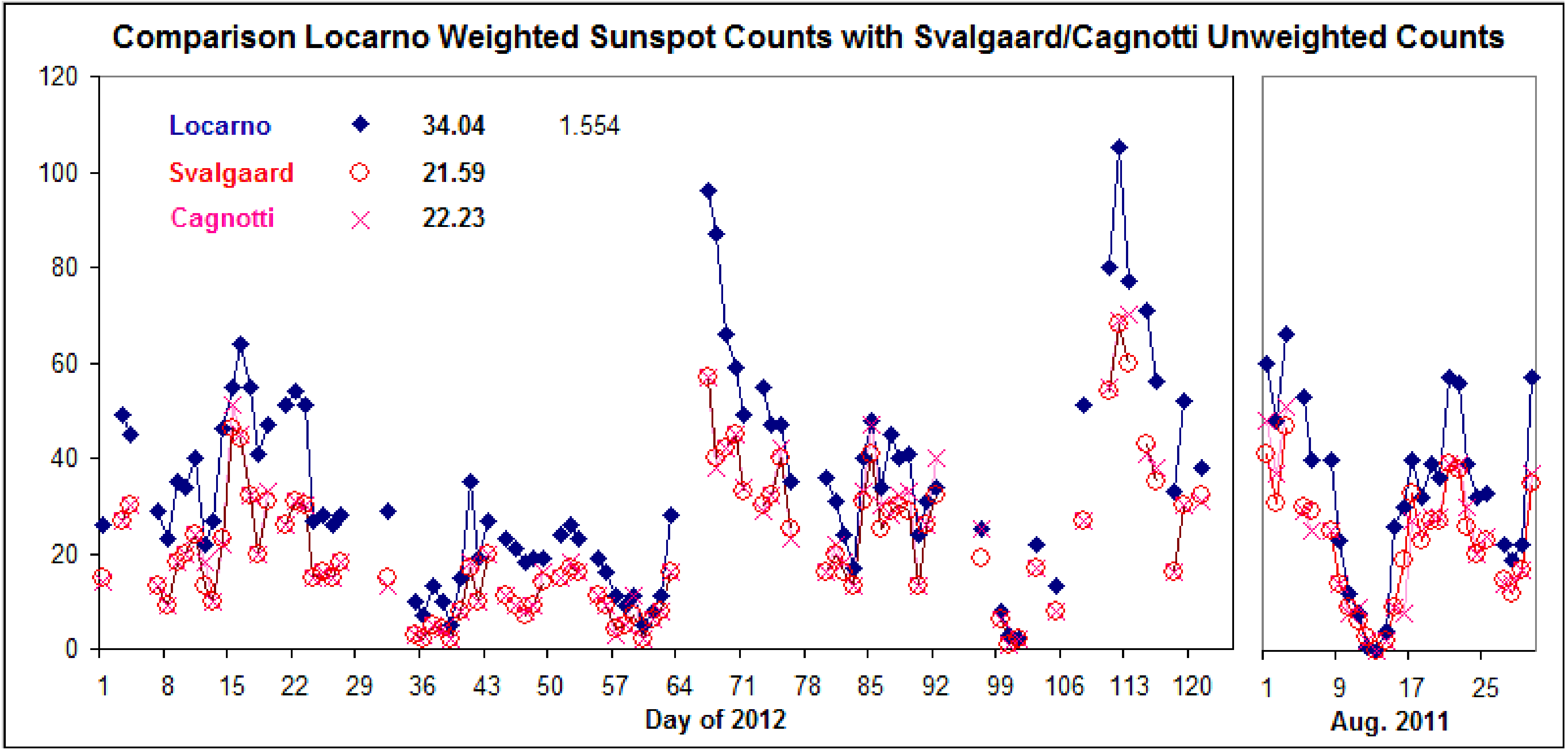
g	f		B
143	4	2	-16°
144	7	4	+15°
145	5	4	+15°
146	12	6	-21°
147	4	2	+8°
148	5	4	+11°
149	4	2	+15°
150	6	2	+10°
151	1	1	+11°
152	2	2	+6°
153	2	1	-18°
11	52	30	

Groups
'Weighted Spots'

I have re-counted 43,000 spots without weighting for the last ten years of Locarno observations.

http://www.leif.org/EOS/Kopecky-1980.pdf specifically notes that "according to [observer] Zelenka (1979a), the introduction of the Zürich group classification with regard to their morphological evolution by Waldmeier and Brunner, has led to increased estimates of number of groups in comparison with Wolfer's estimates". Wolfer was assistant to Wolf and later his successor.

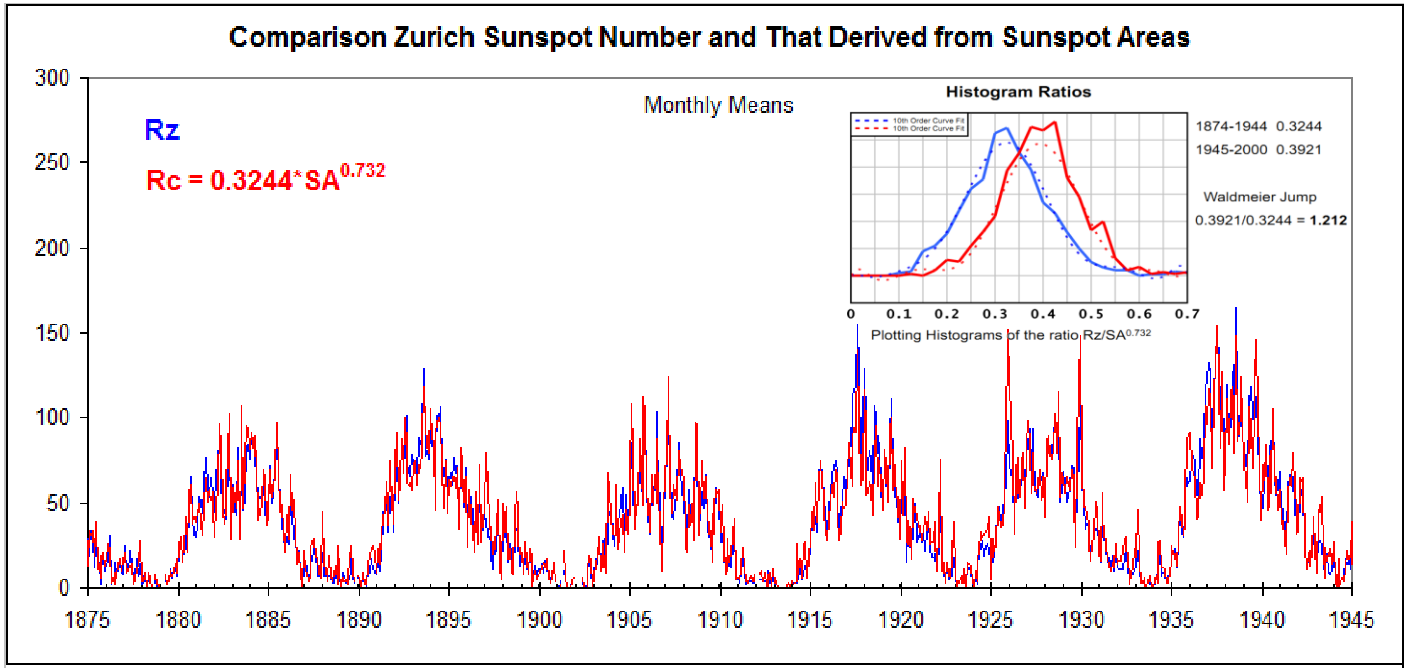
Double-Blind Test of My Re-Count

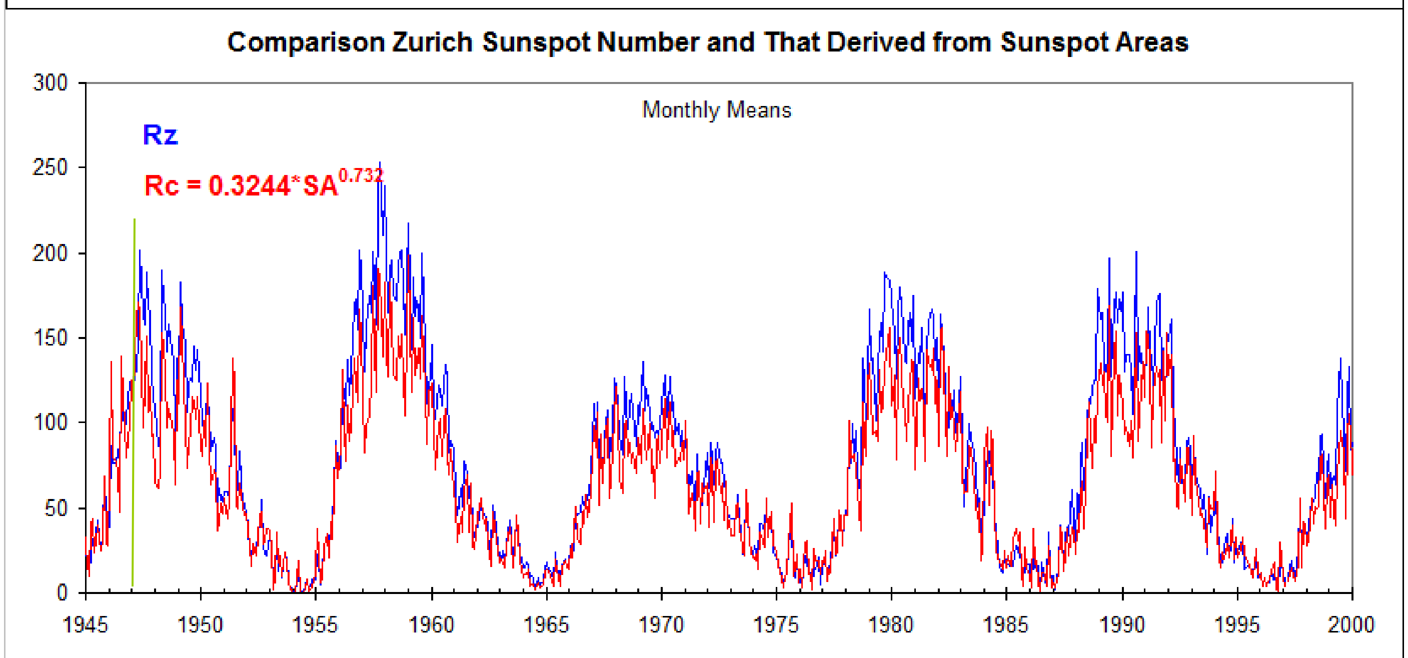


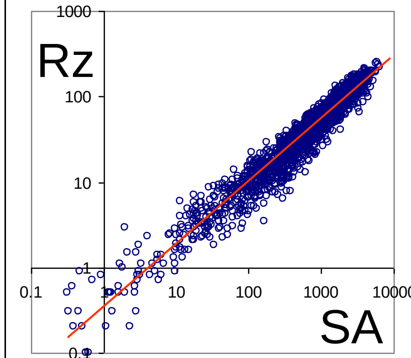
I proposed to the Locarno observers that they should also supply a raw count without weighting

For typical number of spots the weighting increases the ‘count’ of the spots by 30-50% (44% on average)

Compared with Sunspot Area (obs)

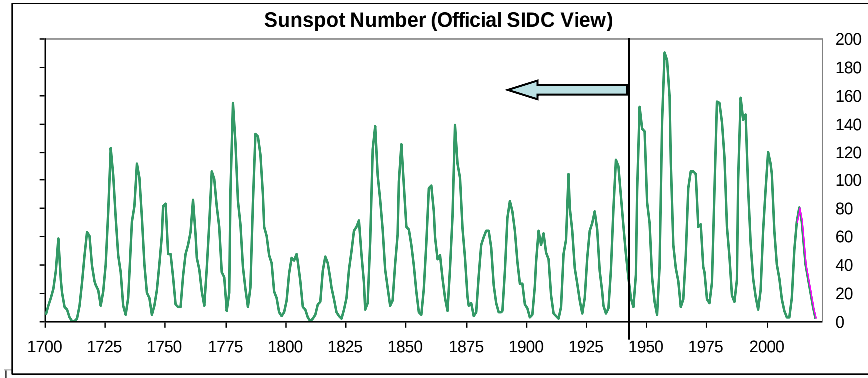


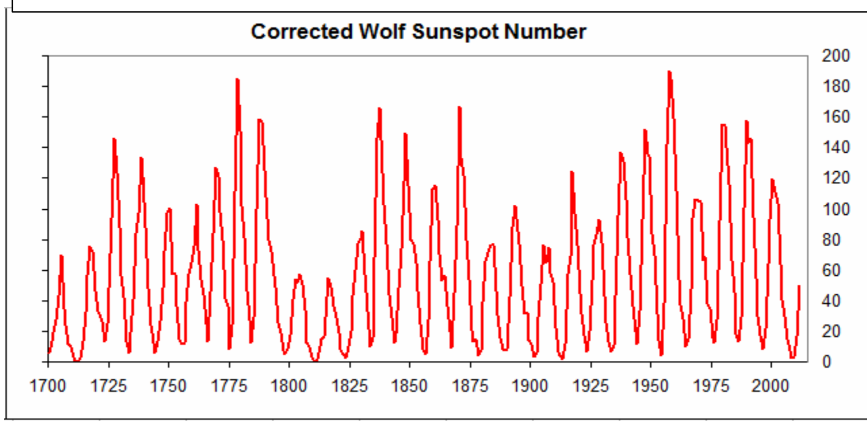


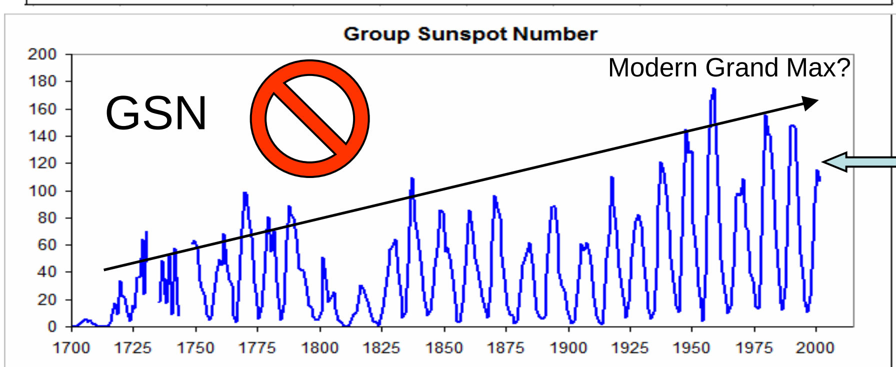


Not linear relation, but a nice power law with slope 0.732. Use relation for pre-1945 to compute Rz from Area, and note that the reported Rz after 1945 is too high [by 21%]

Correcting for the 20% Inflation







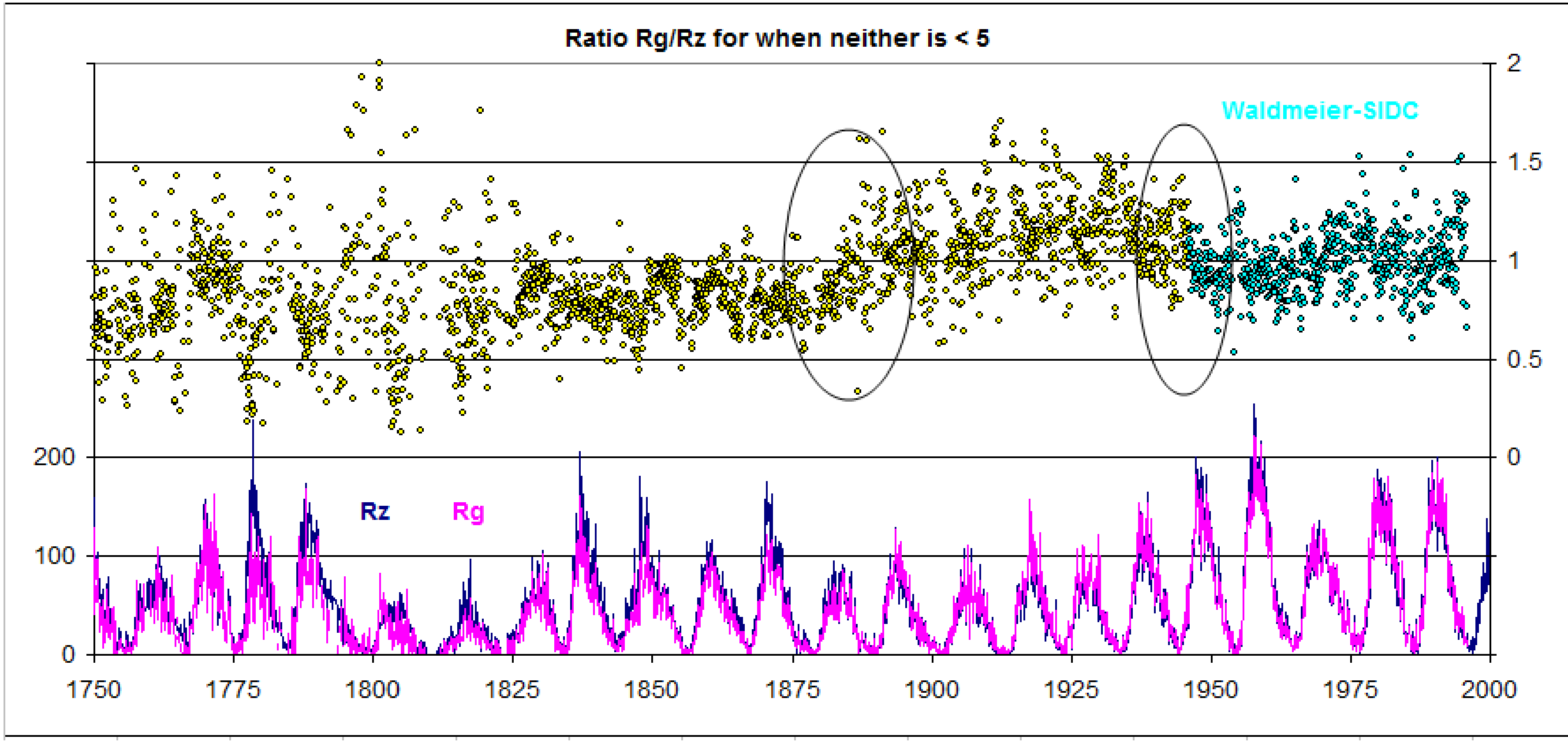
R*corr* = R*official* * 1.2 before ~1947

This issue is so important that the agencies producing sunspot number series have instituted a series of now ongoing Workshops to, if at all possible, converge to an agreed upon, common, corrected series: http://ssnworkshop.wikia.com/wiki/Home

The inflation due to weighting is now an established fact

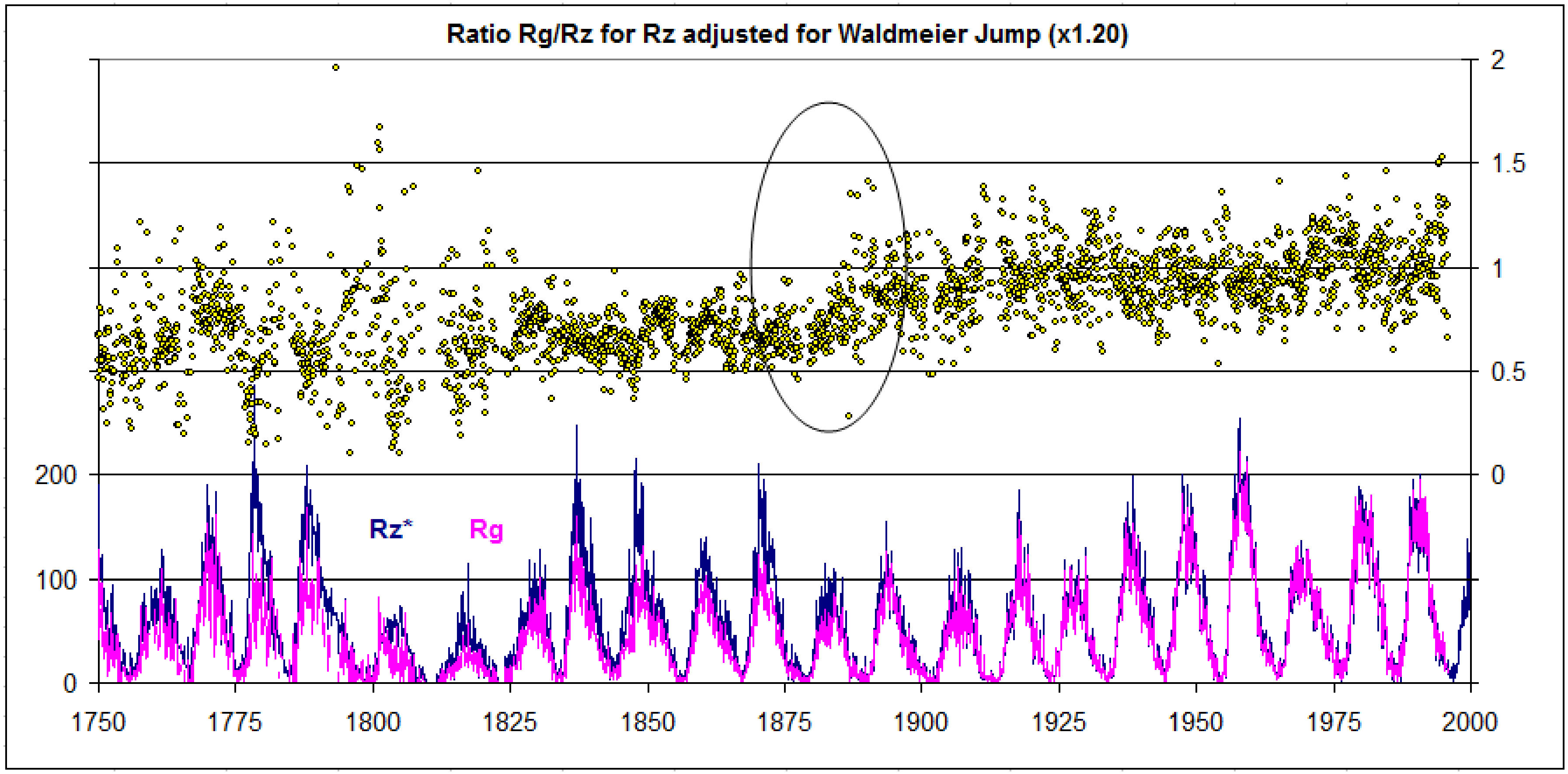
That the corrected sunspot number is so very different from the Group Sunspot Number is a problem for assessing past solar activity and for predicting future activity. This problem must be resolved.

The Ratio Group/Zürich SSN has Two Significant Discontinuities



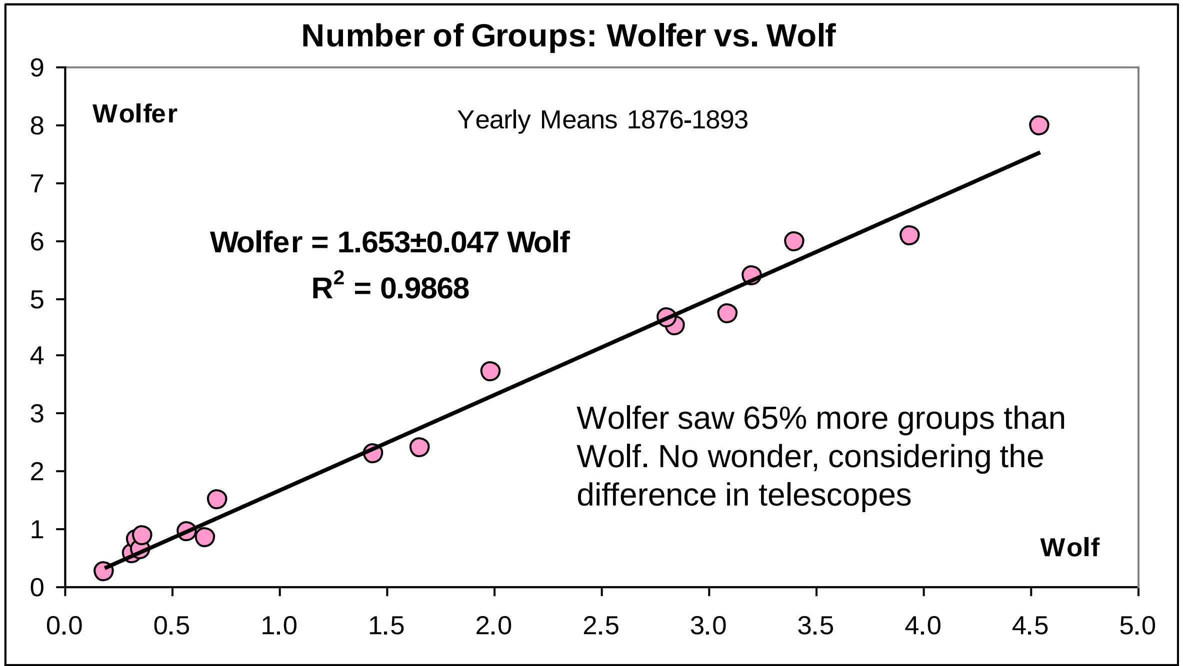
At ~1946 (After Max Waldmeier took over) and at ~1885

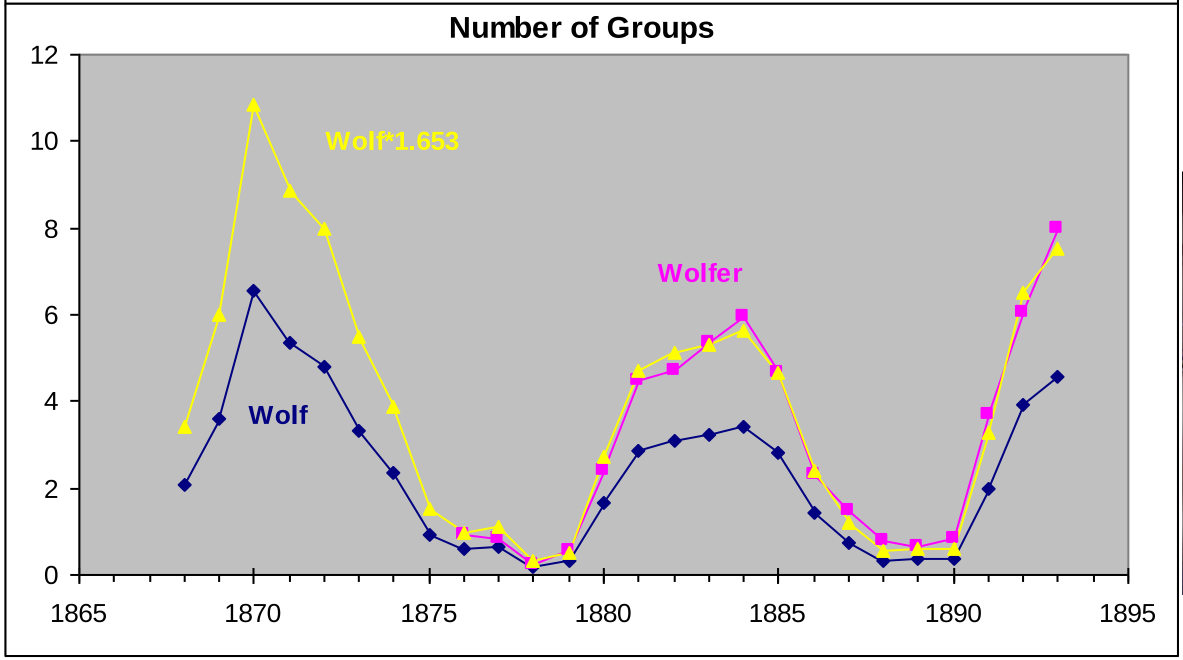
Removing the Recent one [+20%] by Multiplying Rz before 1946 by 1.20, Yields

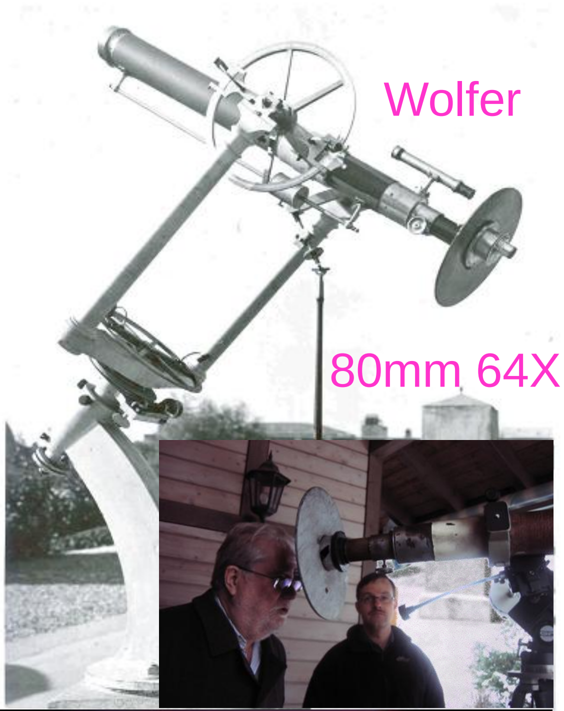


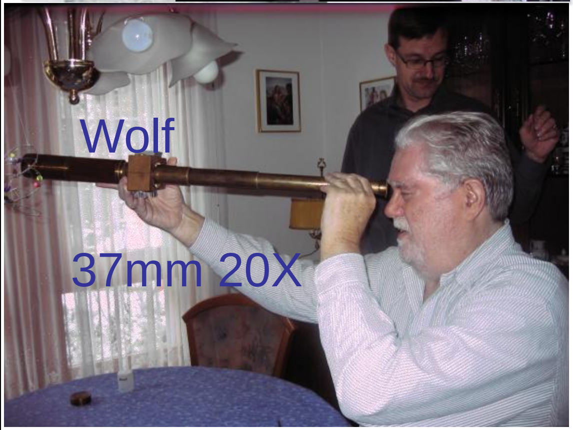
Leaving one significant discrepancy ~1885

K_G-factor for Wolf to Wolfer Groups









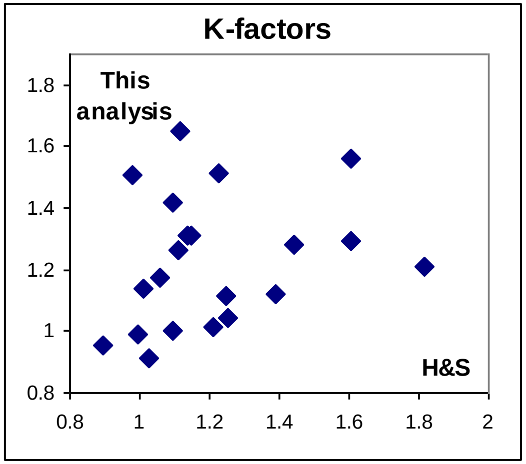
Why are these so different?

This is the main reason for the discrepancy

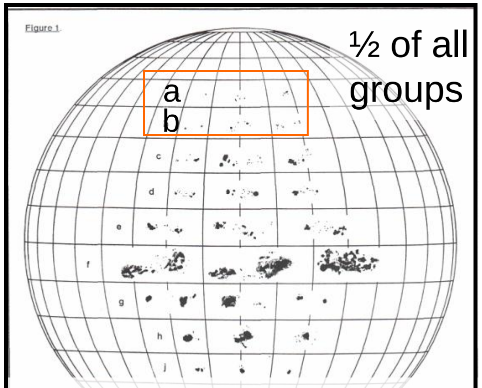
K-Factors

2% diff.

Observer	H&S RGO	to Wolfer	Begin	End
Wolfer, A., Zurich	1.094	1	1876	1928
Wolf, R., Zurich	1.117	1.6532	1876	1893
Schmidt, Athens	1.135	1.3129	1876	1883
Weber, Peckeloh	0.978	1.5103	1876	1883
Spoerer, G., Anclam	1.094	1.4163	1876	1893
Tacchini, Rome	1.059	1.1756	1876	1900
Moncalieri	1.227	1.5113	1876	1893
Leppig, Leipzig	1.111	1.2644	1876	1881
Bernaerts, G. L., England	1.027	0.9115	1876	1878
Dawson, W. M., Spiceland, Ind.	1.01	1.1405	1879	1890
Ricco, Palermo	0.896	0.9541	1880	1892
Winkler, Jena	1.148	1.3112	1882	1910
Merino, Madrid	0.997	0.9883	1883	1896
Konkoly, Ogylla	1.604	1.5608	1885	1905
Quimby, Philadelphia	1.44	1.2844	1889	1921
Catania	1.248	1.1132	1893	1918
Broger, M, Zurich	1.21	1.0163	1897	1928
Woinoff, Moscow	1.39	1.123	1898	1919
Guillaume, Lyon	1.251	1.042	1902	1925
Mt Holyoke College	1.603	1.2952	1907	1925

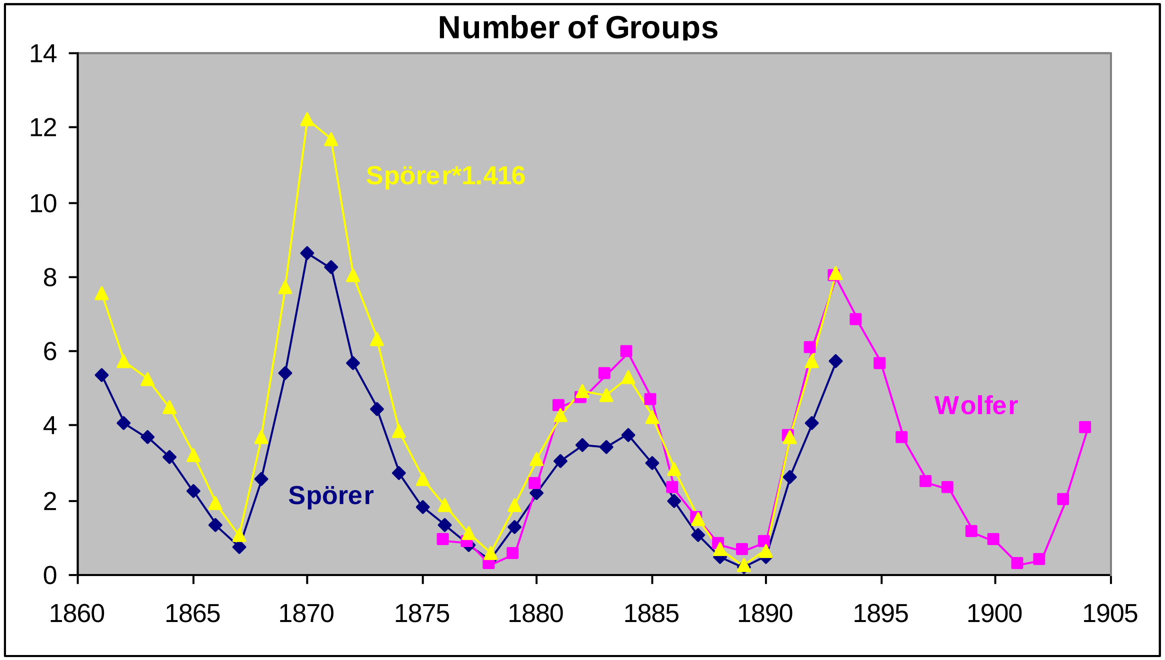


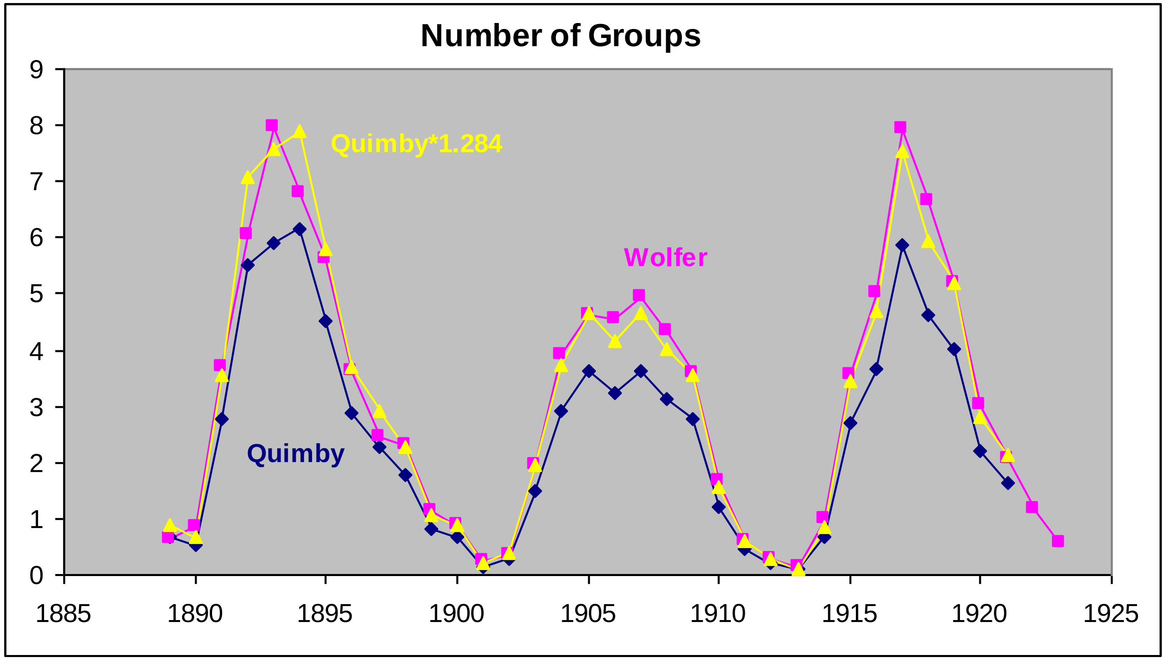
Zürich Classification:



Wolf couldn't see most a & b groups with his small telescope

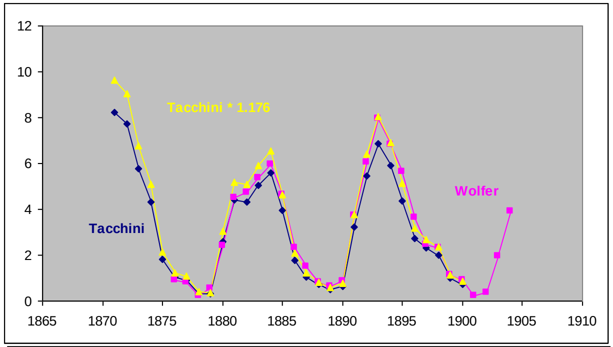
A still unresolved question is how Hoyt & Schatten got the *K*-factors so wrong

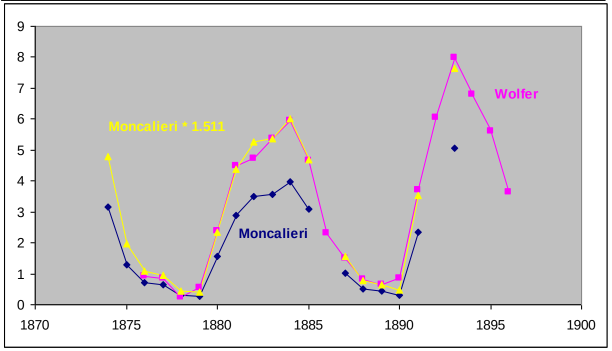




Comparing G. Spörer & Rev. A. Quimby [Philadelphia] to Wolfer

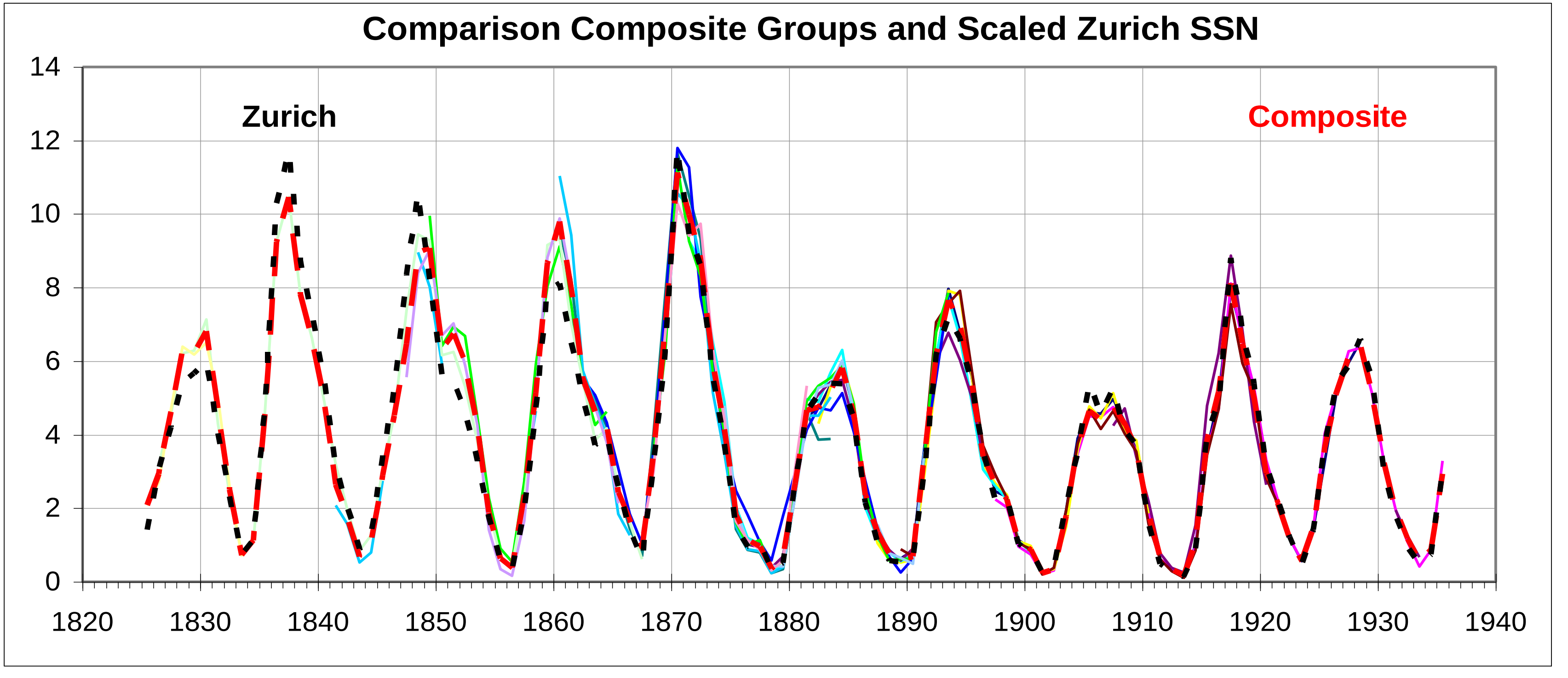
Same good and stable fit, showing that Wolfer's count had not drifted with time





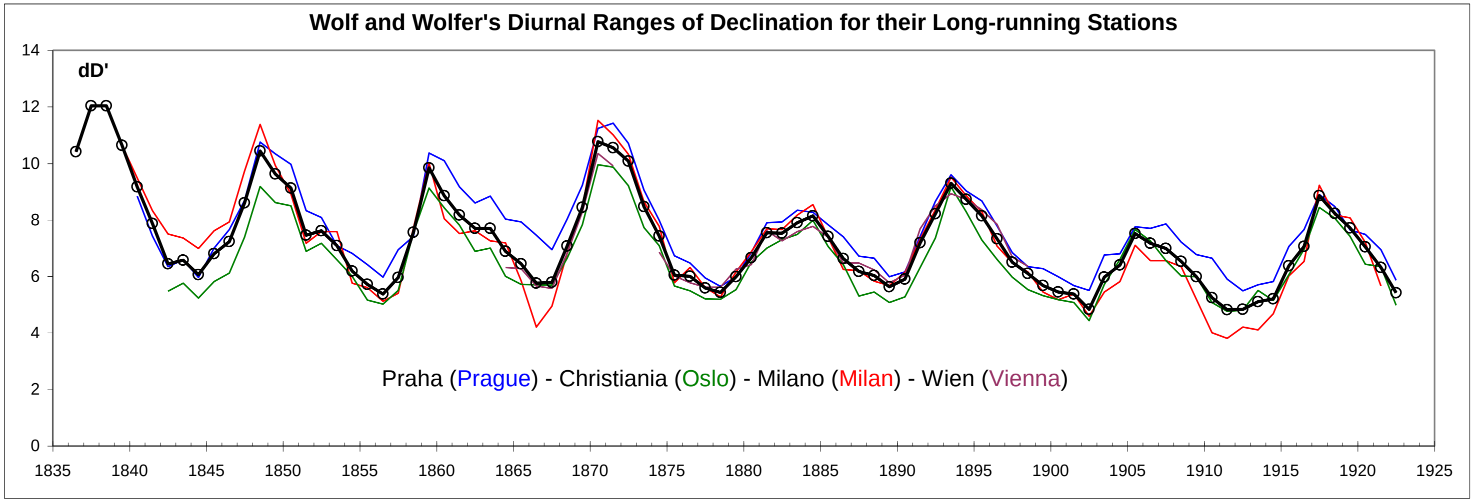
Constructing a Composite

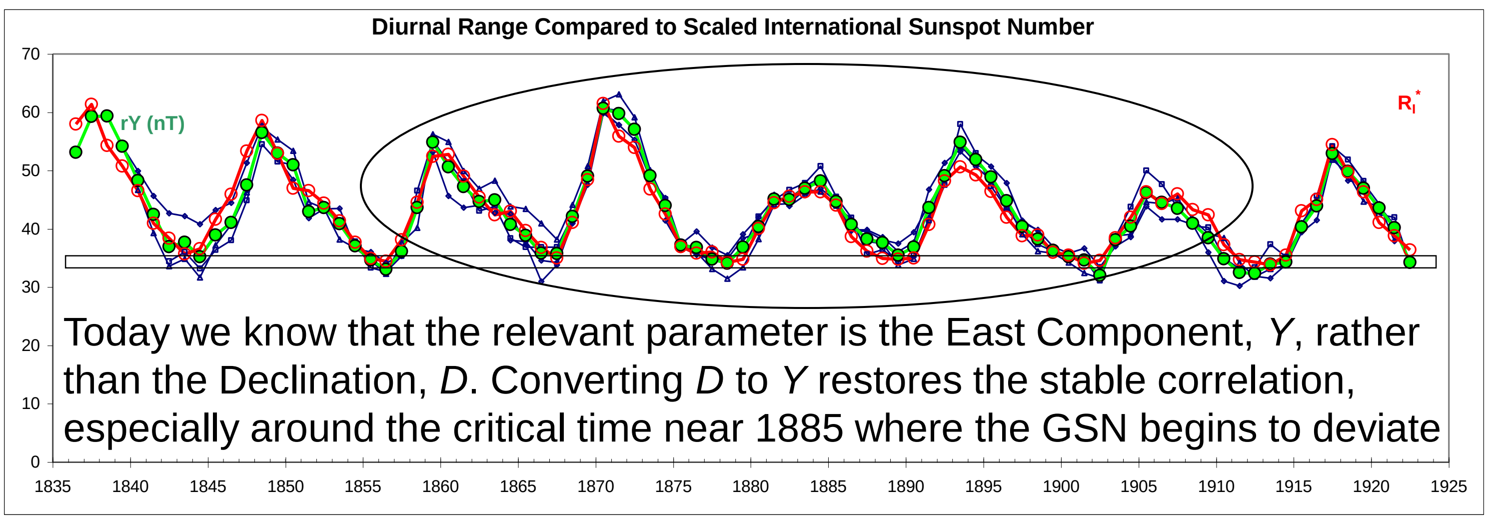
Comparing 22 observers that overlap with each other one can construct a composite group number successively back to Schwabe and up to Brunner:



There is now no systematic difference between the Zürich SSN and a Group SSN reconstructed here by using correct *K*-factors relative to Wolfer.

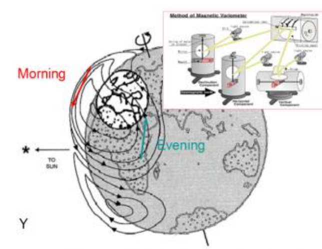
Wolf's Original Geomagnetic Data





Today we know that the relevant parameter is the East Component, *Y*, rather than the Declination, *D*. Converting *D* to *Y* restores the stable correlation, especially around the critical time near 1885 where the GSN begins to deviate

Wolf found a very strong correlation between his Wolf number and the daily range of the Declination.



A current system in the ionosphere [*E*-layer] is created by and maintained by solar FUV radiation. Its magnetic effect is measured on the ground. (Since 1722)

What to do about all this?

The implications of this re-assessment of the sunspot record are so wide-ranging that the SSN community has decided on a series of Workshops to solidify this.

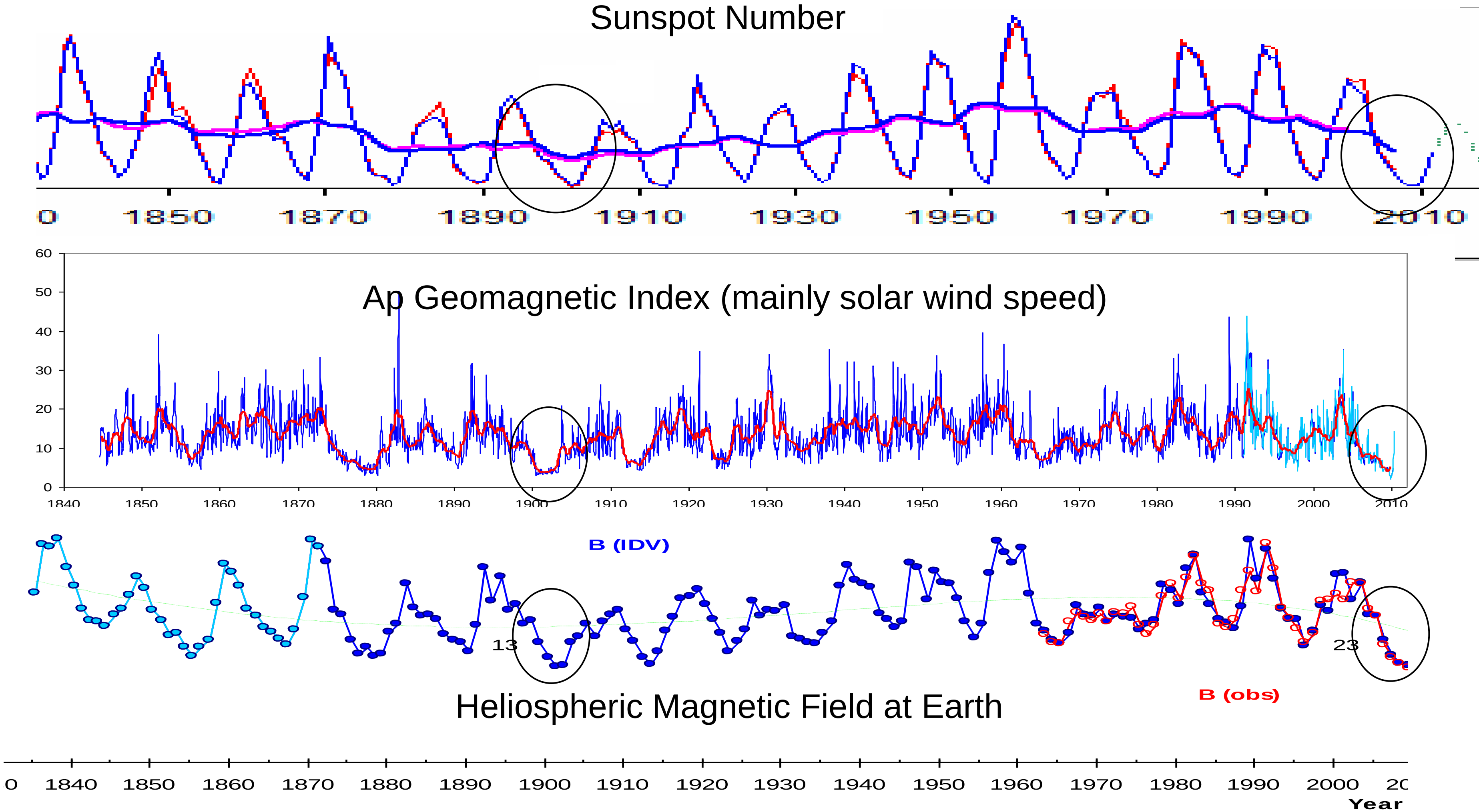
We have a Wiki giving details and presentations: http://ssnworkshop.wikia.com/wiki/Home

The goal is to arrive at a single, vetted series that we all agree on.

A proposal for funding of this work has been rejected by NASA [Nov. 2012].

The SSN workshops are sponsored by the National Solar Observatory (NSO), the Royal Observatory of Belgium (ROB), and the Air Force Research Laboratory (AFRL).

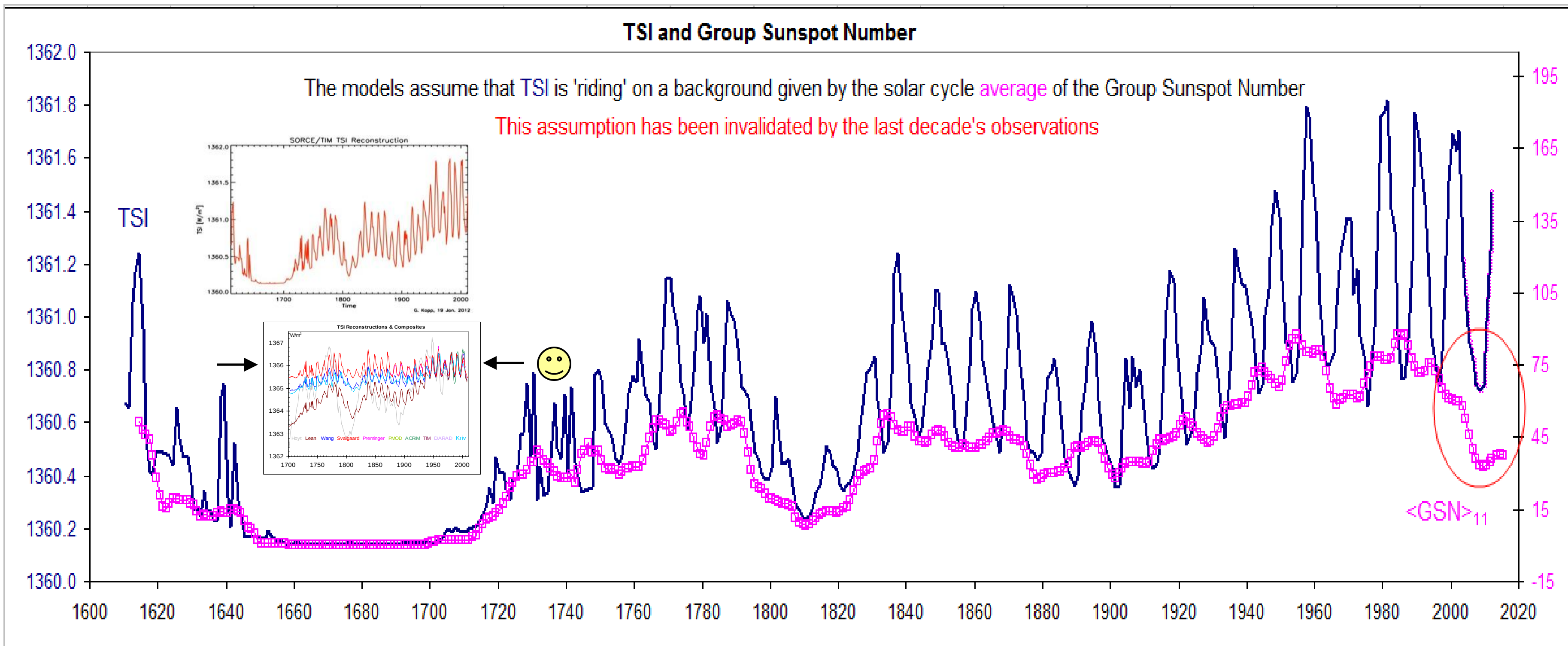
Solar Activity 1835-2011



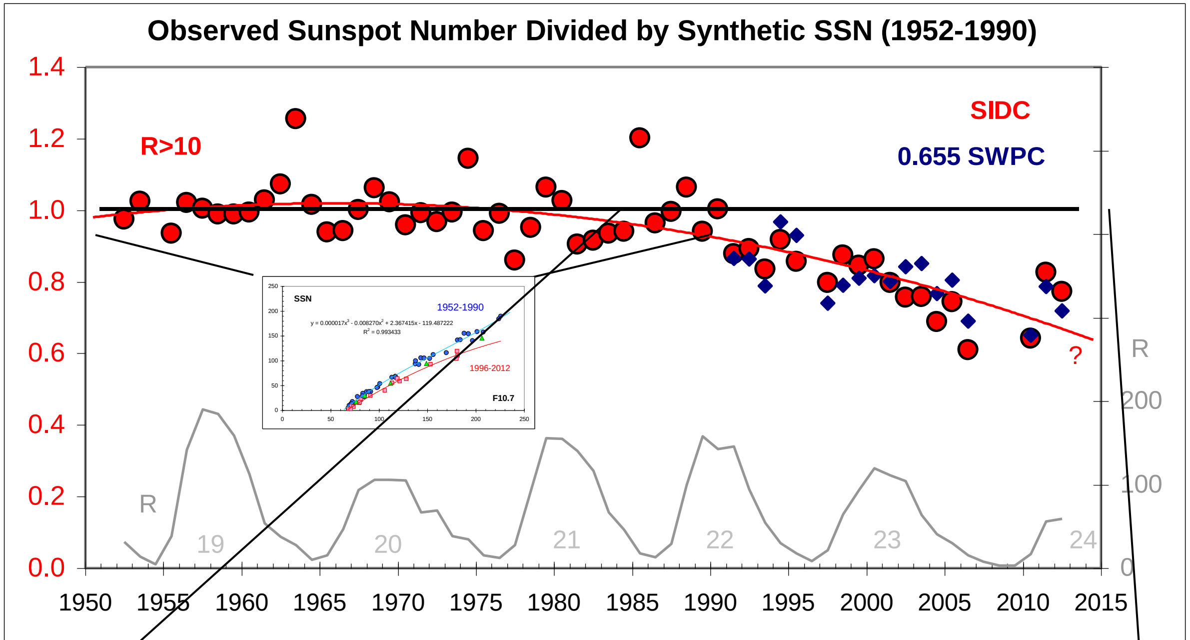
Activity now is similar to what it was a century ago

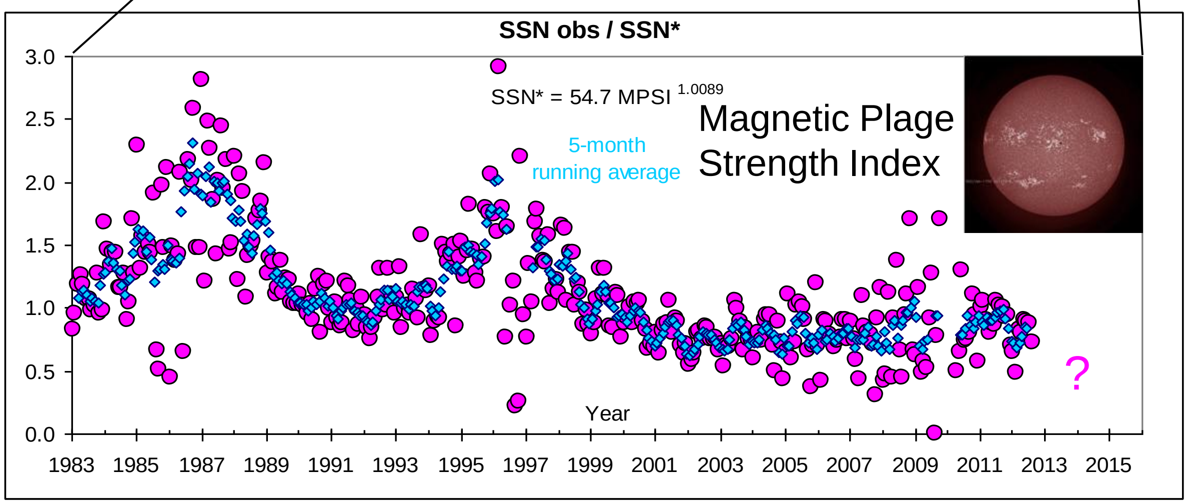
Removing the discrepancy between the Group Number and the Wolf Number removes the ‘background’ rise in reconstructed TSI

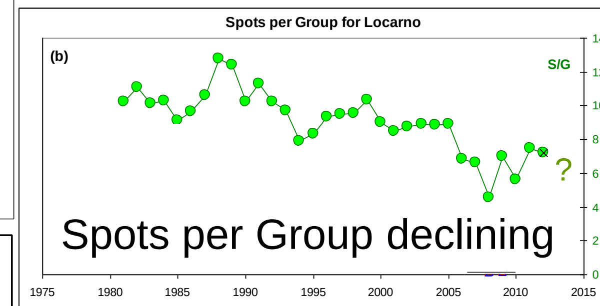
I expect a strong reaction against ‘fixing’ the GSN from people that ‘explain’ climate change as a secular rise of TSI and other related solar variables

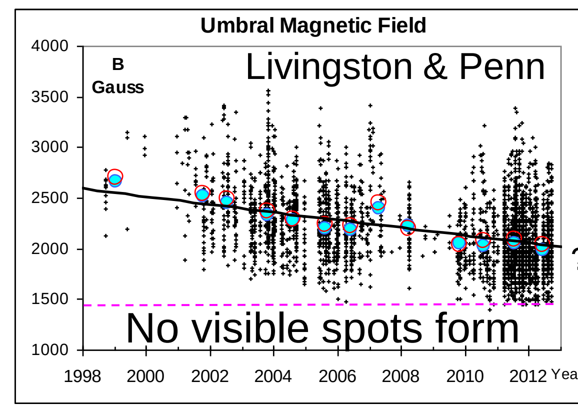


Something *is* happening with the Sun









We don't know what causes this, but sunspots are becoming more difficult to see or not forming as they used to. There is speculation that this may be what a Maunder-type minimum looks like: magnetic fields still present [cosmic rays still modulated], but just not forming spots. If so, exciting times are ahead.

Sun is perhaps entering a new very low activity Regime

- Fewer sunspots for given F10.7 flux
- Fewer sunspots for given Magnetic Plage Index
- Fewer spots per group
- Fewer small spots
- Less magnetic field per spot
- These changes have been progressive and accelerating since ~1990
- If continuing => possible Maunder Minimum

Abstract

A hundred years after Rudolf Wolf's death, Hoyt et al. (1994) asked "Do we have the correct reconstruction of solar activity?" After a heroic effort to find and tabulate many more early sunspot reports than were available to Wolf, Hoyt et al. thought to answer that question in the negative and to provide a revised measure of solar activity, the Group Sunspot Number (GSN) based solely on the number of sunspot groups, normalized by a factor of 12 to match the Wolf numbers 1874-1991. Implicit in that normalization is the assumption or stipulation that the Wolf number is correct over that period. In this talk we shall show that that assumption is likely false and that the Wolf number (WSN) must be corrected. With this correction, the difference between the GSN and WSN becomes even more disturbing: The GSN shows either a plateau until the 1940s followed by a Modern Grand Maximum [MGM], or alternatively a steady rise over the past three hundred years, while the (corrected) WSN shows no significant secular trend and no MGM. As the sunspot number is often used as the basic input to models of the future evolution of the Earth's environment and of the climate, having the correct reconstruction becomes of utmost importance, and the difference between GSN and WSN becomes unacceptable. By re-visiting the construction of the GSN we show how the GSN can be reconciled with the WSN, resolving the issue. We finally report on recent discrepancies between various indices of solar activity which raise the issue of the very meaning of the sunspot number and of the future evolution [and predictability] of solar activity. This work is in support of the Sunspot Number Workshops: http://ssnworkshop.wikia.com/wiki/Home