What is Wrong with the Group Sunspot Number and How to Fix it

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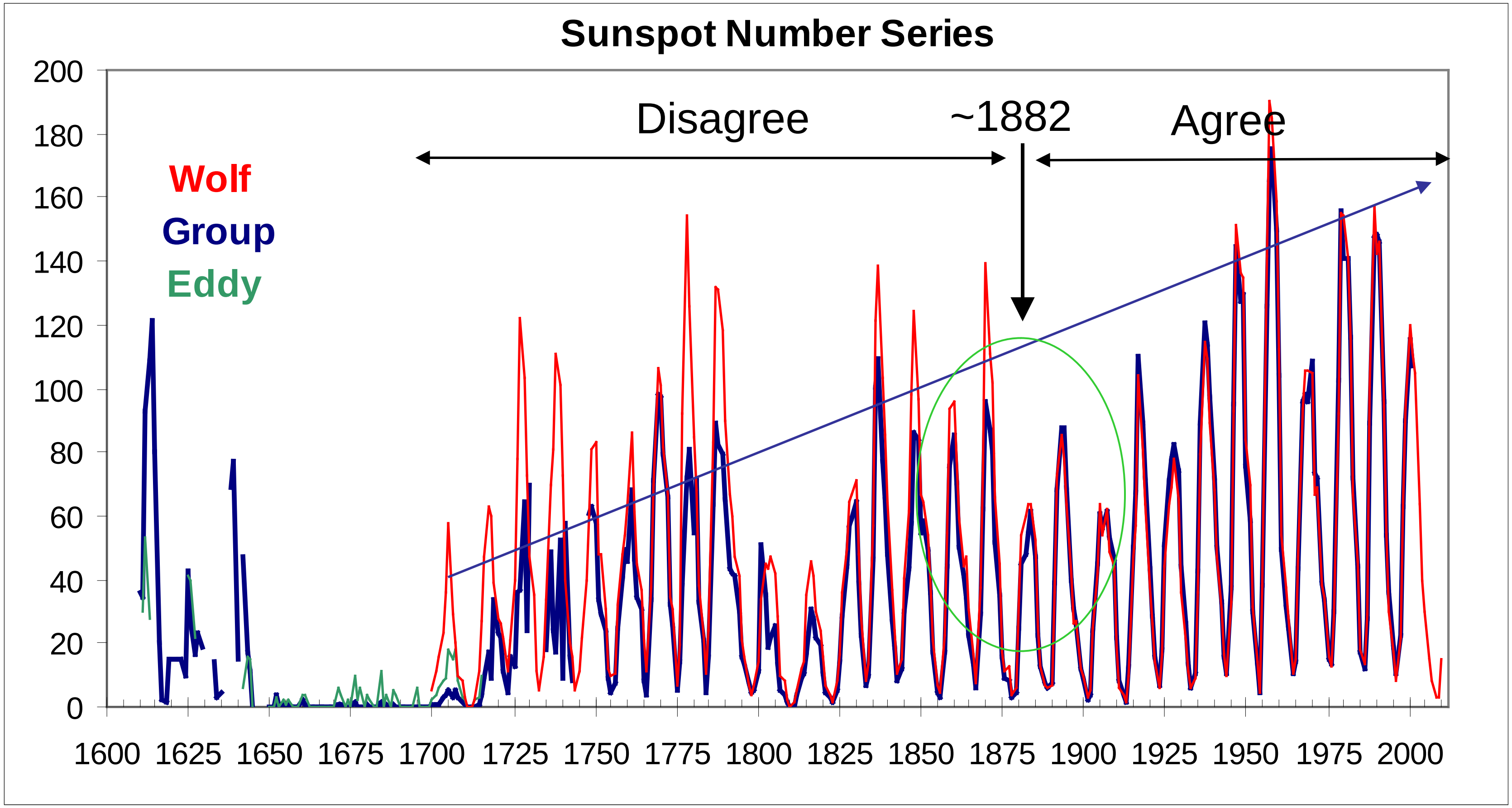
(with help from many people)

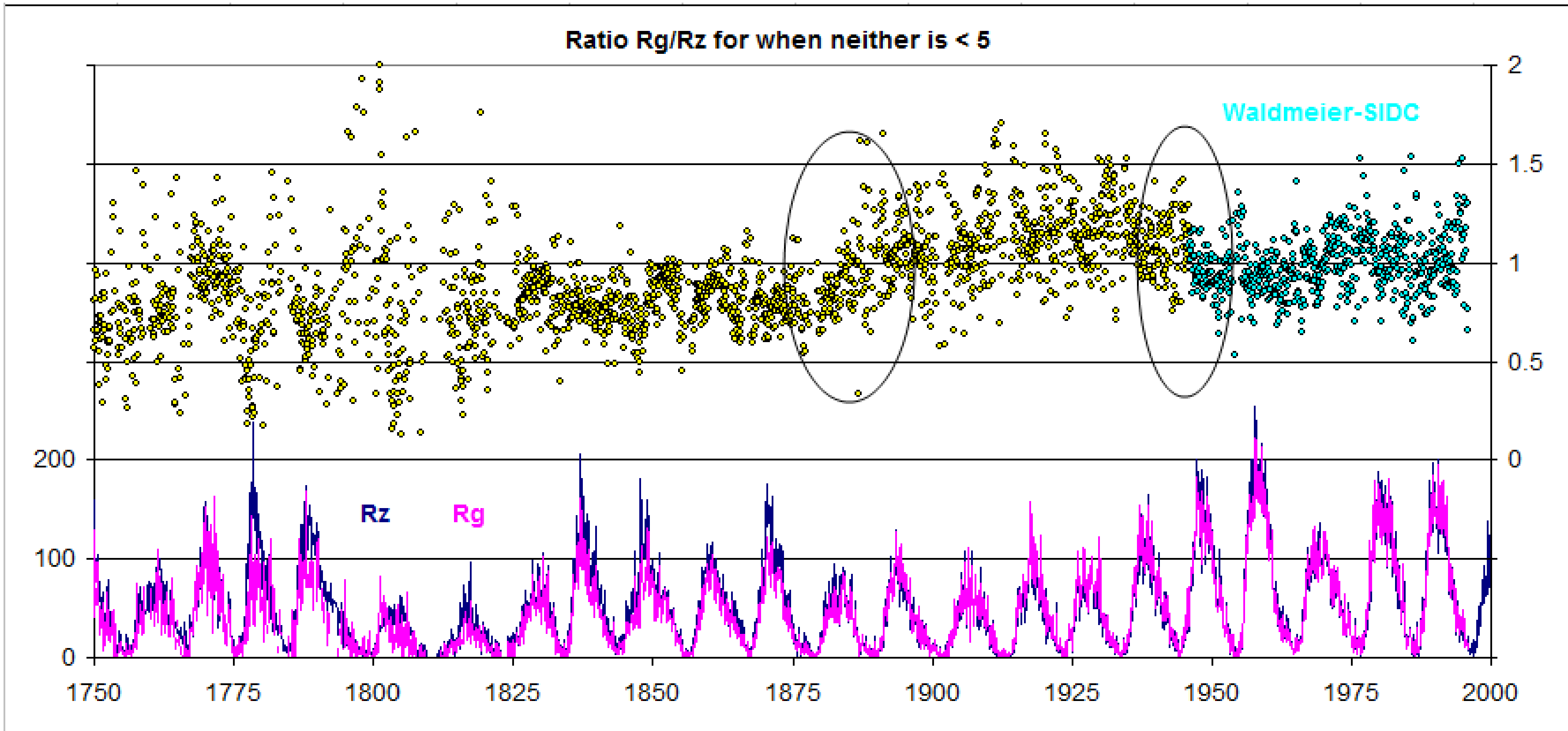
2 March, 2012

The Problem: Two Sunspot Series

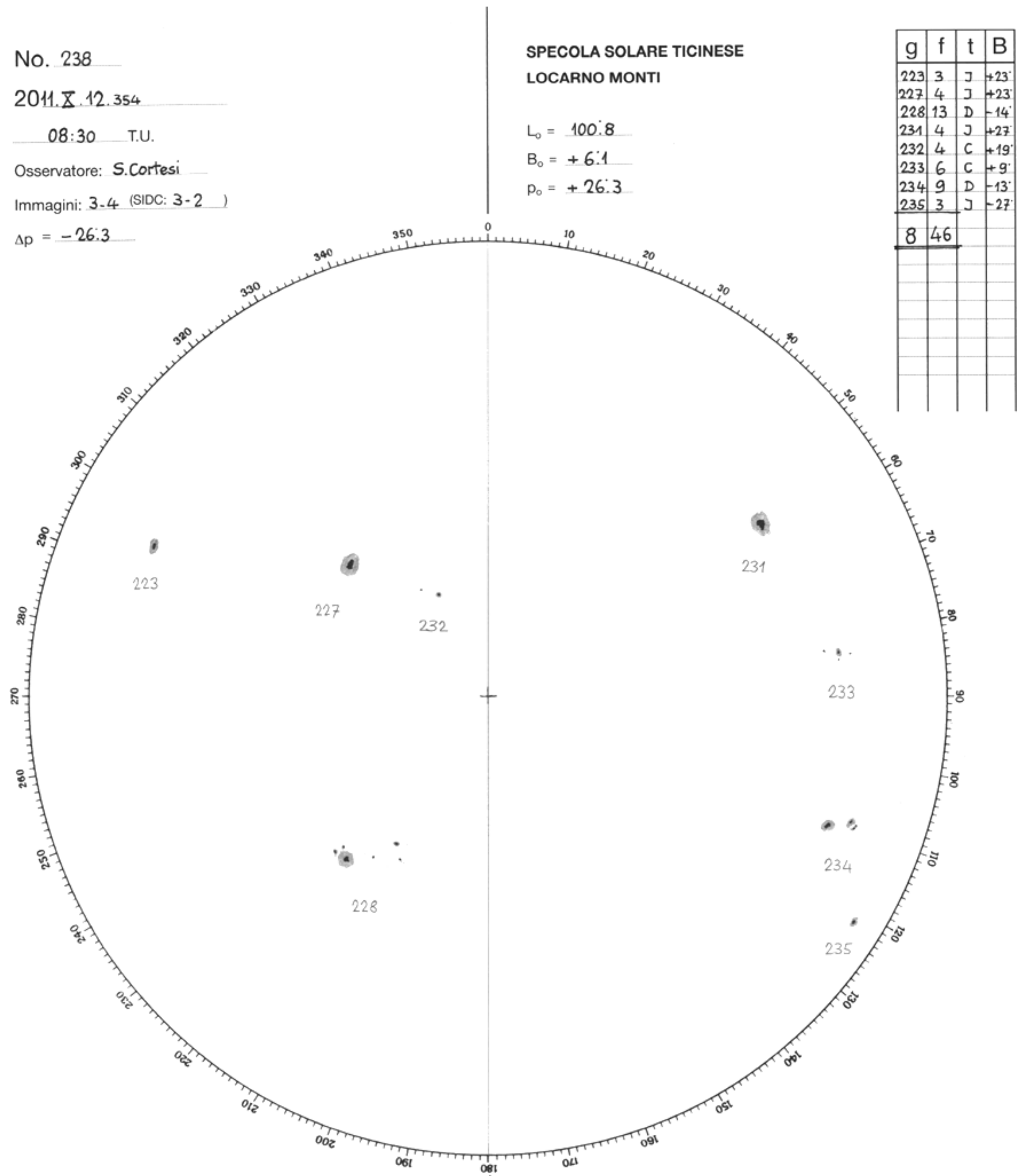


Researchers tend to cherry-pick the one that supports their pet theory the best – this is not a sensible situation. We should do better.

The Ratio Group/Zurich SSN has Two Significant Discontinuities



At ~1946 (After Max Waldmeier took over) and at ~1882



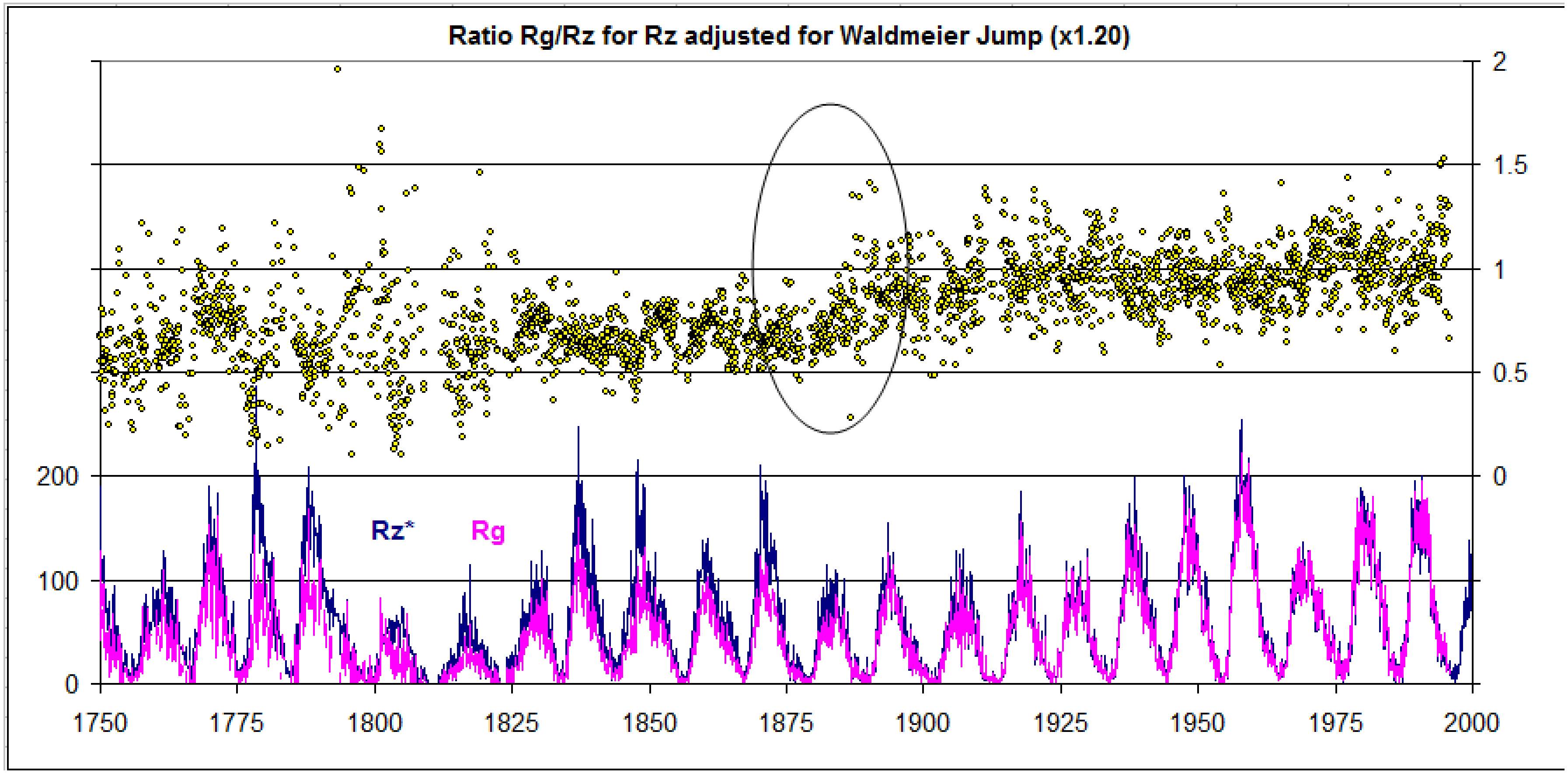
Weighting of sunspot count

223	3	**1**
227	4	**1**
228	13	**6**
231	4	**1**
232	4	**2**
233	6	**4**
234	9	**4**
235	3	**1**
8	46	**20**
	126	**100**

26% inflated

Unweighted count red

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



Leaving one significant discrepancy ~1882

The [Wolf] Sunspot Number

J. Rudolf Wolf (1816-1893) devised his Relative Sunspot Number ~1856 as $R_{Wolf} = k\ (10\ G + S)$ [also R_Z, R_I, *WSN*]

The *k*-factor serving the dual purpose of putting the counts on Wolf's scale and compensating for observer differences

The Group Sunspot Number

Douglas Hoyt and Ken Schatten devised the Group Sunspot Number ~1995 as $R_{Group} = 12\ G$ using only the number, *G*, of Groups normalized [the *12*] to R_{Wolf}

But Groups have *K*-factors too

Schaefer (ApJ, **411**, 909, 1993) noted that with

R_{Group} = *Norm-factor G* , there is no *K* factor. In essence, this is because all telescopic observers see the same groups (at least statistically), so a spot count based on *G* alone will be free of biases.

Alas, as H&S quickly realized, different observers do ***not*** see the same groups, so a correction factor, *K*, had to be introduced into the Group Sunspot Number as well:

$R_{Group} = 12\ K\ G$ [averaged over observers]

And therein lies the rub: it comes down to determination of a *K*-value for each observer [and with respect to what?]

With respect to what?

H&S compared with the number of groups per day reported by RGO in the ‘Greenwich Photographic Results’. The plates, from different instruments on varying emulsions, were measured by several [many] observers over the 100-year span of the data.

H&S – having little direct evidence to the contrary - assumed that the data was homogenous [having the same calibration] over the whole time interval.

We’ll not make any such assumption. But shall compare sunspot groups between different overlapping observers, assuming only that each observer is homogenous within his own data (this assumption can be tested as we shall see)

Reminding you of some Primary Actors

1849-1863 Johann Rudolf Wolf in Berne

The directors of Zürich Observatory were:

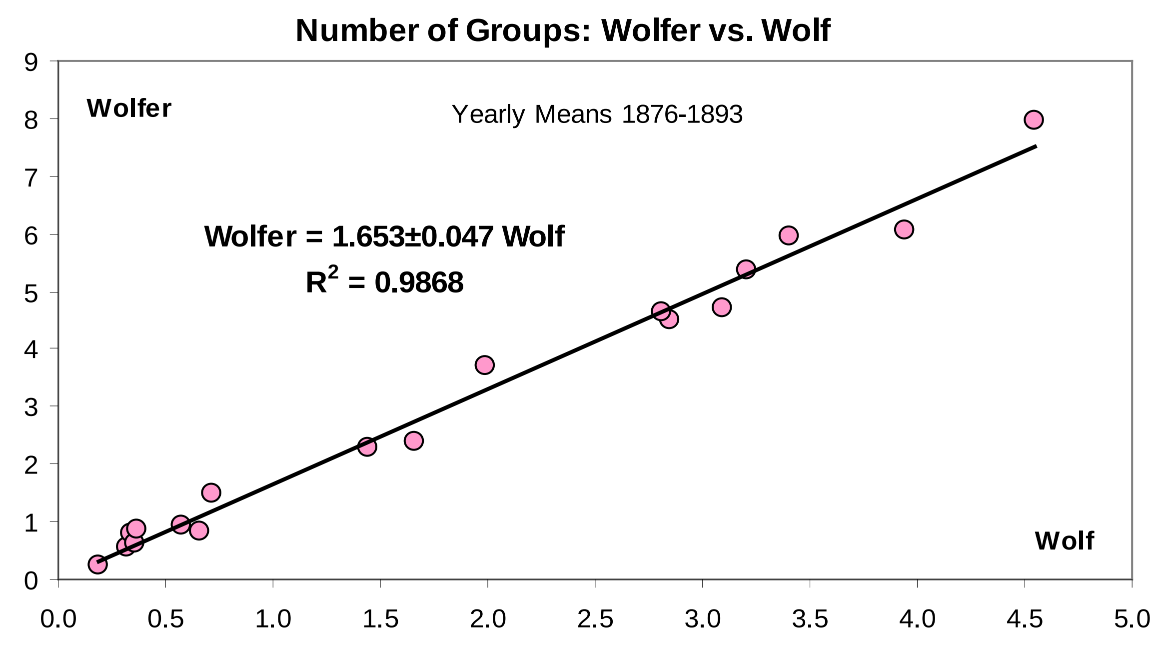
1864-1893 Johann Rudolf Wolf (1816-1893)
1894-1926 Alfred Wolfer (1854-1931)
1926-1945 William Otto Brunner (1878-1958)
1945-1979 Max Waldmeier (1912-2000)

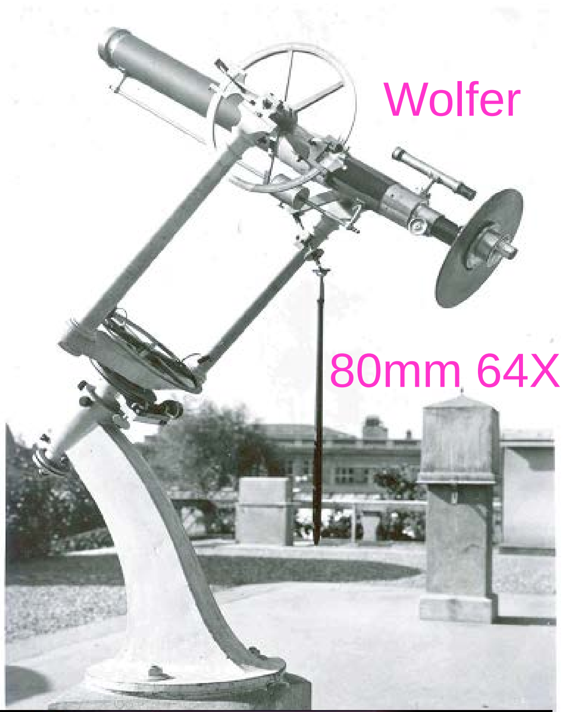
Wolfer was Wolf’s assistant 1876-1893 so we have lots of overlapping data

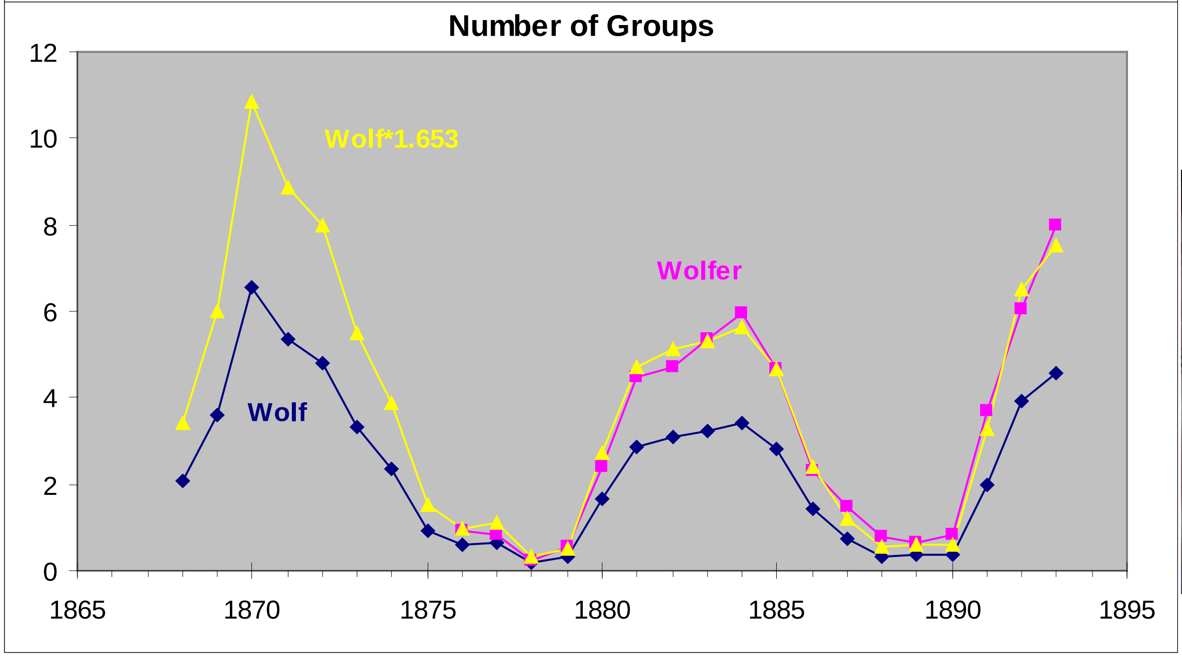
Wolfer's Change to Wolf's Counting Method

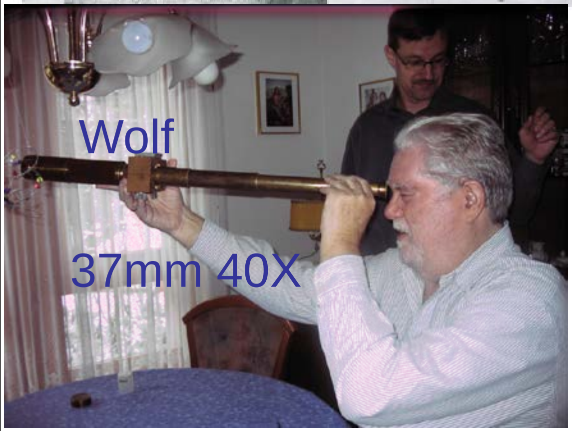
- Wolf only counted spots that were 'black' and would have been clearly visible even with moderate seeing
- His successor Wolfer disagreed, and pointed out that the above criterion was much too vague and instead advocating counting every spot that could be seen
- This, of course, introduces a discontinuity in the sunspot number, which was corrected by using a much smaller *k* value [~0.6 instead of Wolf's 1.0]
- All subsequent observers have *adopted* that same 0.6 factor to stay on the original Wolf scale for 1849-~1865

Wolf-Wolfer Groups



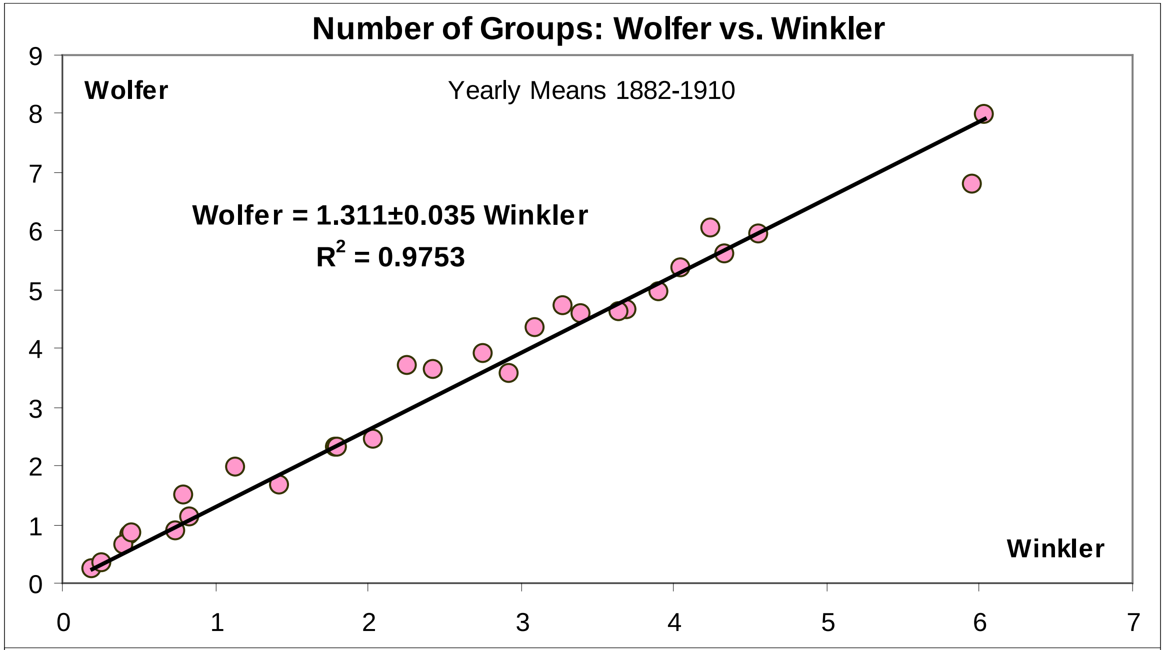


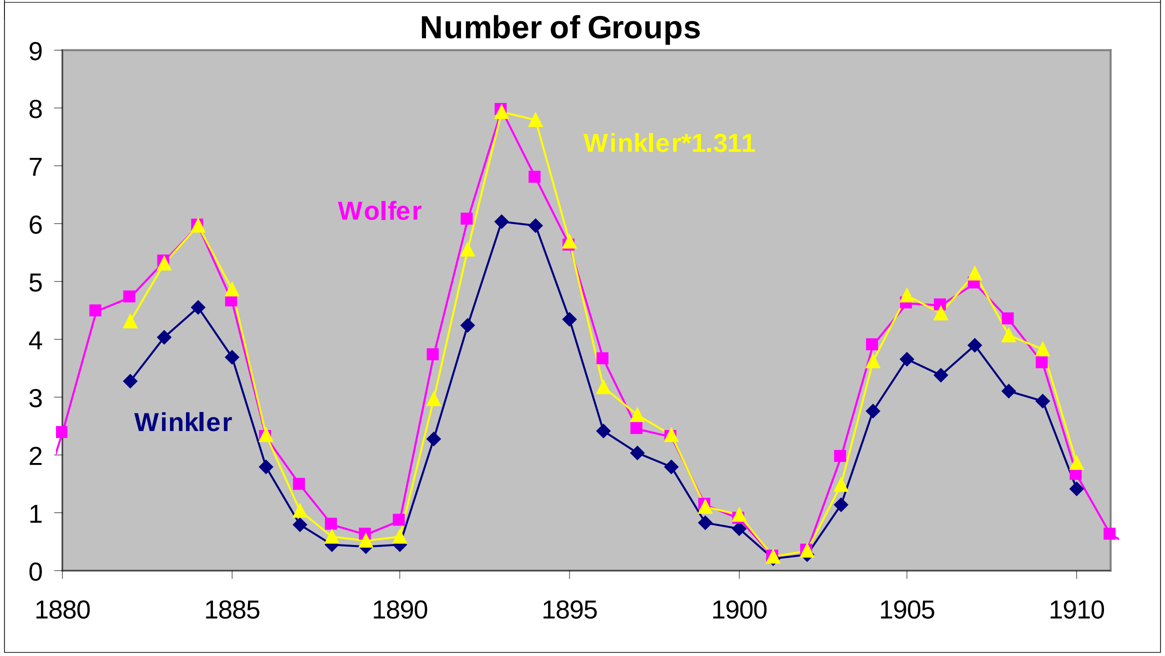




The K-factor shows in daily values too

1883 Month	Day	Wolf G	Wolf S	Wolf R	Wolfer G	Wolfer S	Wolfer R
8	16	**3**	4	34	**7**	29	99
8	17	**3**	6	36	**11**	29	139
8	18	**3**	6	36	**7**	31	101
8	19	**3**	5	35	**8**	30	110
8	20	**2**	3	23	**7**	18	88
8	21	**2**	3	23	**7**	40	110
8	22	**2**	4	24	**7**	41	111
8	23	**2**	4	24	**5**	37	87
8	24	**2**	4	24	**6**	35	95
8	25	**2**	4	24	**5**	32	82
8	26	**4**	8	48	**4**	55	95
8	27	**3**	9	39	**4**	60	100
8	28	**4**	12	52	**5**	91	141
8	29	**4**	10	50	**5**	62	112
8	30	**6**	12	72	**7**	82	152
8	31	**6**	16	76	**6**	88	148
9	1	**5**	15	65	**8**	81	161
Average		**3.29**	**7.35**	**40.29**	**6.41**	**49.47**	**113.59**
				x1.5	G Ratio	S Ratio	x0.6
To place on Wolf's scale with the 80mm →				**60**	**1.95**	**6.73**	**68**

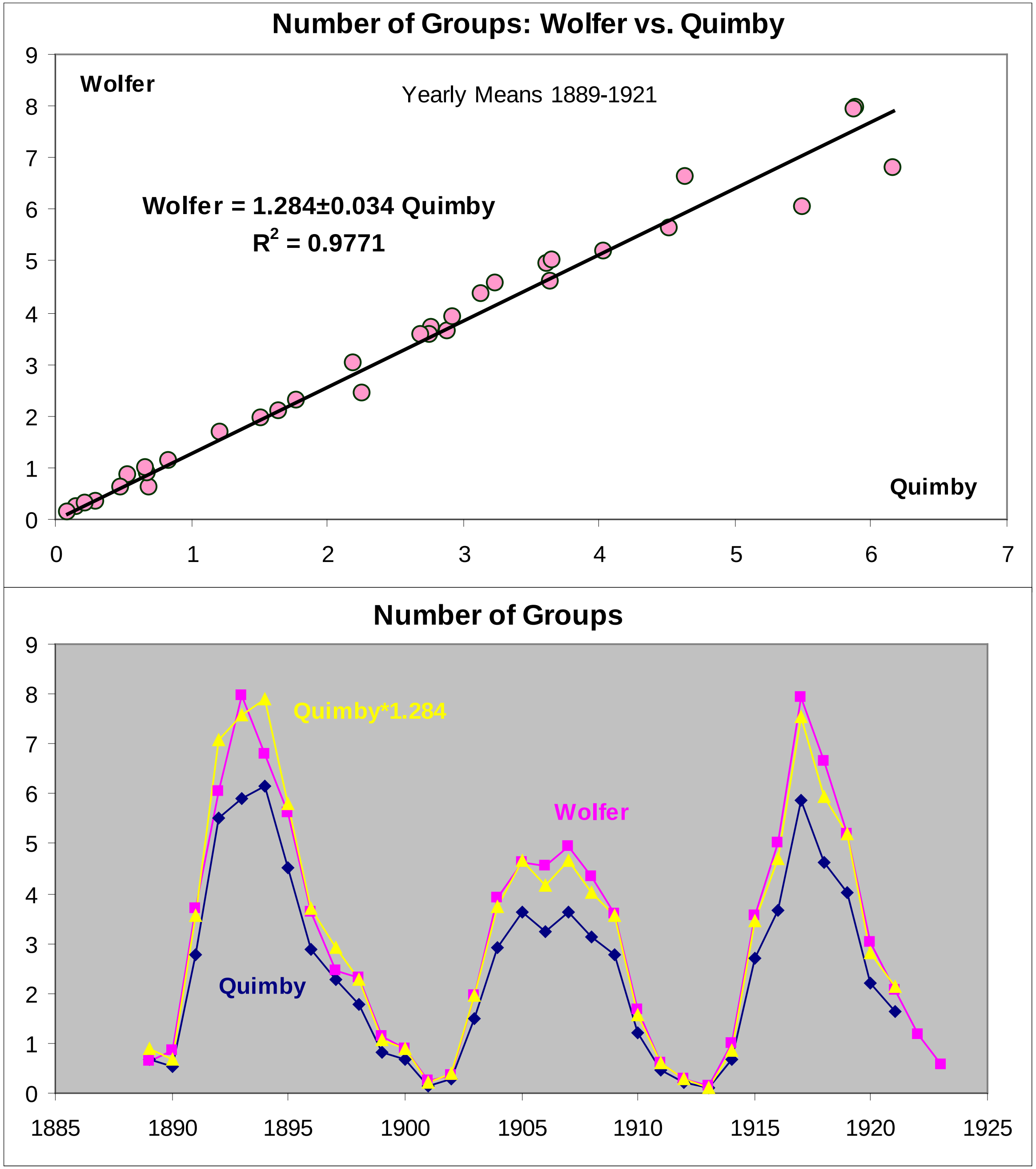




We can make the same type of comparison between observers Winkler and Wolfer

Again, we see a strong correlation indicating homogenous data

Again, scaling by the slope yields a good fit



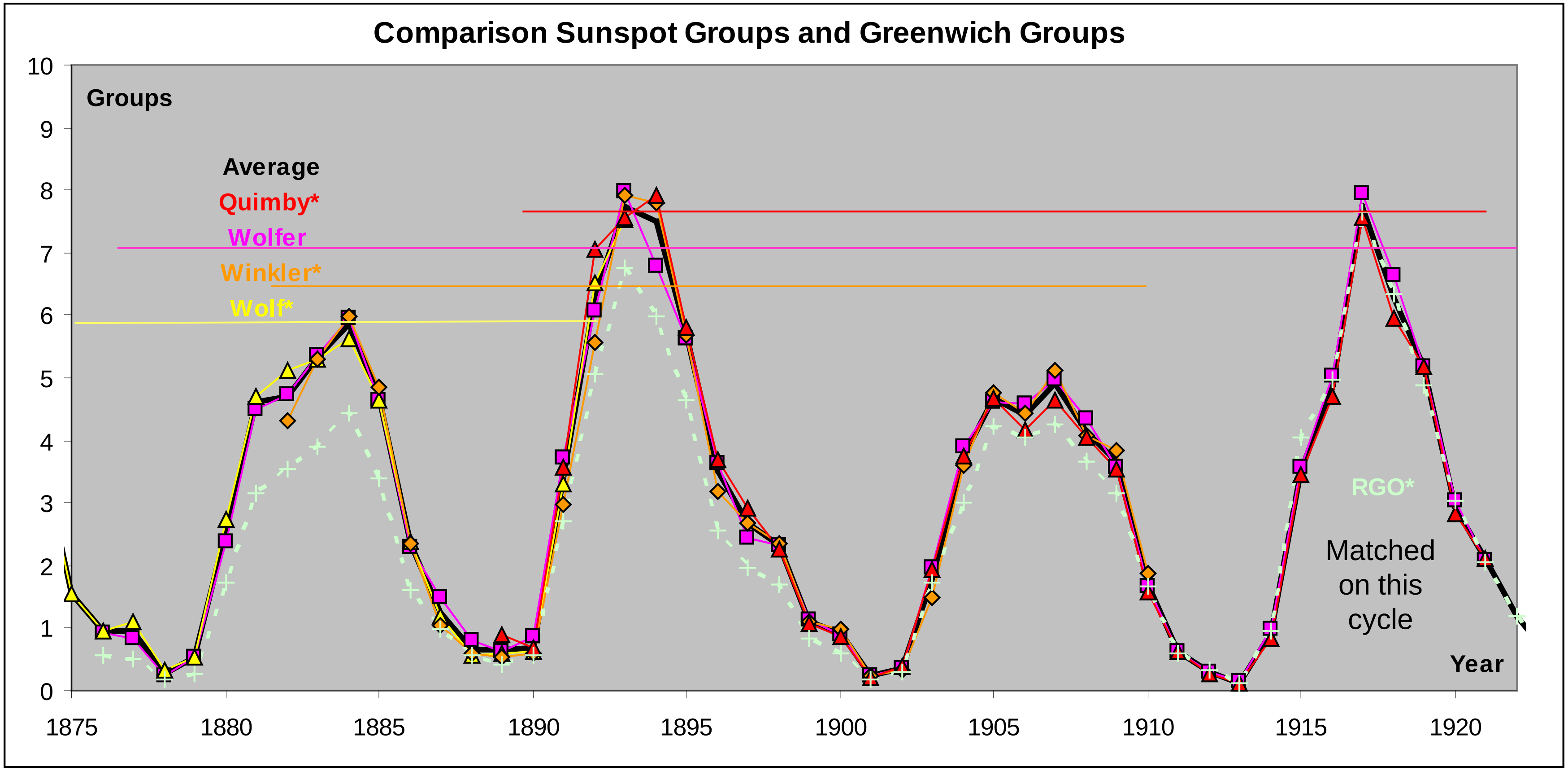
And between Rev. A. Quimby [Philadelphia] and Wolfer

Same good and stable fit

Quimby's friend H. B. Rumrill continued the series of observations until 1951, for a total length of 63 years.

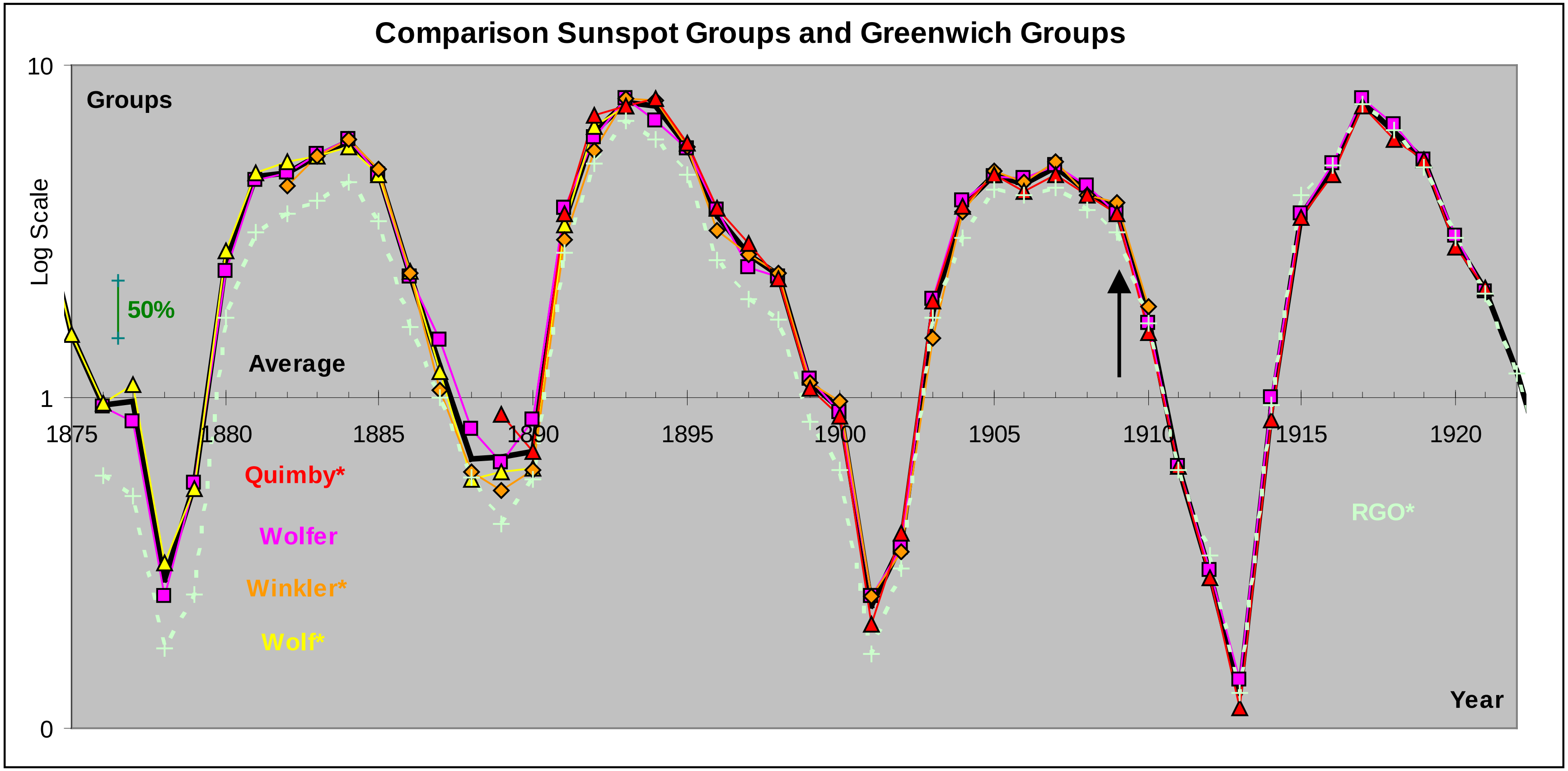
The Rumrill data has been considered lost, but I have just recently found the person that has all the original data.

Making a Composite



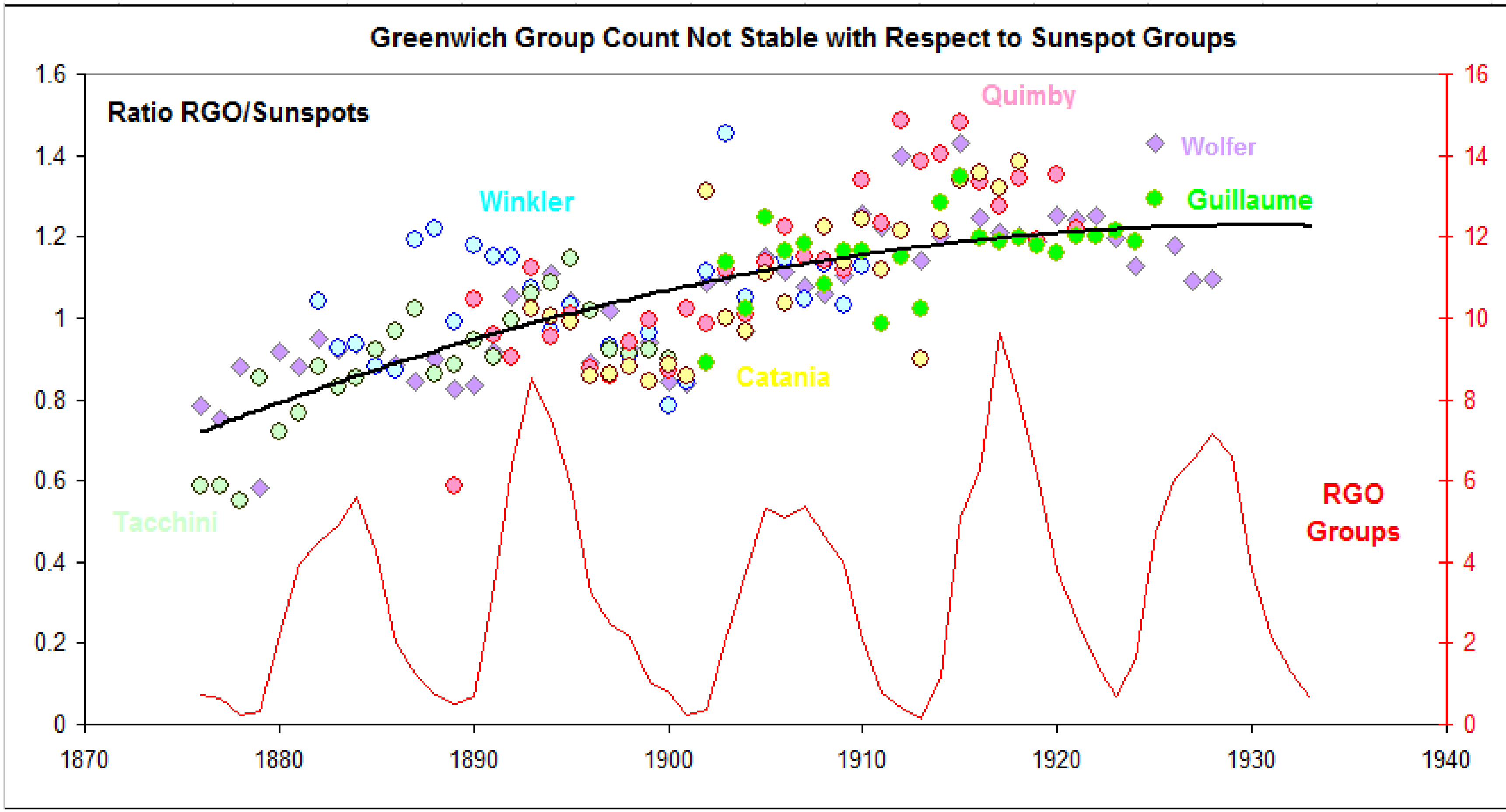
Compare with group count from RGO [dashed line] and note its drift

Composite on Logarithmic scale



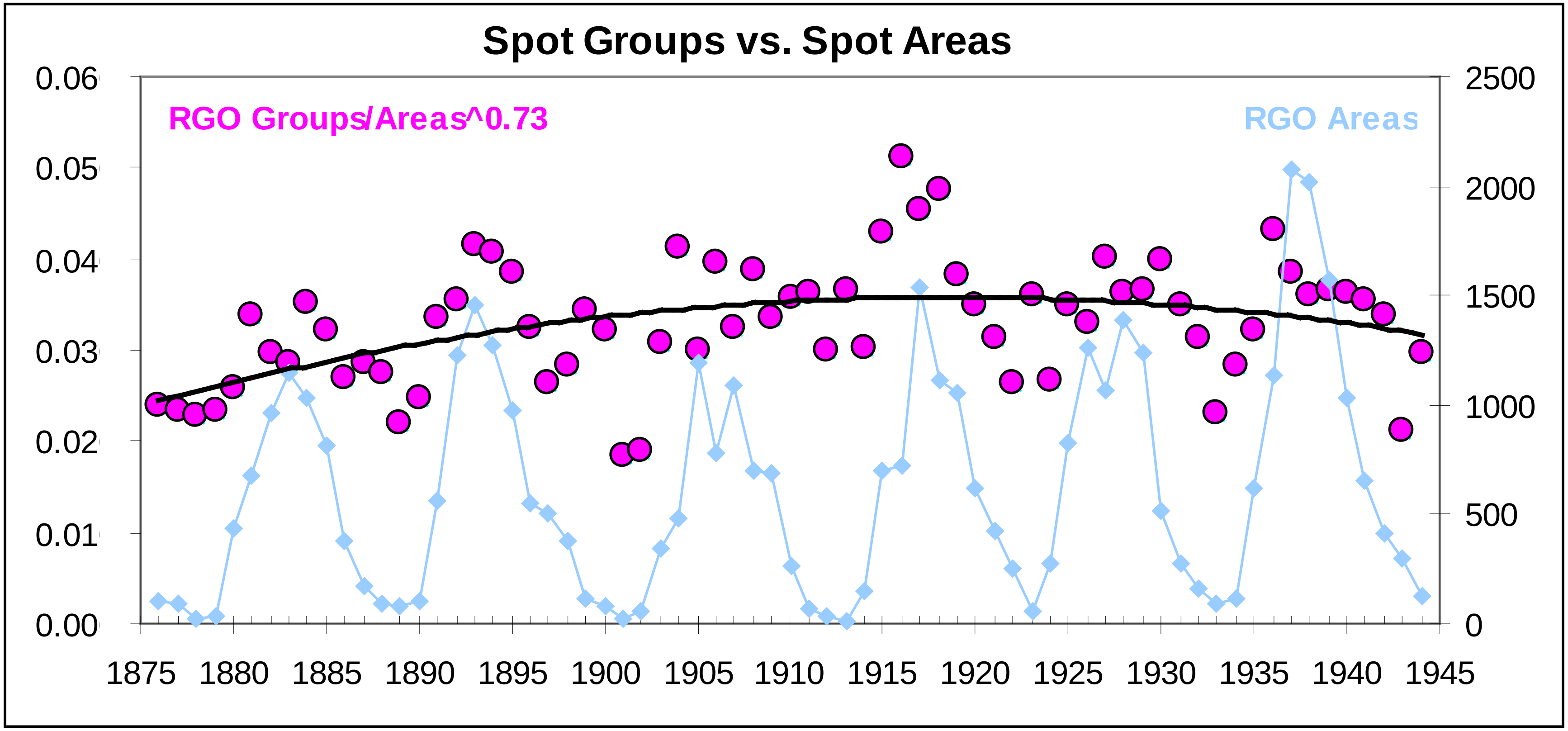
Note that the discrepancy between the composite and RGO approaches 50%

RGO Groups/Sunspot Groups



Early on RGO count fewer groups the Sunspot Observers

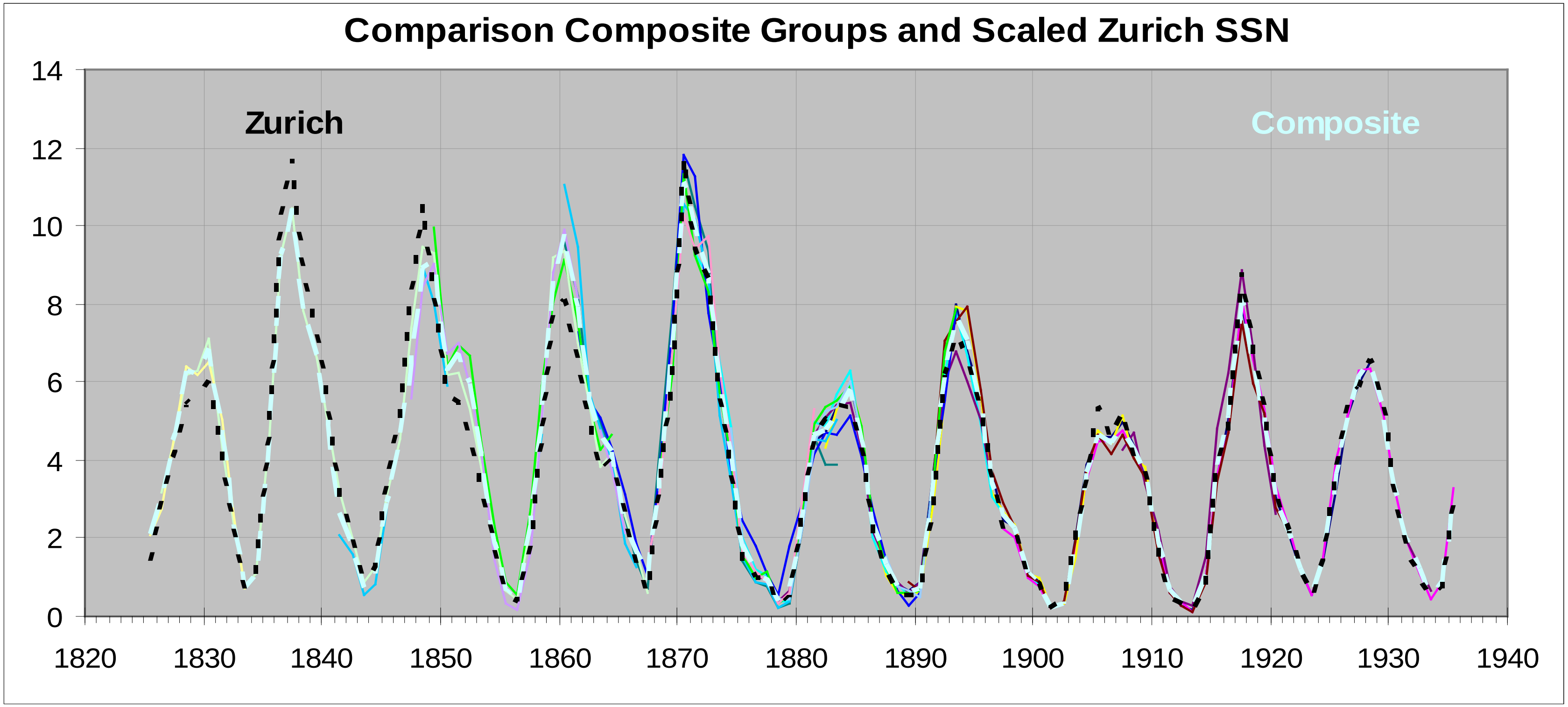
Same trend seen in Group/Areas



There can be several instrumental reasons for such a drift, but there is also a 'procedural' reason: Early on, there was a significant fraction of days with no observations. H&S count these days as having a group count of zero.

Extending the Composite

Comparing observers back in time [that overlap first our composite and then each other] one can extend the composite successively back to Schwabe:

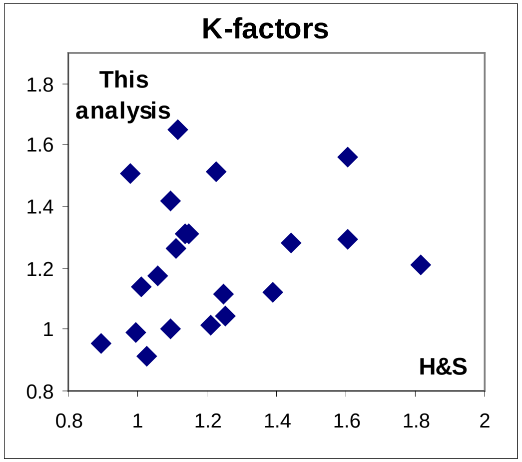


There is now no systematic difference between the Zurich SSN and a Group SSN constructed by not involving RGO.

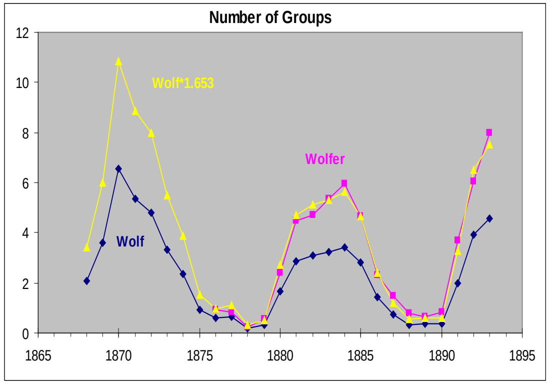
Why are these so different?

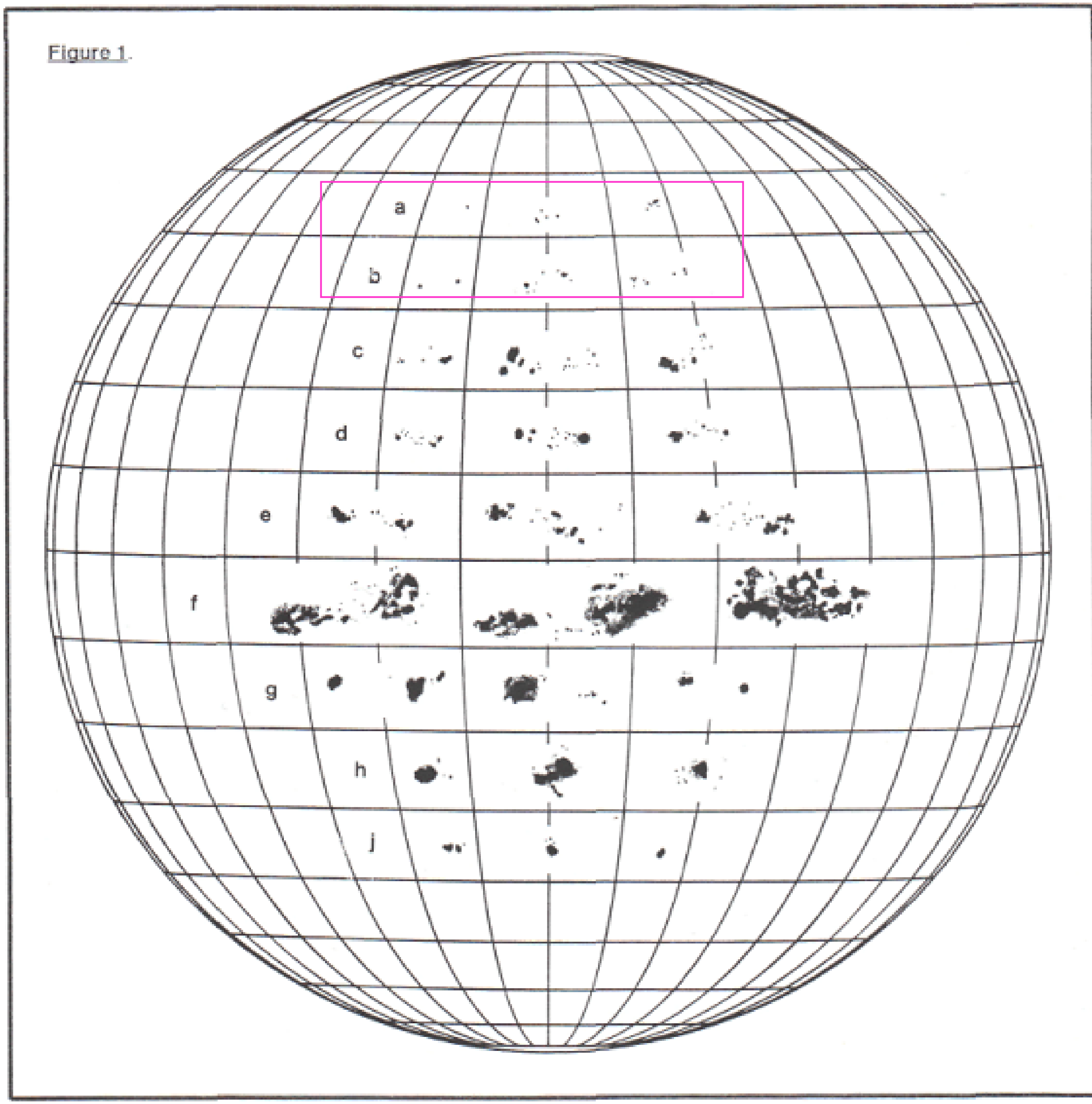
K-Factors

Observer		H&S RGO	to Wolfer	Begin	End
Wolfer, A., Zurich	2% diff.	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, Leibzig		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



No correlation





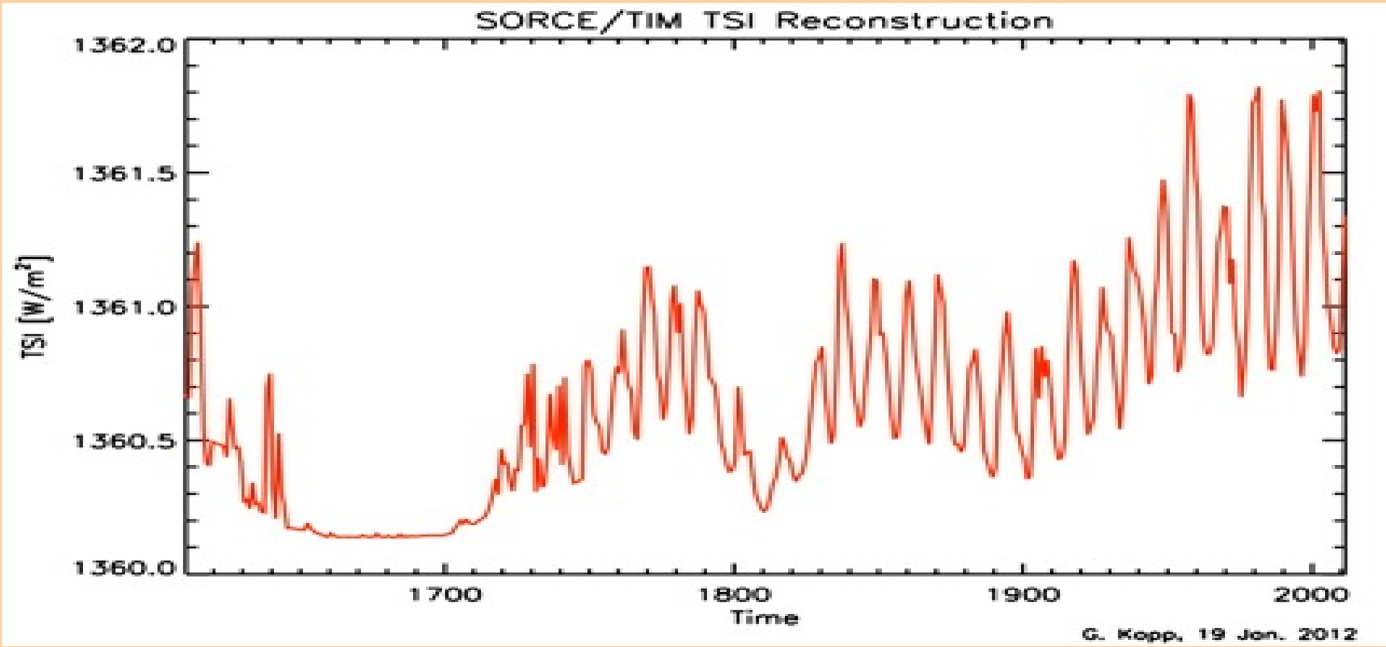
Why the large difference between Wolf and Wolfer?

Because Wolf either could not see groups of Zurich classes A and B [with his small telescope] or deliberately omitted them when using the standard 80mm telescope. The A and B groups make up almost half of all groups

The H&S K-factor Problem

- H&S calculated their K-factor for an observer to RGO using only days when there was at least one spot seen by the observer
- This systematically removes about the lower half of the distribution for times of low solar activity
- Thus skews the K-factors
- This is the main reason for the discrepancy between the two sunspot number series
- And can be fixed simply by using all the data as we have done here

Who Cares about This?

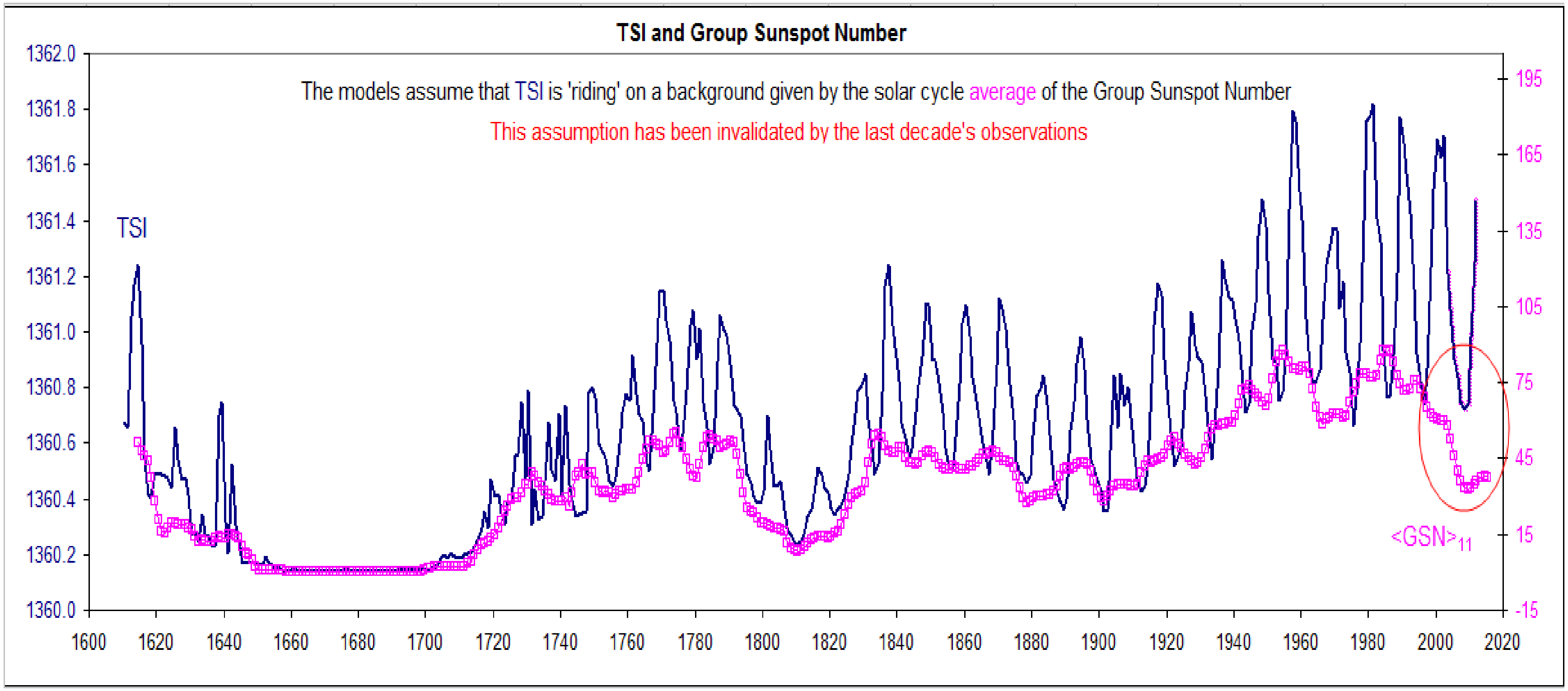


This historical reconstruction of TSI is based on that of Wang, Lean, and Sheeley (The Astrophysical Journal, 625:522-538, 2005 May 20) using a flux transport model to simulate the Sun's magnetic flux, with those annual values provided courtesy of J. Lean. The values from their model have been offset -4.8741 W/m^2 to match the SORCE/TIM measurements during years of overlap and then extended or replaced using SORCE/TIM annual averages from 2003 onward. This more recently accepted TSI absolute value is described by Kopp & Lean (Geophysical Research Letters, 38, L01706, doi:10.1029/2010GL045777, 2011) based on new calibration and diagnostic measurements. The historical reconstruction provided here was computed by G. Kopp using TIM V.12 data on Jan 19, 2012, and is updated annually as new TIM data are available.

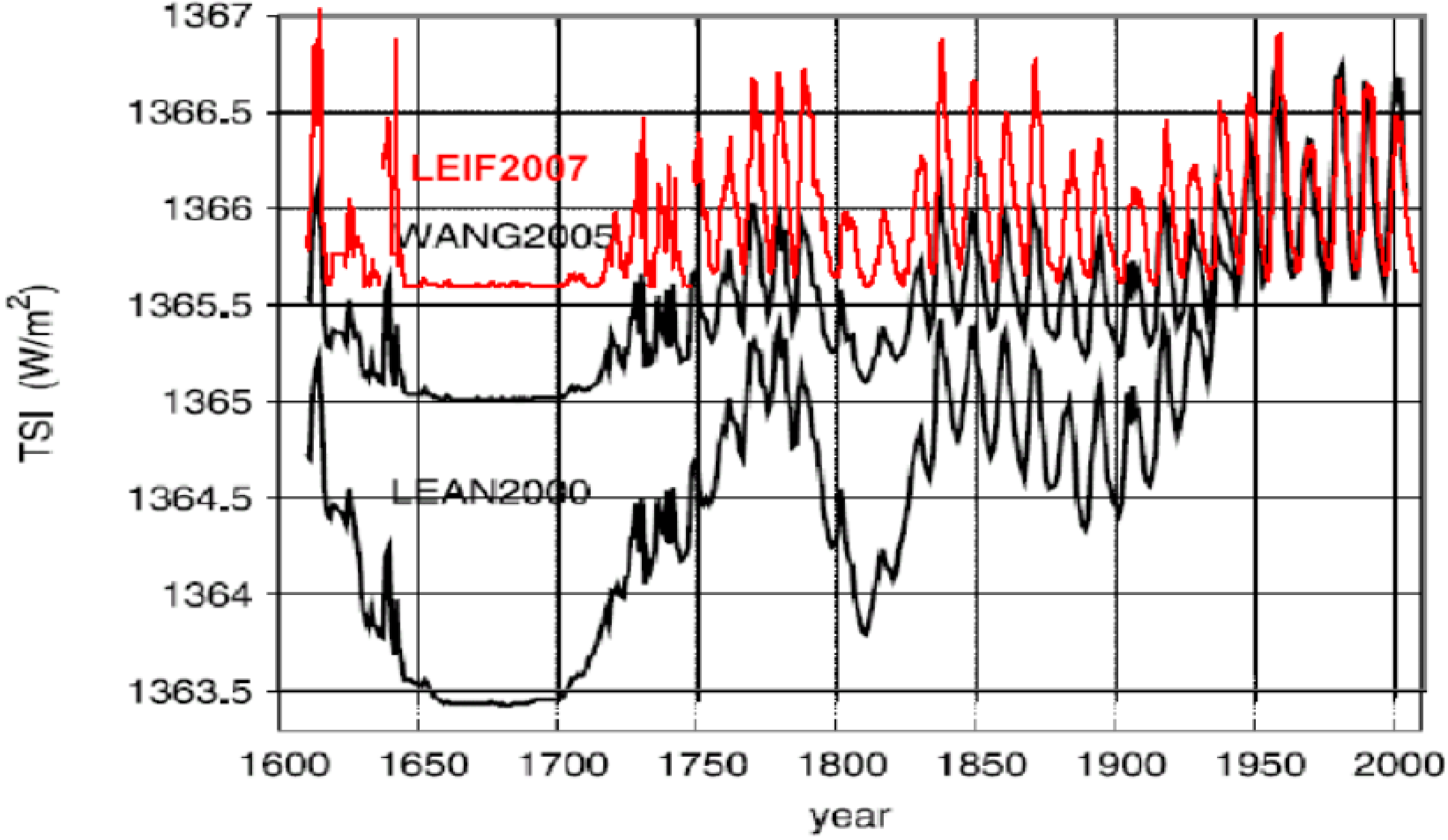
http://lasp.colorado.edu/sorce/data/tsi_data.htm

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

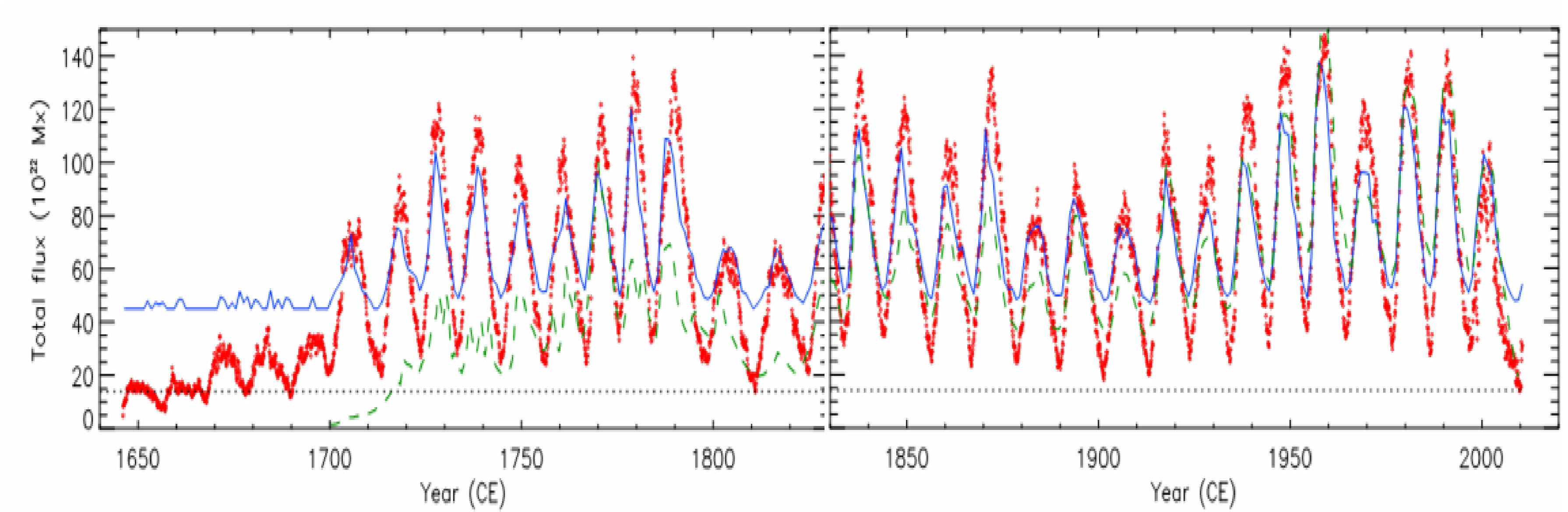
I expect a strong reaction against ‘fixing’ the GSN from people that ‘explain’ climate change as a secular rise of TSI and other related solar variables



This is what I suggest TSI should look like



Following closely a recent re-evaluation of the Sun's open magnetic flux



The minimal solar activity in 2008–2009 and its implications for long-term climate modeling
C. J. Schrijver, W. C. Livingston, T. N. Woods, and R. A. Mewaldt

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L06701, doi:10.1029/2011GL046658, 2011

What to do about this?

A plug for our Sunspot Workshop: http://ssnworkshop.wikia.com/wiki/Home

SSN-Workshop Wiki

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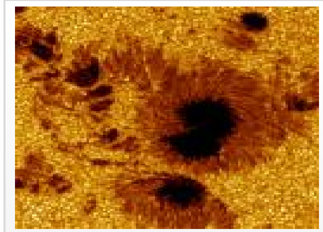
Welcome to the Wiki of the Sunspot Number Workshops.

Here you'll find the latest information about the meetings.

Why the Sunspot Number Needs Re-examination



Added by Lsvalgaard

The SSN workshops are sponsored by the National Solar Observatory (NSO), the Royal Observatory of Belgium (ROB), and the Air Force Research Laboratory (AFRL). We are happy to report that Frédéric Clette of ROB has joined Leif and Ed as a Co-Organizer of the SSN Workshop Series. We view the September workshop as the first step in an effort to provide the solar community with a vetted long-term (single) sunspot number and the tools to keep it on track. This will take a lot of work and we look forward to collaborating with each of you. We will hold a second workshop at ROB on Brussels in May 2012 (and perhaps a third one later) and are considering a special Topical Issue of Solar Physics for the eventual joint publication of the SSN series and the accompanying historical, procedural, and scientific papers.

Sincerely yours, Ed, Frédéric, & Leif.

1st SSN Workshop September, 2011

2nd SSN Workshop May, 2012

Abstract

We have identified the flaw in Hoyt & Schatten's construction of the Group Sunspot Number (GSN). We demonstrate how a correct GSN can be constructed using only the Hoyt & Schatten raw data without recourse to other proxies. The new GSN agrees substantially with the Wolf Sunspot number, resolving the long-standing discrepancy between the two series. Modeling based on the old GSN of solar activity and derived TSI and open flux values are thus invalidated. This will have significant impact on the Sun-climate debate and on solar cycle prediction and statistics.