Sunspot Number Reconstructions

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ISSI-233 May, 2012

Outline

- Effect of Weighting on Zürich SSN
- What is Wrong with the Group SSN
- Geomagnetic Calibration of Sunspot Number
- What to Do about This

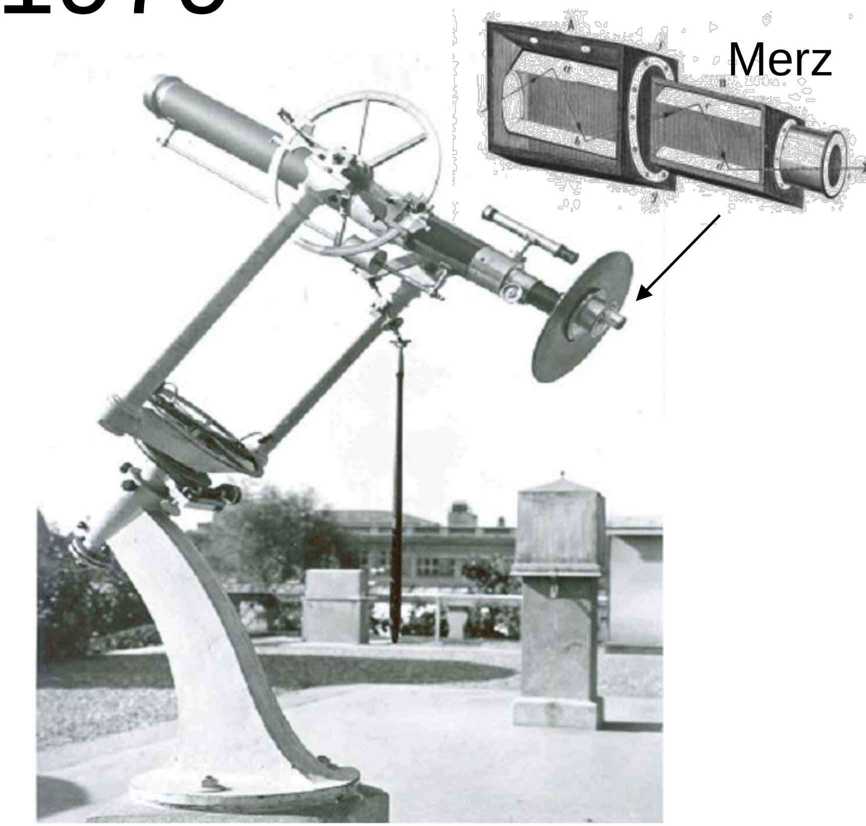
The Effect of Weighting in Counting Sunspots

‘The Waldmeier Discontinuity’

Max Waldmeier's Tenure as Director of Zürich Observatory 1945-1979

Wolf's Relative Sunspot Number

R = k (10*Groups + Spots)



Rudolf Wolf's Telescope

Built by Fraunhofer 1822

Wolf’s Telescopes, used by Wolf, Wolfer, Brunner, Waldmeier, Friedli

Still in use today [by T. Friedli] continuing the Swiss tradition [under the auspices of the Rudolf Wolf Gesellschaft]

Most of Wolf’s observations (since the 1860s) were made with this telescope. Also still in use today

How does one count sunspots?

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

Astronomische Mitteilungen der Eidgenössischen Sternwarte Zürich
Nr. 285

1968

Die Beziehung zwischen der Sonnenflecken-relativzahl und der Gruppenzahl

Von

M. Waldmeier

Hofflecken handelte. 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. Die Gruppen- und

"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.

Waldmeier claimed that the counting with weighting began in 1882:

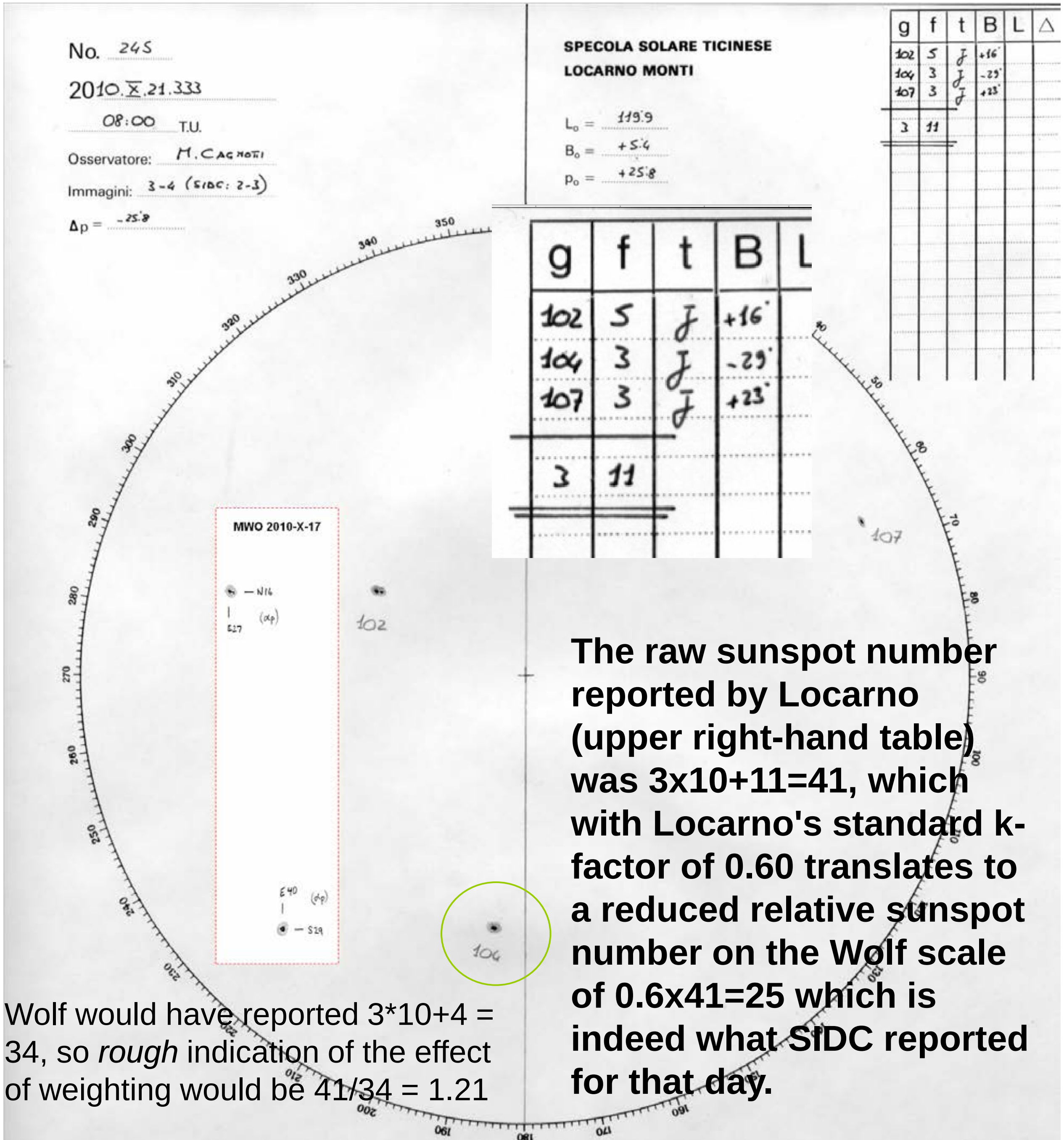
CHANGES TO THE COUNTING METHOD

Since Rudolph Wolf began the sunspot measurement, he set the standard. And although he counted each spot regardless of its size, he failed to include those smallest spots visible only under a stable atmosphere. Around 1882 Wolf's successors permanently changed the counting method in two ways to compensate for the large variation in spot size:

(1) by including the smallest spots visible under an atmosphere of constant transparency and

(2) by weighting spots with penumbrae according to their size and umbral structure.

This ‘modified’ counting method is still in use at the reference station Locarno used by SIDC in Brussels . As a typical example we take the drawing made at Locarno on 21st October, 2010 [next slide]. Three sunspot groups are visible, numbered by Locarno as 102, 104, and 107, corresponding to NOAA active region numbers 11113, 11115, and 11117.



The raw sunspot number reported by Locarno (upper right-hand table) was 3x10+11=41, which with Locarno's standard k-factor of 0.60 translates to a reduced relative sunspot number on the Wolf scale of 0.6x41=25 which is indeed what SIDC reported for that day.

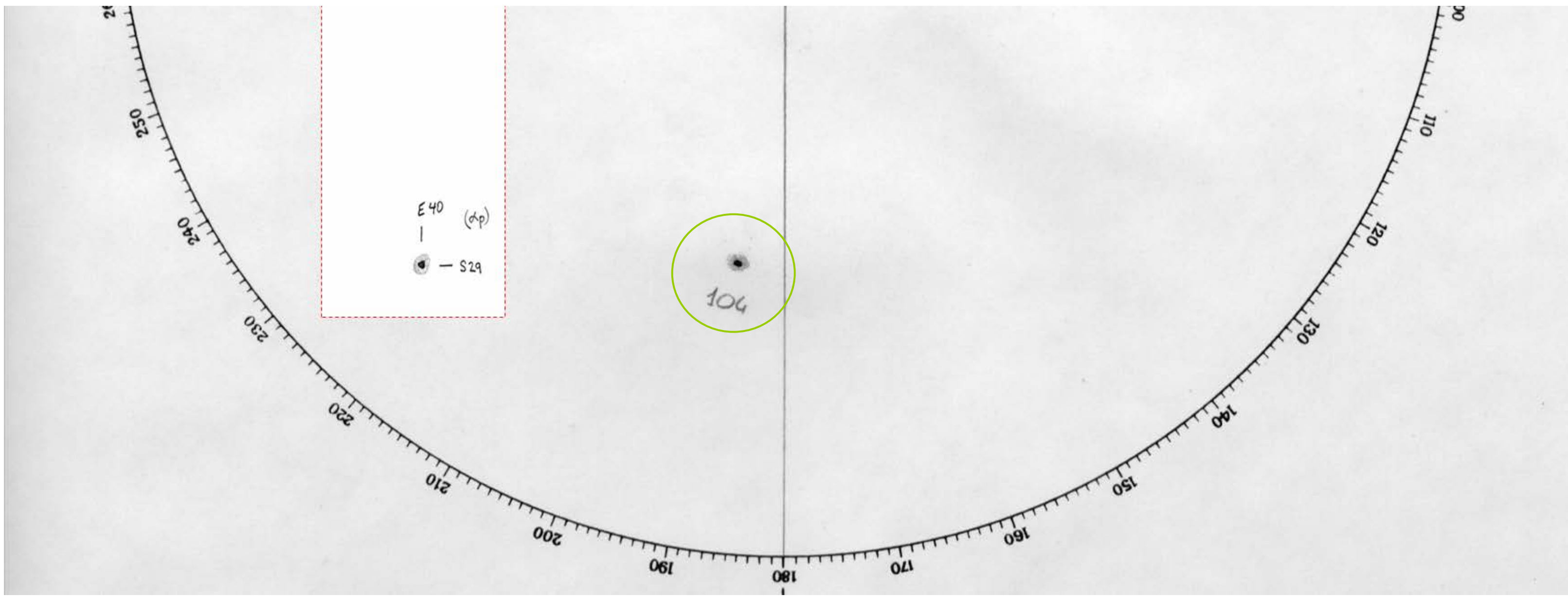
Wolf would have reported 3*10+4 = 34, so *rough* indication of the effect of weighting would be 41/34 = 1.21

Drawing from Locarno 21 October, 2010 showing the three Locarno Regions 102, 104, and 107. The table gives the weight assigned to each group.

An insert (red border) shows the regions as observed at MWO on the 17th October (no observation the 21st).

From Hathaway’s list we get the areas of those spots:

Year	M	D.	UT	NOAA	Loc#	Area (obs.)
2010	10	21.50	11113	102	134 µH	
2010	10	21.50	11115	104	**223** µH	
2010	10	21.50	11117	107	104 µH	



-Note there is a spot of the same size back in 1920:
1920 11 21.55 *9263 MWO* **223** µH (it was the only spot)

Up until Waldmeier [who discontinued this!] the Zürich observers recorded their raw data for each day in this format

"Group Count . Total Spot Count"

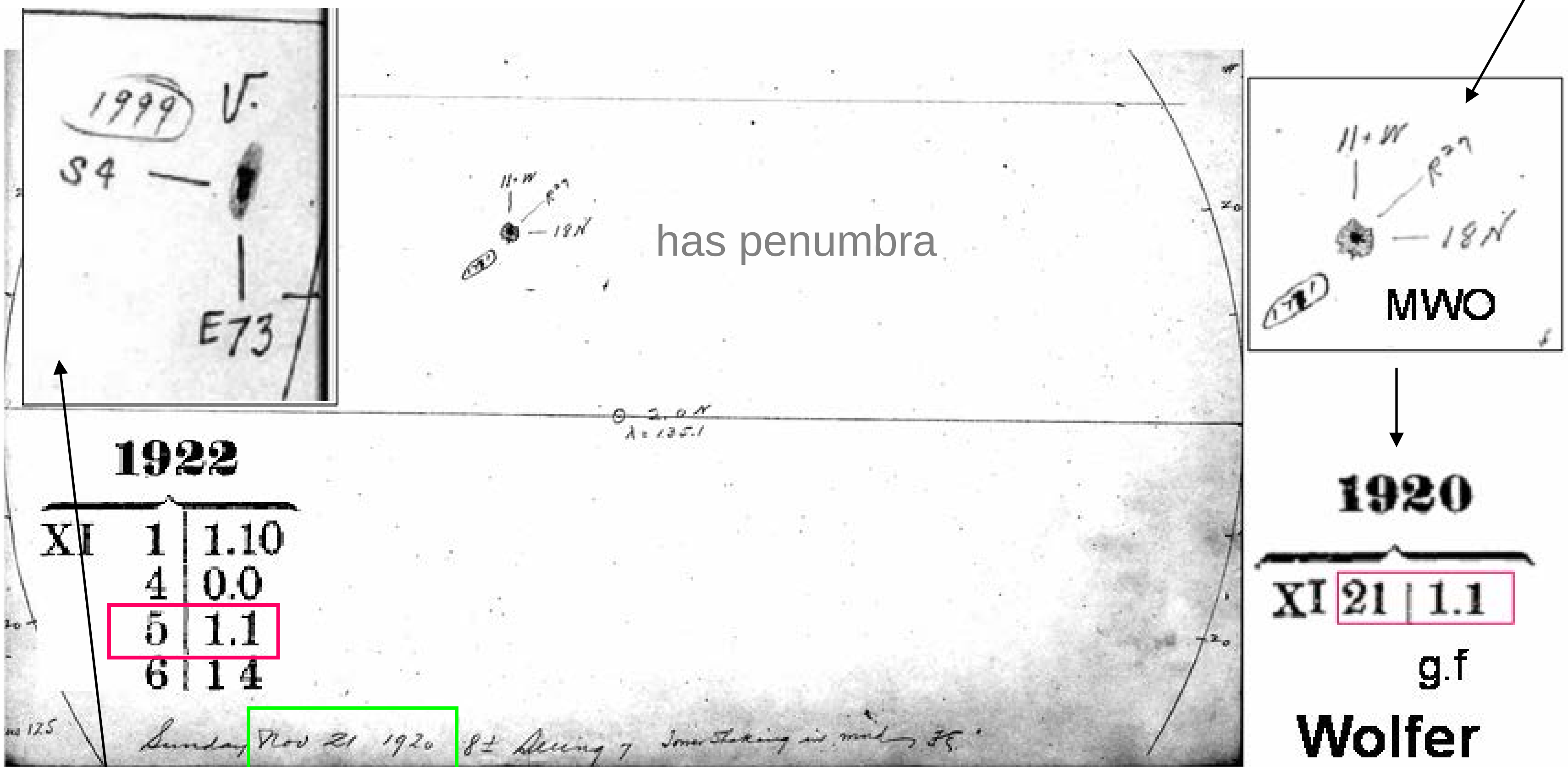
Sonnenfleckenbeobachtungen im Jahre 1849.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
1	9.31	3. 6	4. –	10.70	9.30	8.48	4.13	4 15	7.64	8.10	5.16	—
2	9.34	7.40	5. —	7. —	9.40	9.64	3. 3	6.18	5.35	7.10	7.41	8. 9
3	15. —	2. —	6.12	10.38	5.12	8.50	3. 6	6.15	4.27	3. 4	3.10	8.17
4	9.31	7.27	7.15	$\boxed{12.58}$	7.45	10.50	3 10	4.12	5.41	2. 3	4.31	—
5	9. –	9.22	2. —	8.20	8 50	8.45	7. —	5.20	1. 1	1. 2	—	9.47
6	8. —	10 34	7.24	10.60	7.38	7.45	4. 8	4.18	6.25	4. 6	—	2. 2
7	—	3. –	3. —	8.24	1. –	5. –	5.10	3.20	7.48	—	6.22	—
8	8.28	10.21	4. —	6.20	6.20	5.12	6.15	3.15	5.38	5.16	7.35	—
9	8.30	10.35	3. —	9.45	6.25	3. –	7.20	4.14	7.50	5.26	6.20	–

To calculate the relative sunspot number, e.g. on April 4th, one performs $R = k * (10*12 + 58) = 178$

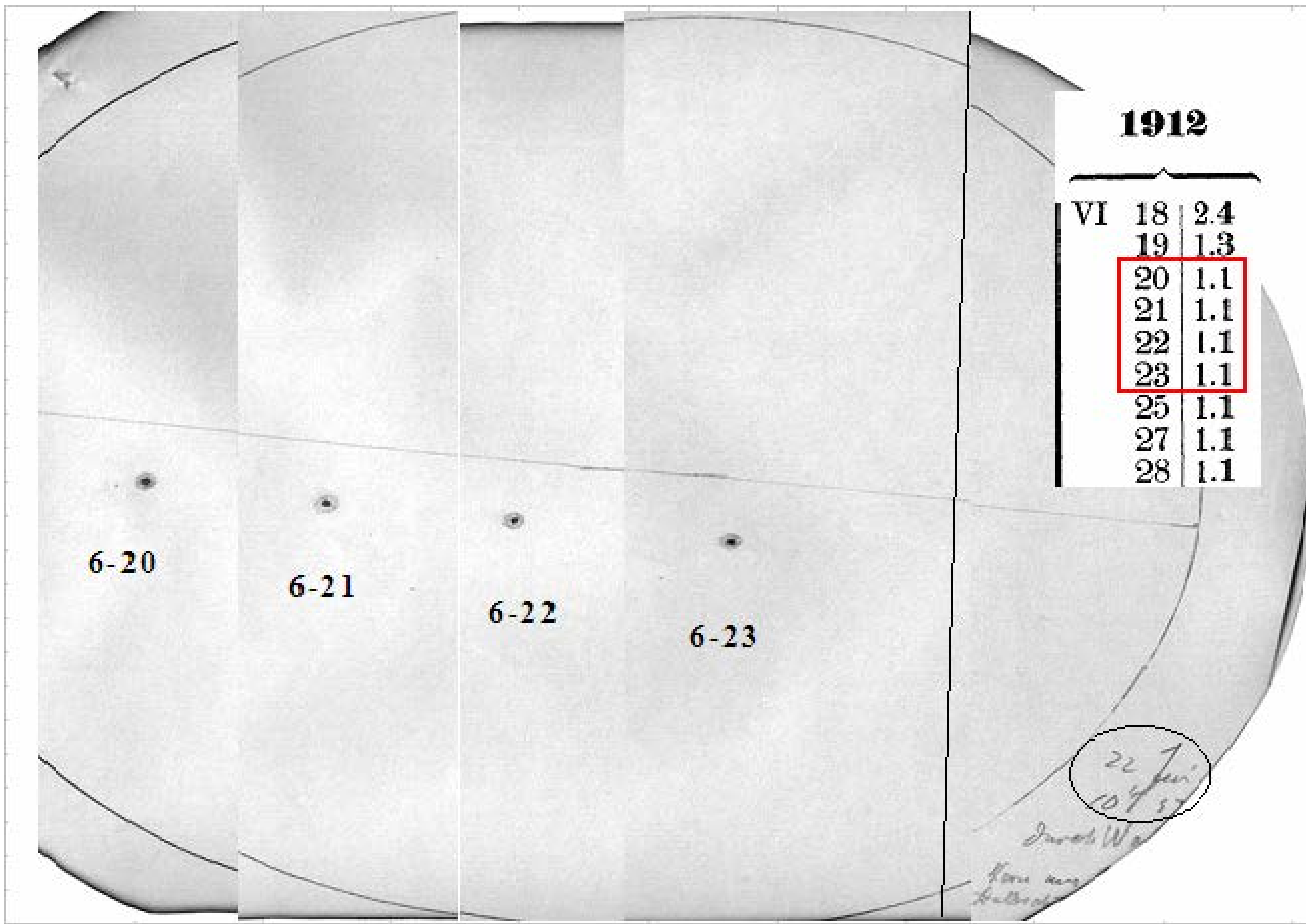
where the scale factor k is 1.00 for Wolf himself.

So, now back to the MWO spot on 21st Nov. 1920 that had the same size as Locarno 104 [which was counted as three spots or 1 spot with weight of 3.]



The insert shows a similar group observed at MWO on 5th Nov., 1922. For both groups, Wolfer should have recorded the observation as 1.3 if he had used the weighting scheme, but they were recorded as 1.1, clearly counting the large spots only once (*thus with no weighting*). The historical record Zürich sunspot number was 7 {=0.6x(10+1)} on both those days, consistent with ***no*** weighting.

Other Observatory Drawings Show Similar Results, e.g. Haynald (Kalocsa, Hungary):



This spot should have been counted with weight 3, so the recorded value should have been 1.3, if Wolfer had applied the weighting, which he obviously didn’t

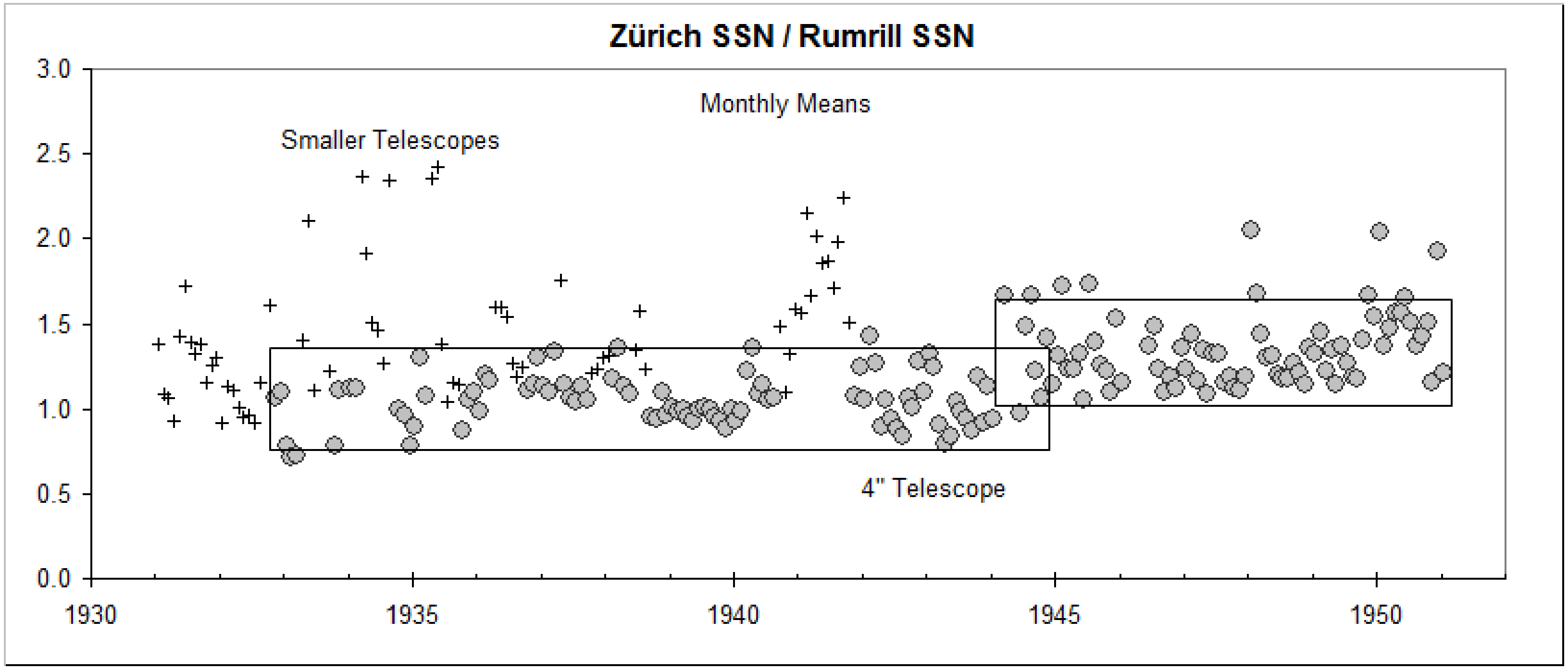
There are many other such examples, (e.g. 16th September, 1922 and 3rd March, 1924 for which MWO drawings are readily available). In addition, Wolfer himself in 1907 (Mitteilungen, Nr. 98) explicitly states: “Notiert ein Beobachter mit seinem Instrumente an irgend einem Tage *g* Fleckengruppen mit insgesamt *f* Einzelflecken, ohne Rücksicht auf deren Grösse, so ist die daraus abgeleitete Relativzahl jenes Tages $r = k(10g+f)$".

We thus consider it established that Wolfer (and by extension [?] the other observers before Waldmeier) did not apply the weighting scheme contrary to Waldmeier's assertion.

This is consistent with the fact that nowhere in Wolf's and Wolfer's otherwise meticulous yearly reports in the *Mittheilungen über Sonnenflecken* series is there any mention of a weighting scheme. Waldmeier himself was an assistant to Brunner in 1936 and performed routine daily observations with the rest of the team so should have known what the rules were. There is a mystery lurking here. Perhaps the Archives [in Zürich? Or the microfilm in Brussels] will provide a resolution of this conundrum.

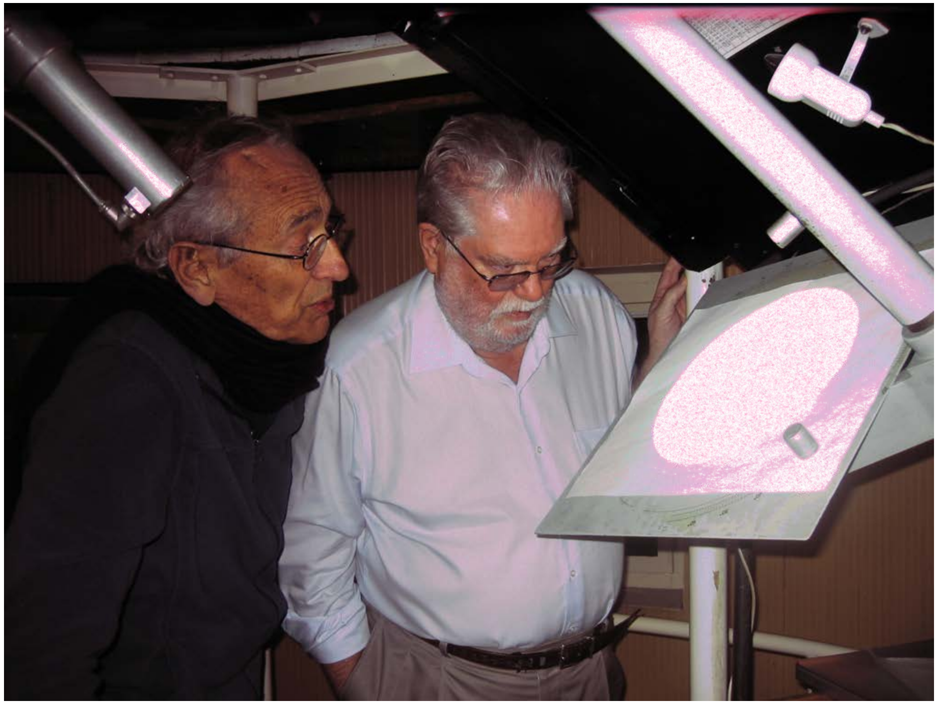
The weighting is not generally known and was downplayed by Waldmeier

Rumrill's Data



Seems to show that Brunner did not introduce the weighting [to its full scale, at least]

What Do the Observers at Locarno Say About the Weighting Scheme:



Sergio Cortesi started in 1957, still at it, and in a sense is the *real* keeper of the SSN, as SIDC normalizes everybody's count to match Sergio's

"For sure the main goal of the former directors of the observatory in Zürich was to maintain the coherence and stability of the Wolf number[…] Nevertheless the decision to maintain as "secret" the true way to count is for sure source of problems now!"

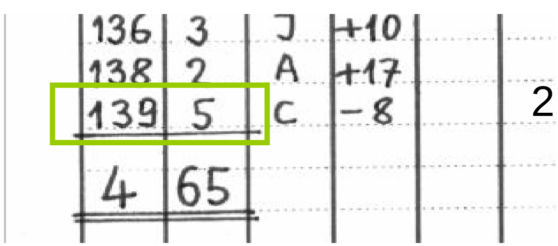
(email 6-22-2011 from Michele Bianda, IRSOL, Locarno)

Estimating Unweighted Sunspot Count From Locarno Drawings

I look at the drawing of a group and from experience [I have looked at thousands of spots, 42025 at last count, on Locarno's drawings going back many years], assign a weight to each spot, then subtract the weight from the count given for the group and add 1 for the spot.

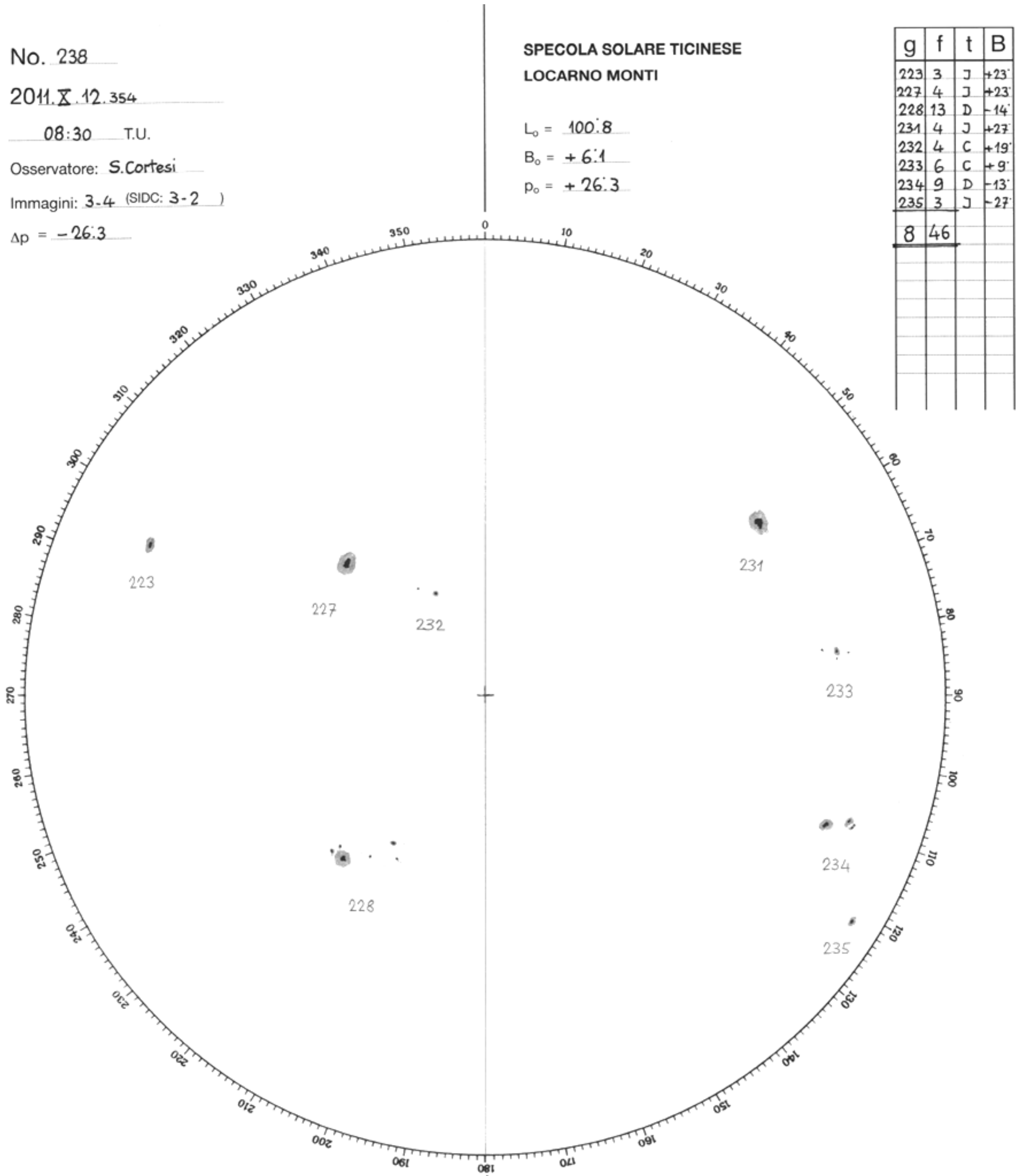
Example 1: A group has four spots on the drawing, one is large with weight 3, one is medium with weight 2 and two are small with weight 1. The total count given by Locarno was 6. That tells me that one of the small spots was not counted [otherwise the total would have been 3+2+1+1 = 7]. So, I subtract 3, 2, and 1 from their total: 6 - 3 - 2 - 1 = 0 and add 1 for each spot for a total of 3 as the unweighted count.

Example 2: Most of the time it is enough just to count the spots:



2

2004-8-12



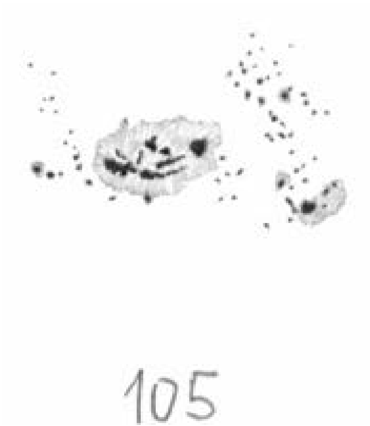
Try it yourself…

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

Difficult (Rare) Cases



2005 . IX . 15 . 333

8.00 T.U.

Osservatore: S.Cortesi

Immagini: 3

74 spots

g	f	t	B	L
105	58	E	-11	
1	58			

36

3,2,3,2,2,3,2,3,3,3,3,3,3: sum 35, 58-35+13 spots = 36

g	f	t	B	L	△
134	55	E	-13		
136	3	J	+10		
138	2	A	+17		
139	5	C	-8		
4	65				

40
1
1
2

44

2004-08-12 (group 134)

Double-Blind Test

Email from Leif Svalgaard

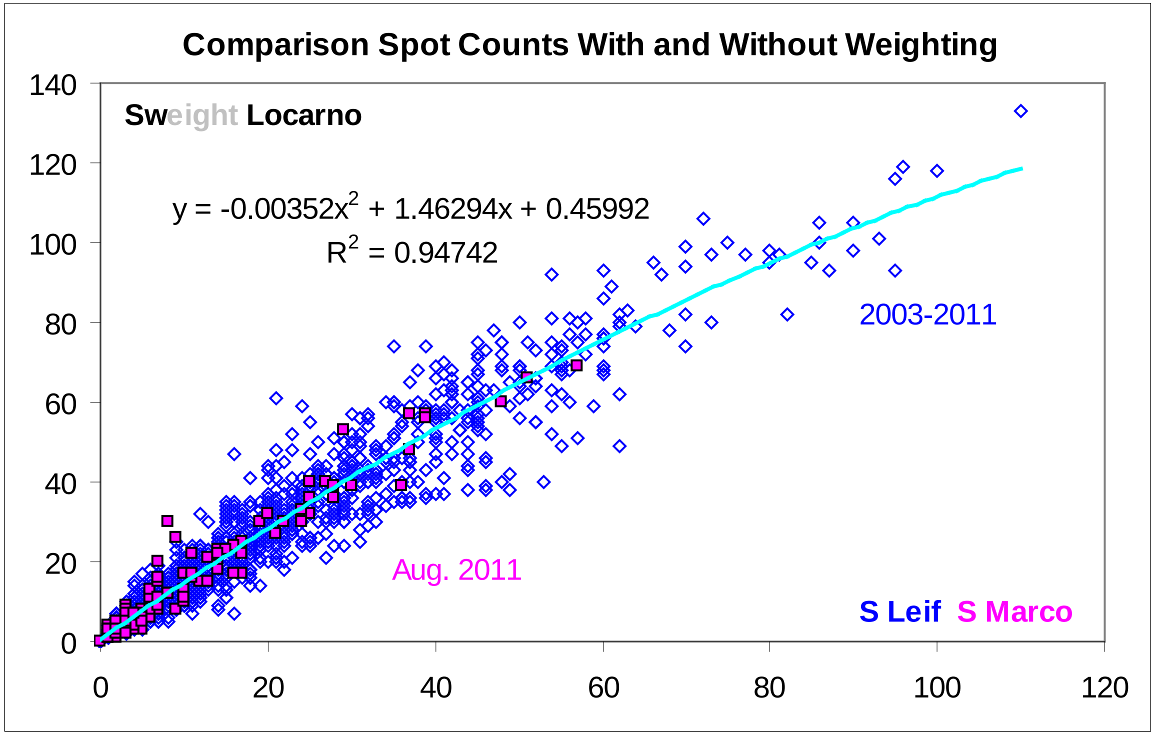
Sat, Jun 18, 2011 at 9:26 PM

Dear Everybody,

As you may know we are holding a sunspot workshop at Sunspot, New Mexico in September. For this I would like to propose a simple test, that hopefully should not put a great extra burden on everybody. I ask that the observer for each day writes down somewhere what the actual number of spots counted was without the weighting, but without telling me. Then in September you let me know what the counts for [rest of] June, July, and August were. This allows me to calibrate my method of guessing what your count was. It is, of course, important that the test be blind, that I do not know until September what you all are counting. I hope this will be possible.

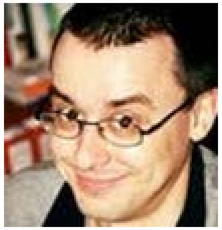
My modest proposal was met with fierce resistance from everybody [incl. Frédéric], but since I persisted in being a pest, I finally got Locarno to go along

Current Status of the Test

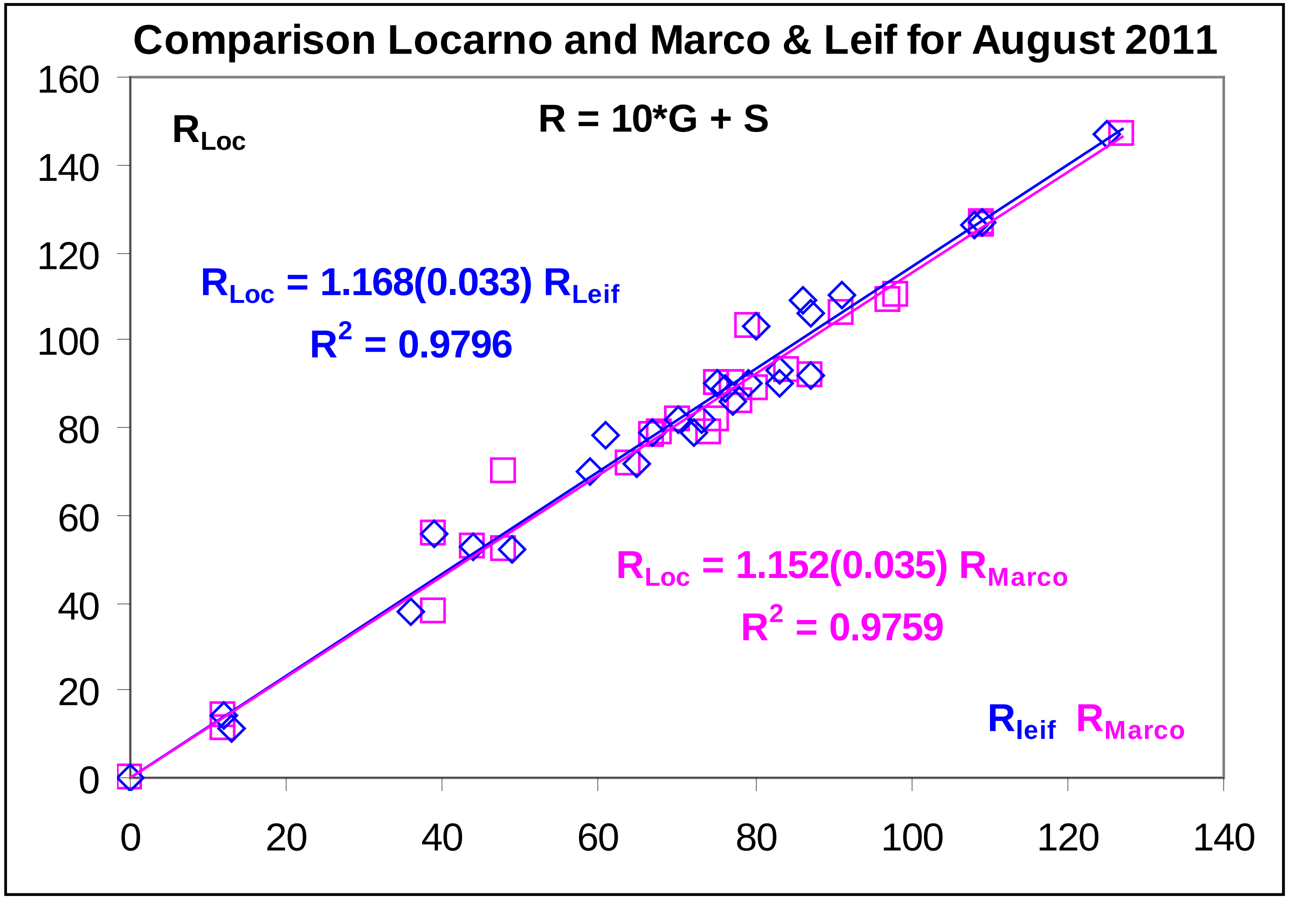


For typical number of spots the weighting increases the 'count' of the spots by 30-50% (42% on average)

For the limited data for August 2011 Marco Cagnotti and Leif Svalgaard agree quite well with no significant difference. **The test has continued until today with the same result.**



Comparison of 'Relative Numbers'



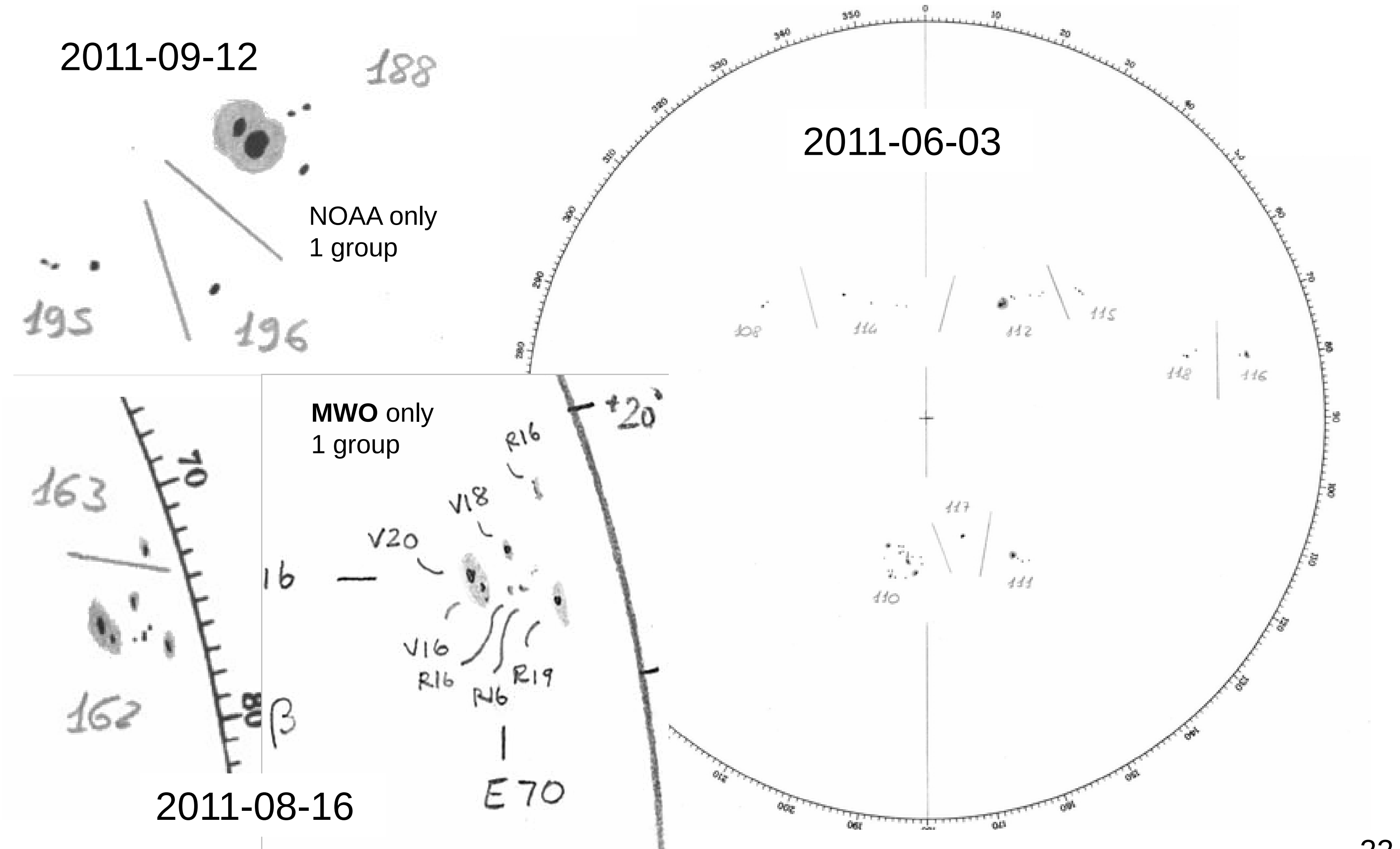
But we are interested in the effect on the SSN where the group count will dilute the effect by about a factor of two.

For Aug. 2011 the result is at left. There is no real difference between Marco and Leif.

We take this a [preliminary] justification for my determination of the influence of weighting on the Locarno [and by extension on the Zürich and International] sunspot numbers

How Many Groups?

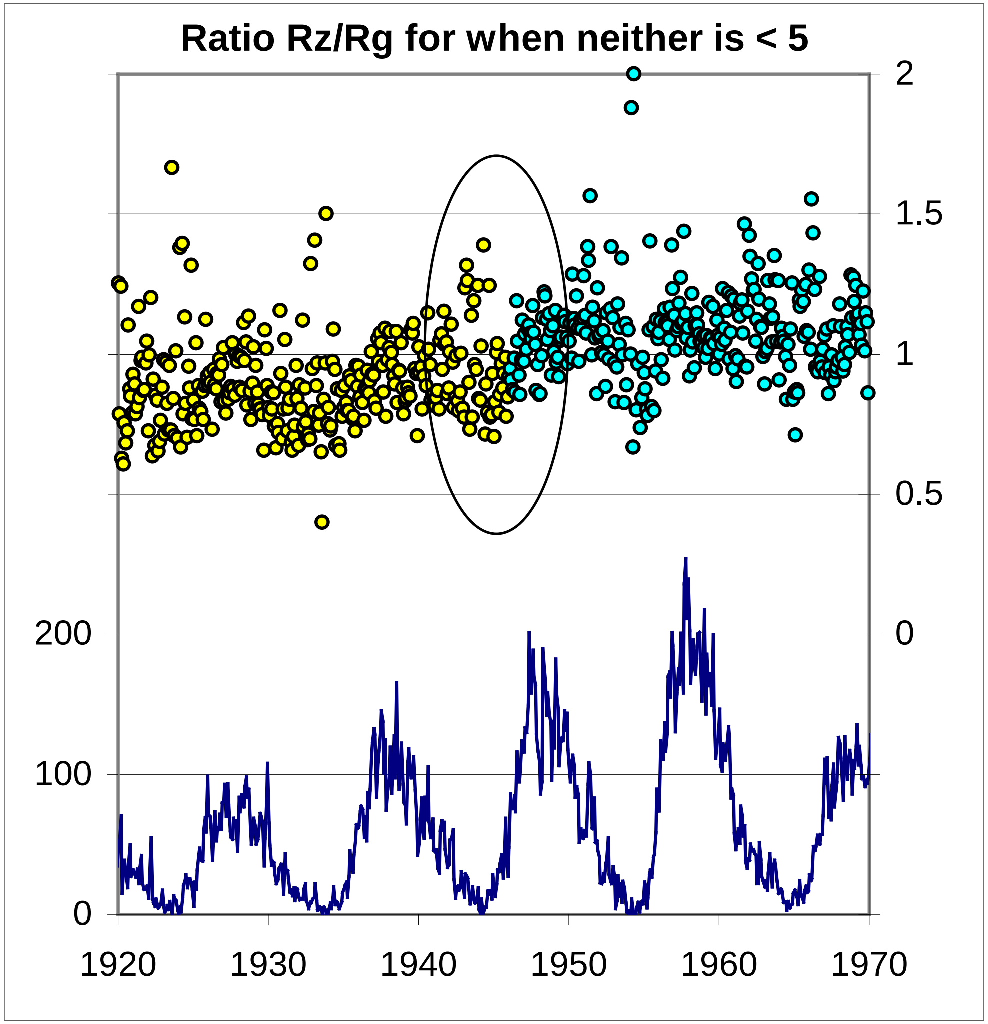
The Waldmeier Classification May lead to Better [larger] Determination of Groups



Counting Groups

- This deserves a full study. I have only done some preliminary work on this, but estimate that the effect amounts to a few percent only, perhaps 5% [?] One day in five has an ‘extra’ group.
- This would increase the ‘Waldmeier Jump” to about 21%
- My suggested solution is to increase all pre-Waldmeier SSNs by 21%, rather than decrease the modern counts which may be used in operational programs

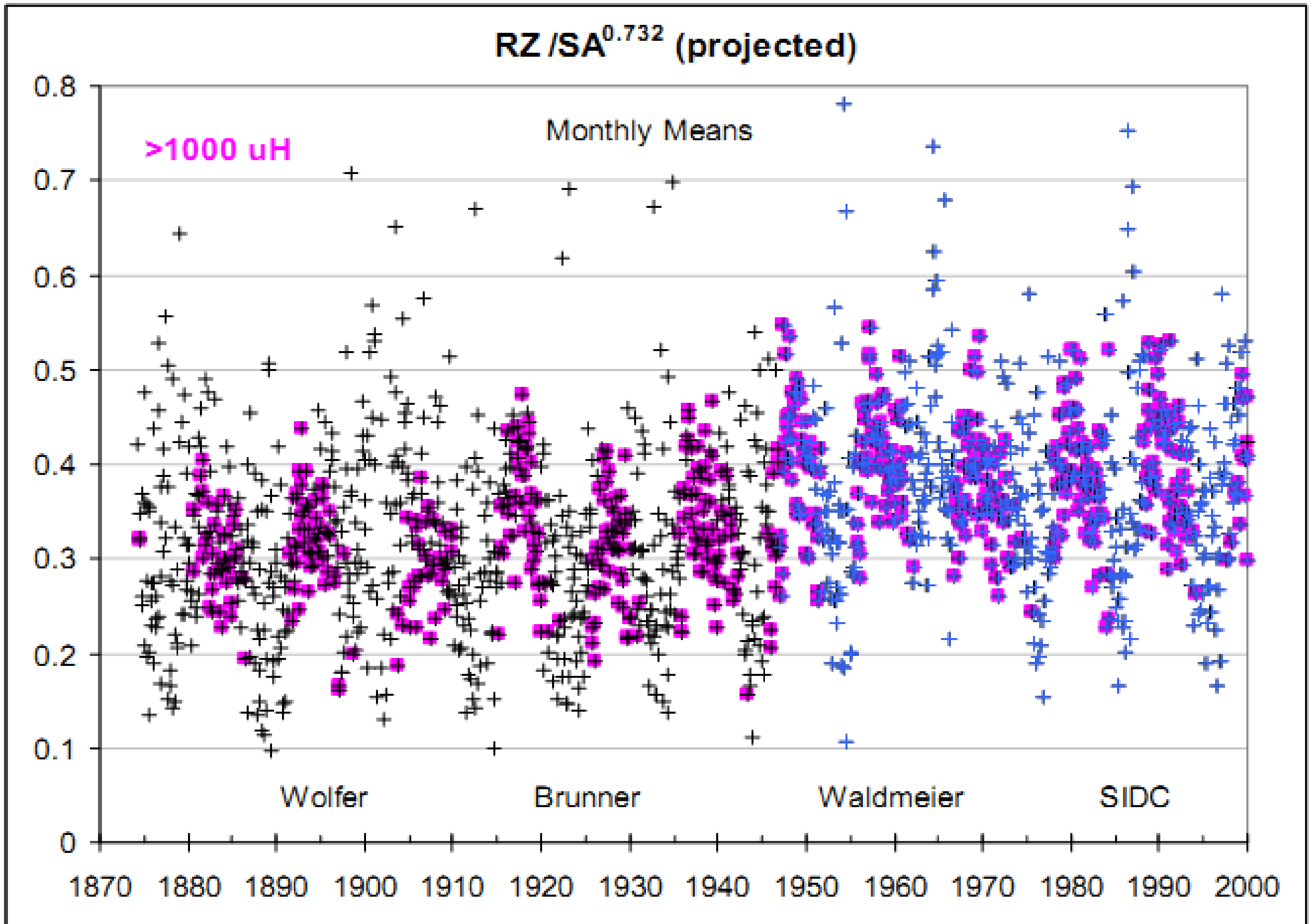
Can we see the Effect in the Data?



We can compute the ratio Rz/Rg [staying away from small values] for some decades on either side of the start of Waldmeier's tenure, assuming that Rg derived from the RGO data has no trend over that interval.

There is a clear discontinuity corresponding to a jump of a factor of 1.18 between 1945 and 1946. This compares favorably with the estimated size of the increase due to the weighting [with perhaps a very small additional influence from a greater group count]

Sunspot Areas vs. Rz

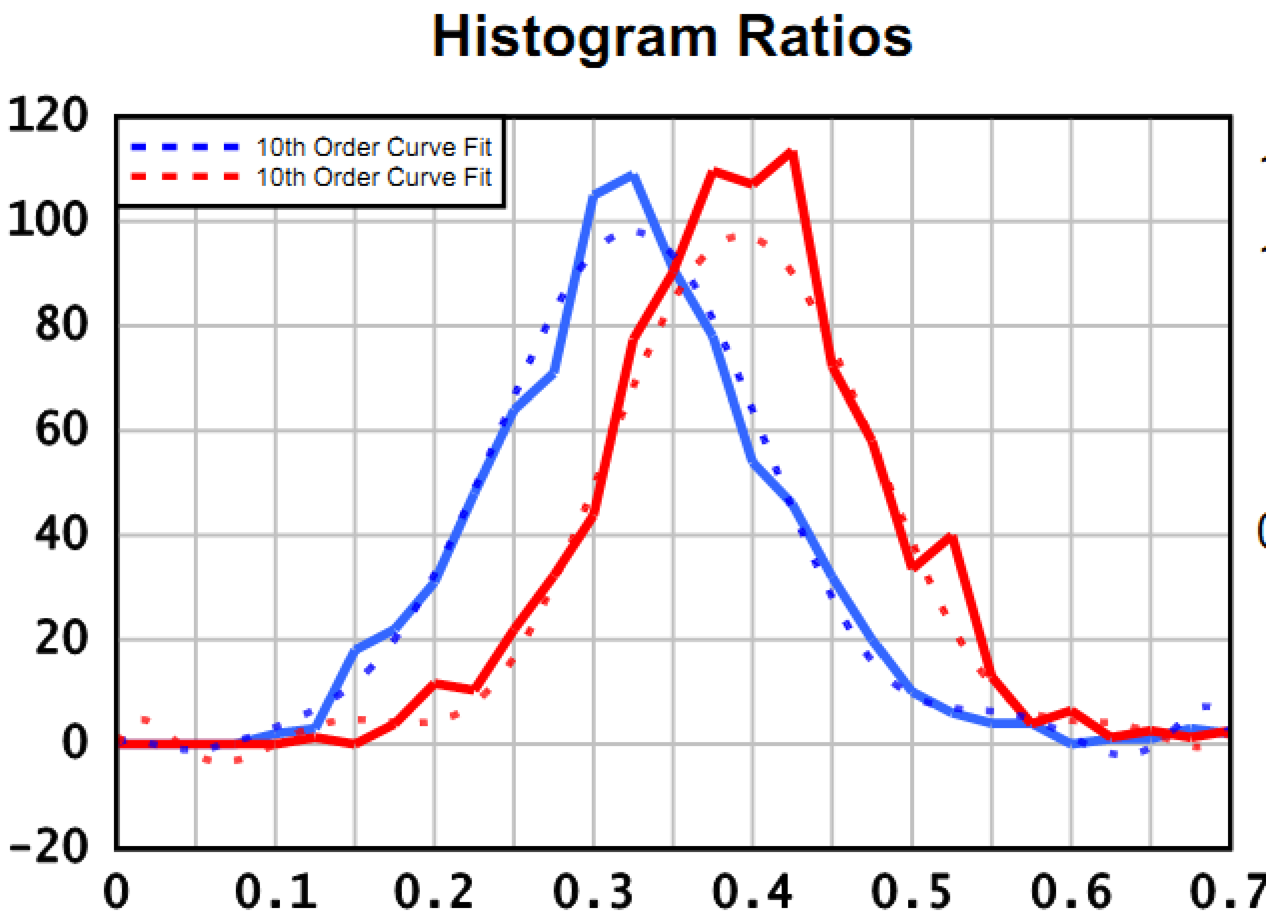


Clear change in the relationship around 1945

The relationship between sunspot number and sunspot area [SA, Balmaceda] is not linear, but can be made linear raising SA to the power of 0.732. Then taking the ratio makes sense.

Pink squares show the ratios for SA exceeding 1000 micro-hemispheres

Quantifying the Waldmeier ‘Jump’



Plotting Histograms of the ratio $Rz/SA^{0.732}$

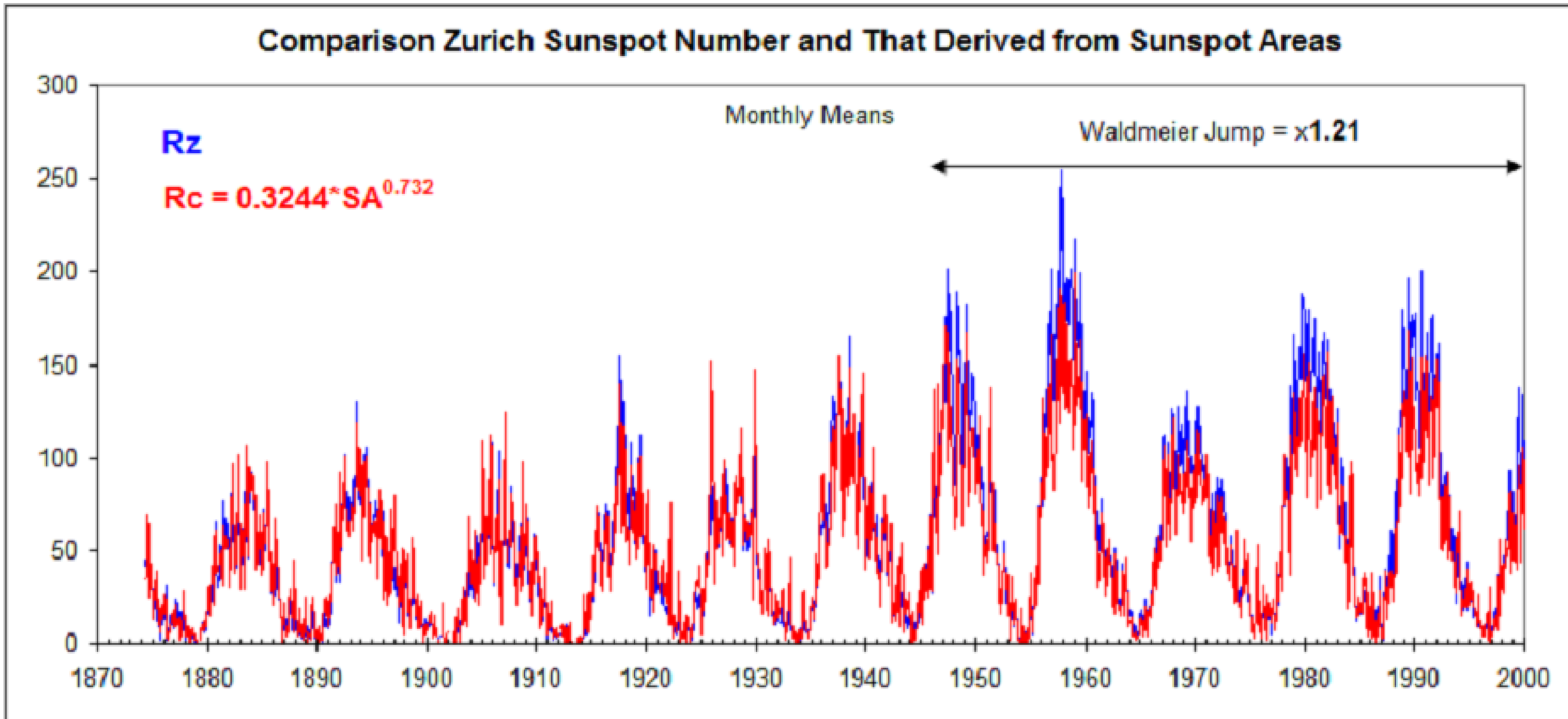
1874-1944 0.3244

1945-2000 0.3921

Waldmeier Jump

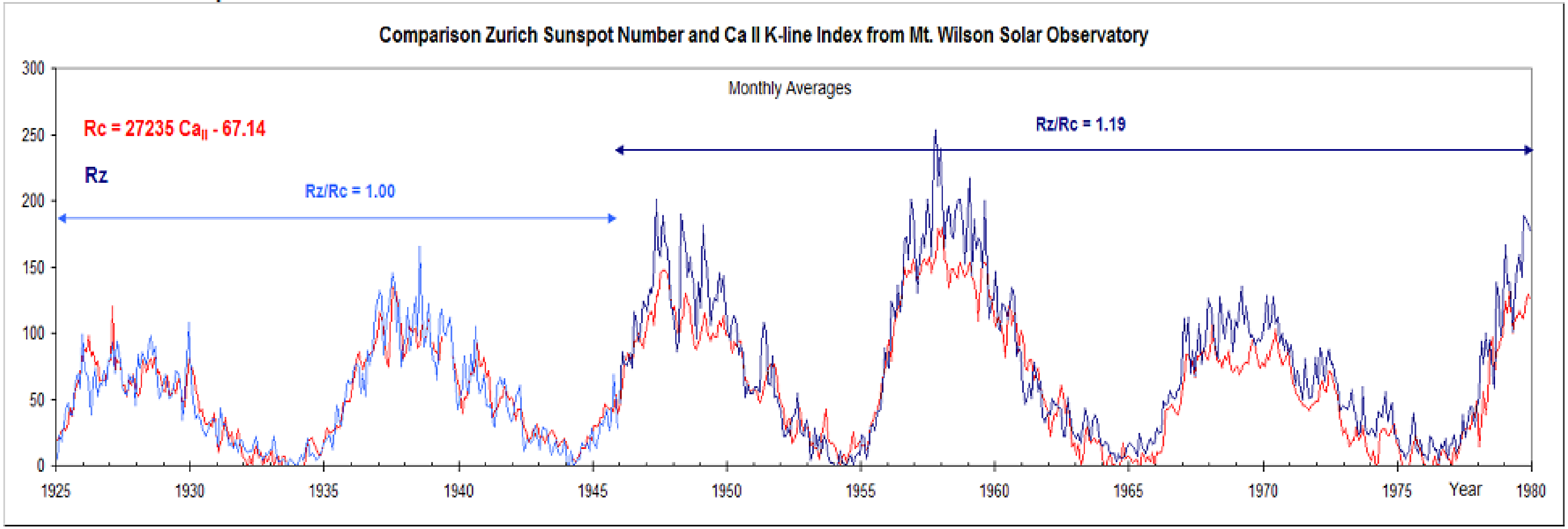
0.3921/0.3244 = **1.212**

Illustrating that Observed Rz after 1945 is Higher than Deduced from Sunspot Areas



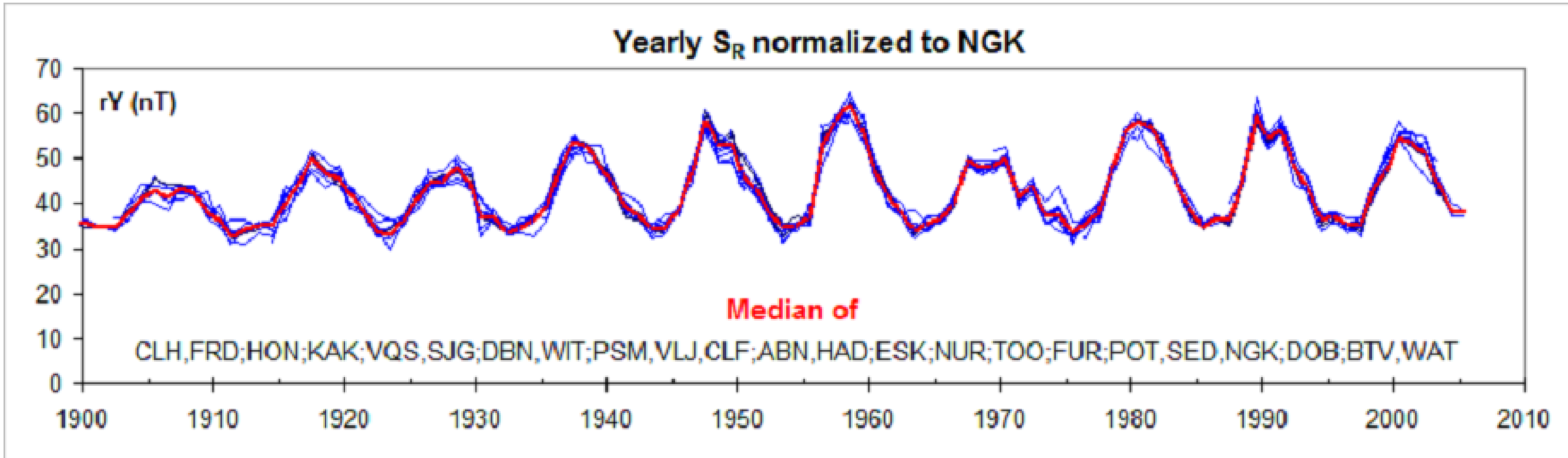
Ca II K-line Data Scaled to Rz shows similar Jump in Rz Sunspot Number after 1945

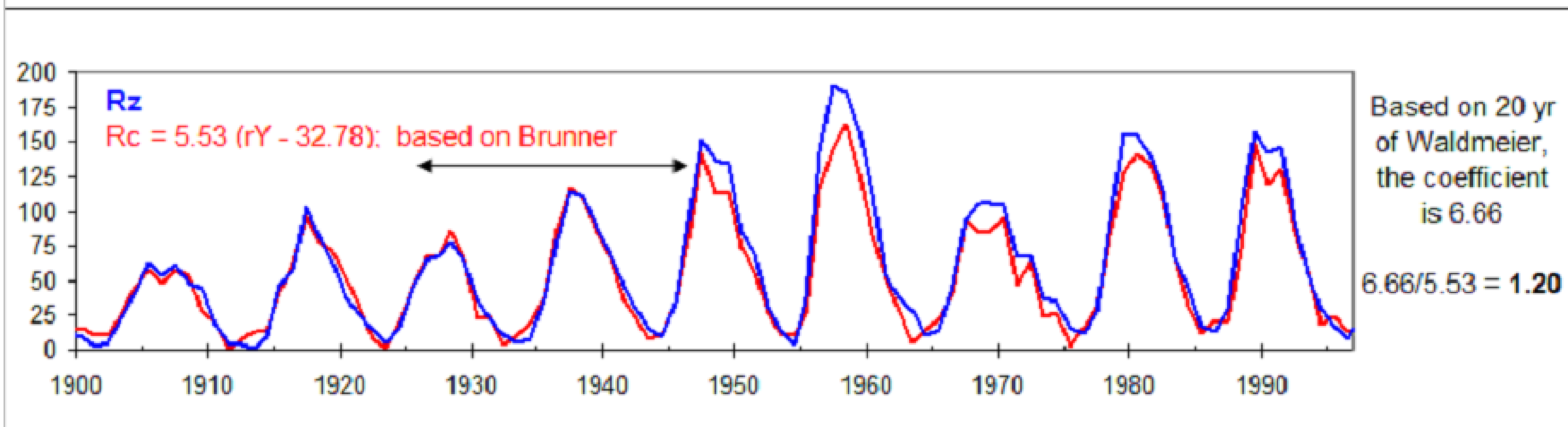
From ~40,000 CaK spectroheliograms from the 60-foot tower at Mount Wilson between 1915 and 1985, a daily index of the fractional area of the visible solar disk occupied by plages and active network has been constructed [Bertello et al., 2008]. Monthly averages of this index is strongly correlated with the sunspot number SSN = 27235 CaK – 67.14 [before 1945].

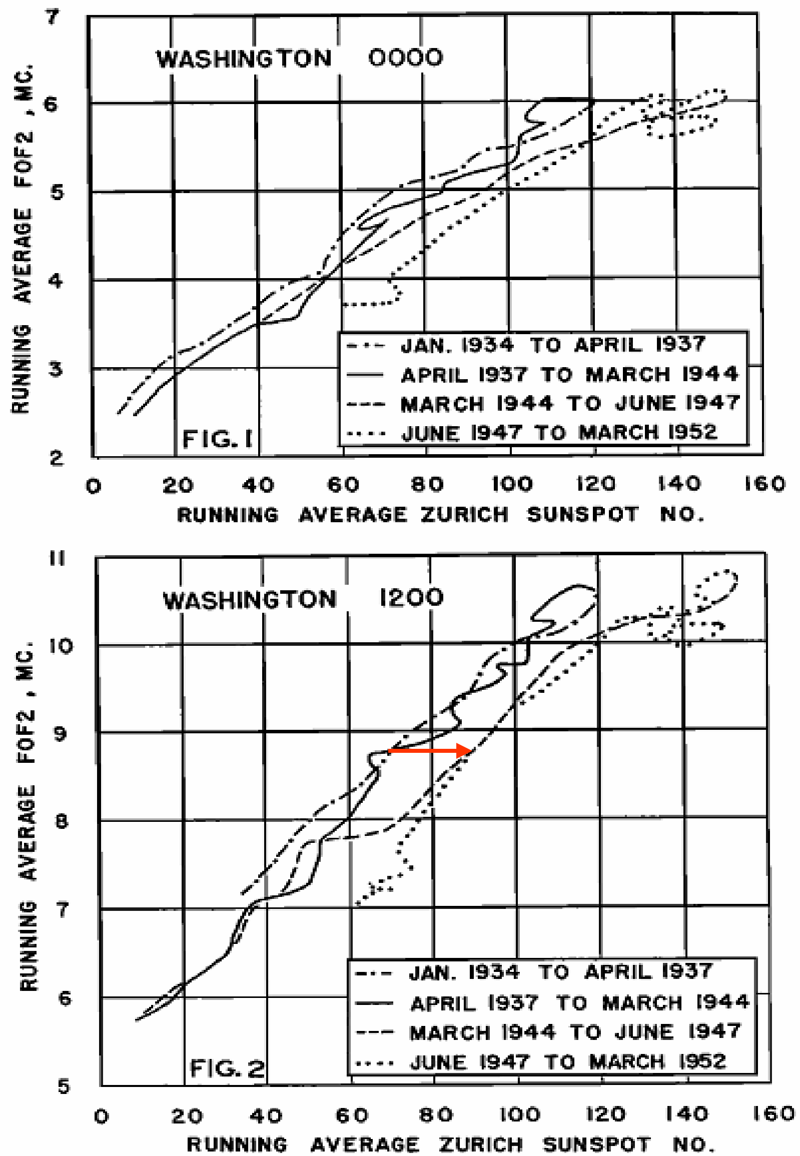


Waldmeier's Sunspot Number 19% higher than Brunner's from Ca II K-line

The Amplitude of the Diurnal Variation [from many stations] shows the same Change ~1945







FIGS. 1 AND 2—PLOT OF 12-MONTH RUNNING AVERAGE OF MONTHLY MEDIAN f^oF2 AGAINST 12-MONTH RUNNING AVERAGE OF MONTHLY ZURICH SUNSPOT NUMBER, LOCAL TIME

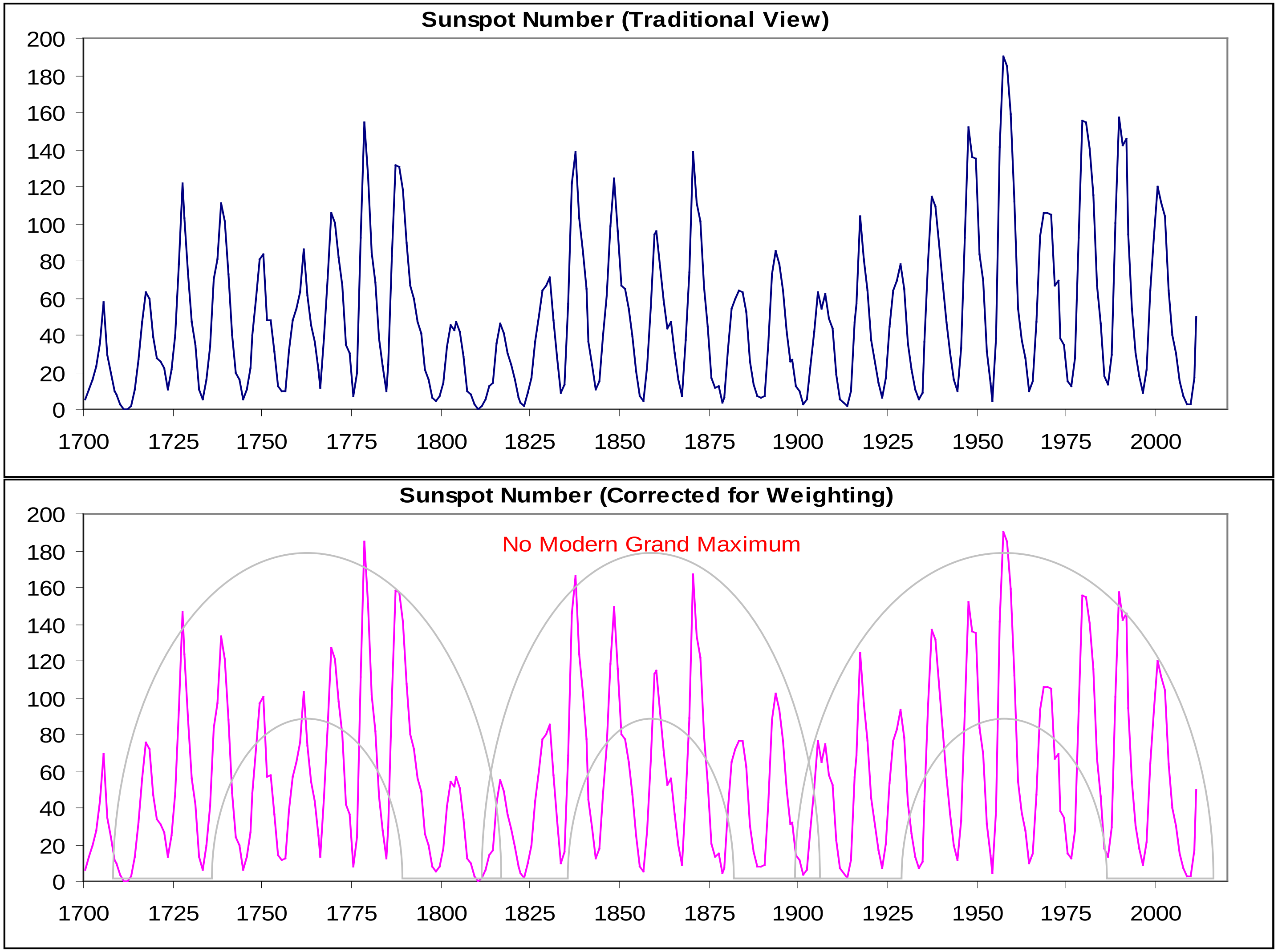
foF2

F2-layer critical frequency. This is the maximum radio frequency that can be reflected by the F2-region of the ionosphere at vertical incidence (that is, when the signal is transmitted straight up into the ionosphere). And has been found to have a profound solar cycle dependence.

The shift in SSN to bring the curves to overlap is 21%

So, many lines of evidence point to an about 20% Waldmeier Weighting Effect

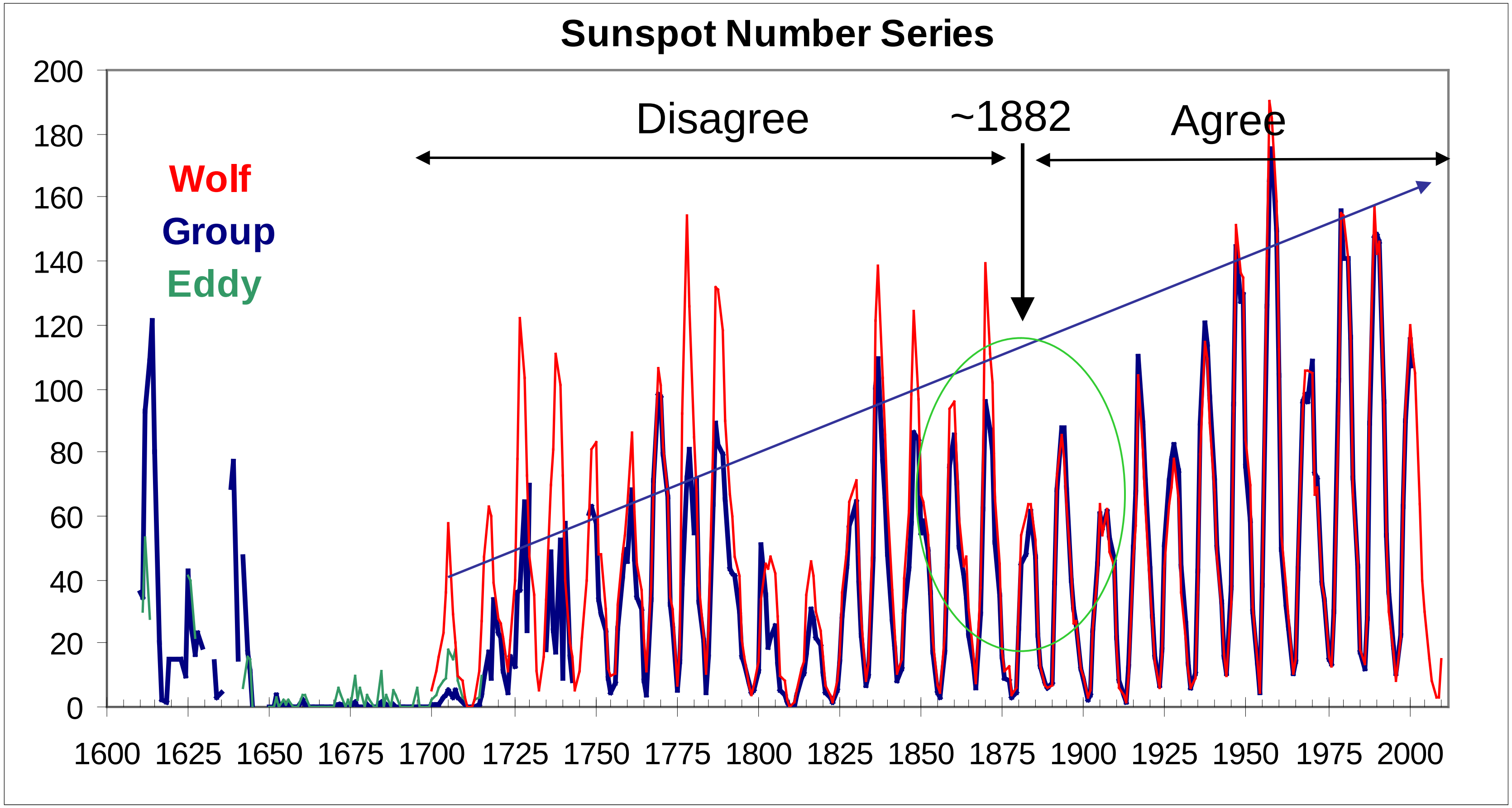
The Effect on the Sunspot Curve



No long-term trend the last 300 years

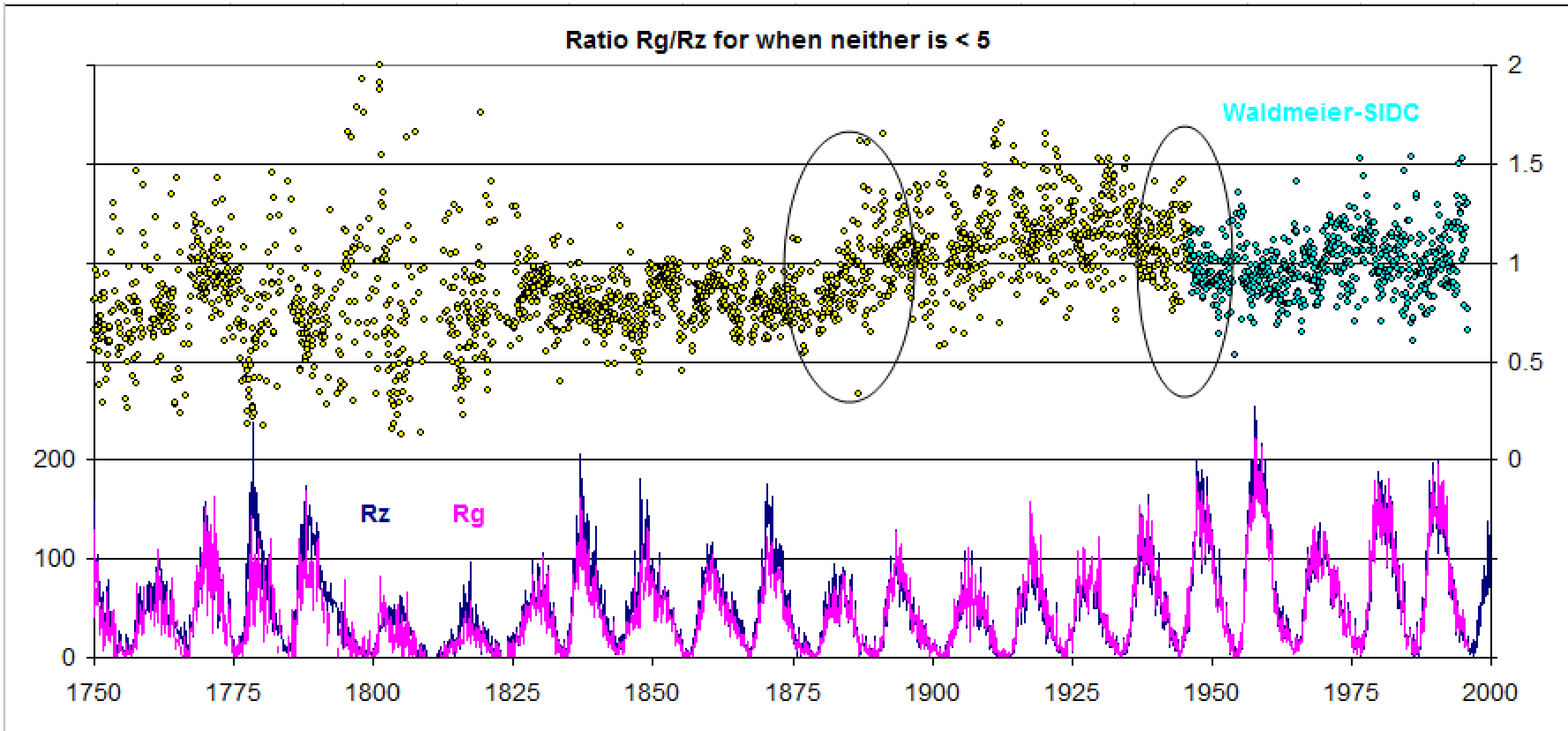
What is Wrong with the Group Sunspot Number and How to Fix it

The Problem: Two Sunspot Series



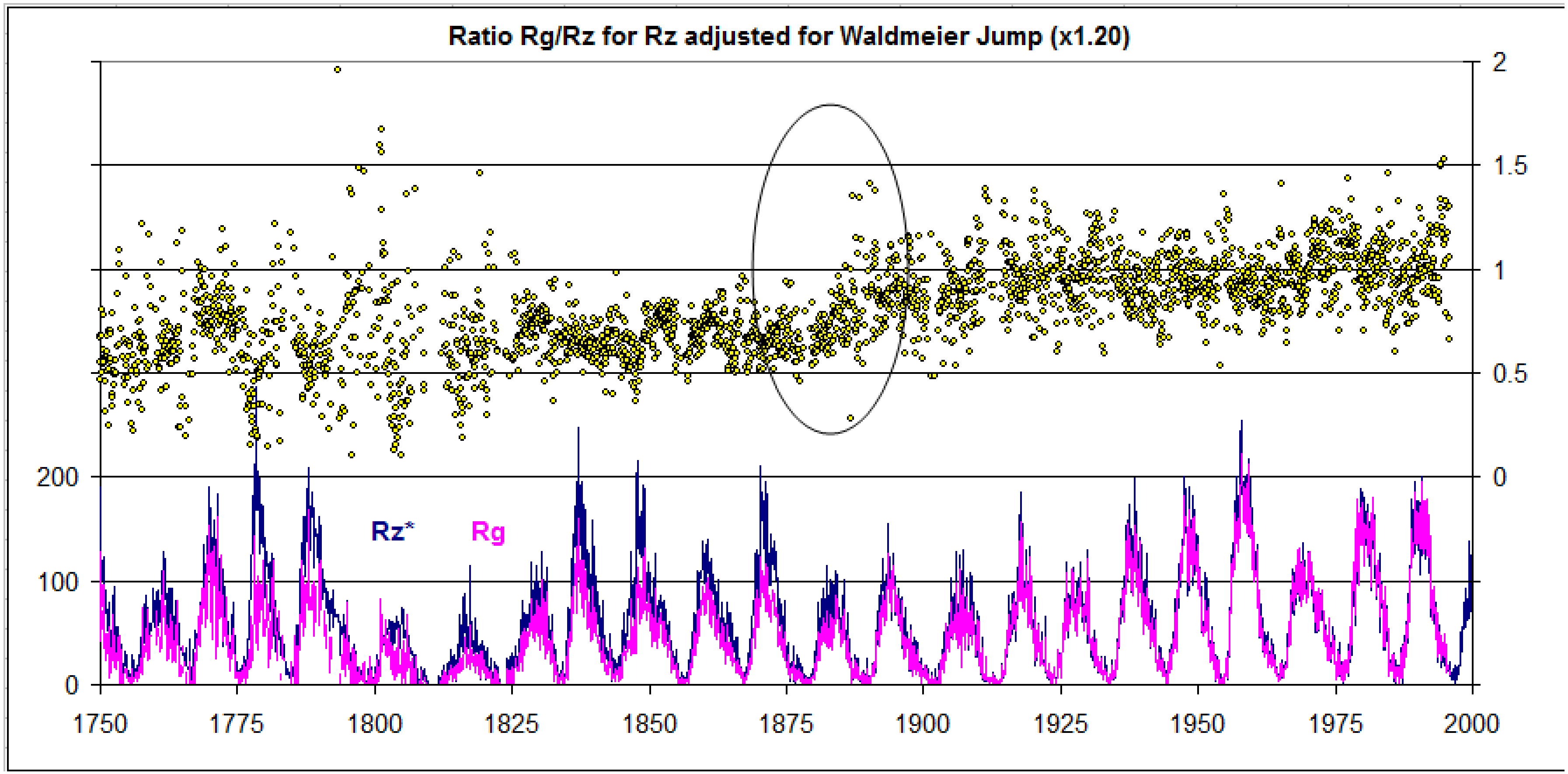
Researchers tend to cherry-pick the one that supports their pet theory the best – this is not a sensible situation. We should do better.

The Ratio Group/Zurich SSN has Two Significant Discontinuities



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

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}

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:
$R_{Group} = 12\ K\ G$ [summed 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:

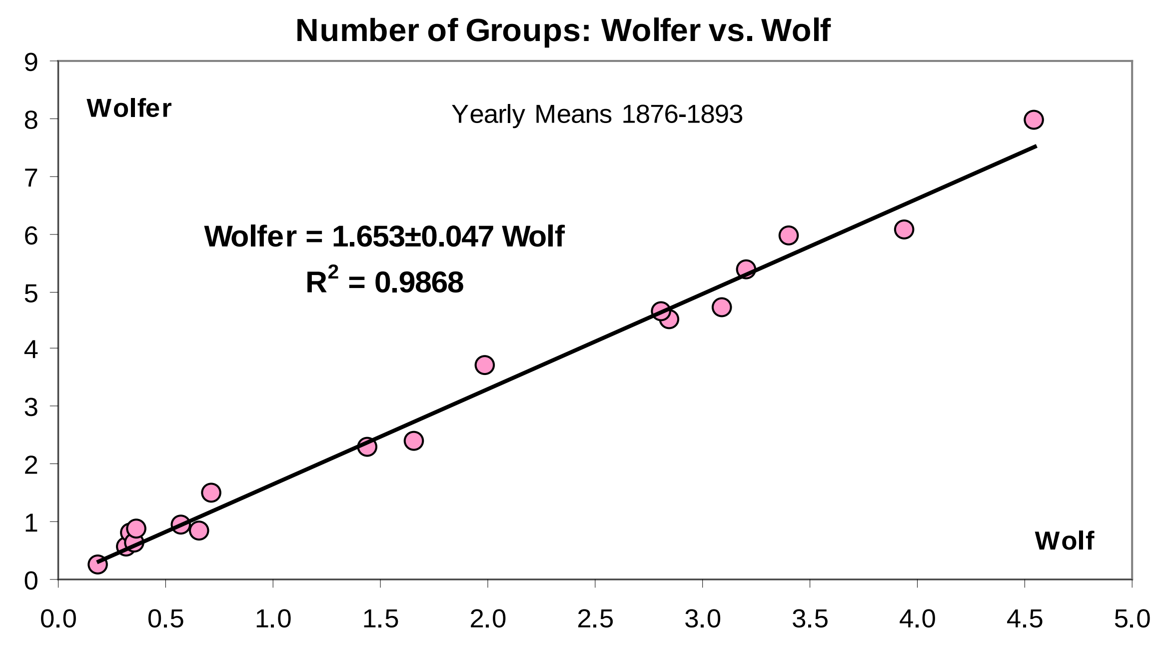
1864-1893 Johann Rudolf Wolf (1816-1893)
1894-1926 Alfred Wolfer (1854-1931)
1926-1945 William Otto Brunner (1878-1958)
1945-1979 Max Waldmeier (1912-2000)

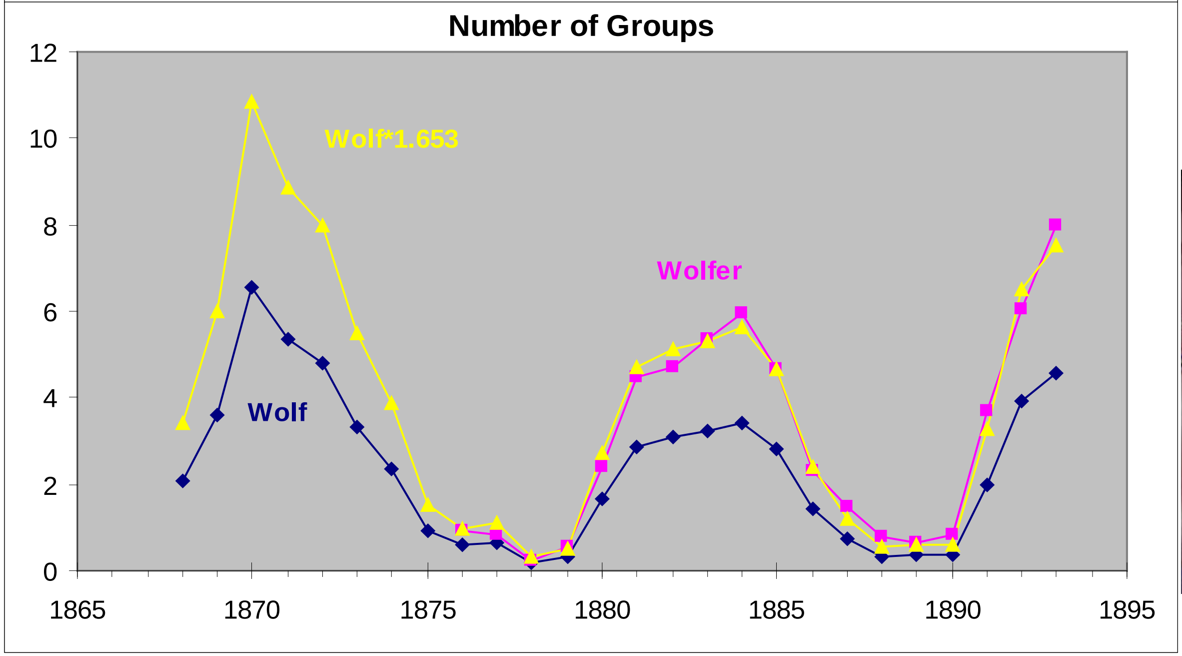
Wolfer was Wolf’s assistant 1876-1893 so we have lots of overlapping data

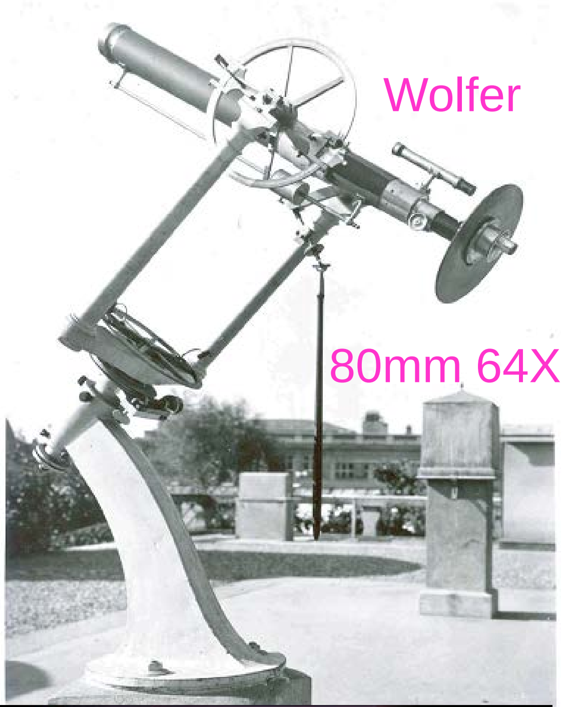
Wolfer’s Change to Wolf’s Counting Method

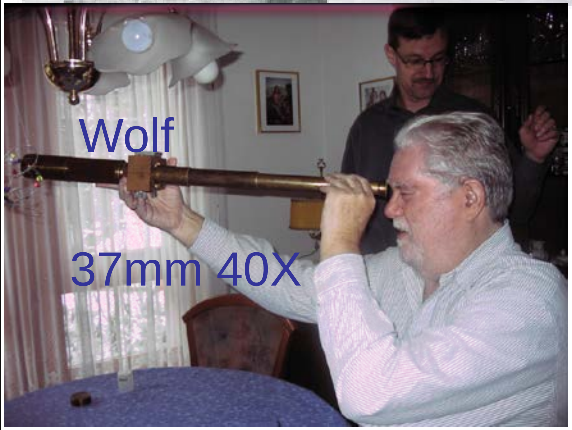
- Wolf only counted spots that were ‘black’ and would have been clearly visible even with moderate seeing
- His successor Wolfer disagreed, and pointed out that the above criterion was much too vague and instead advocating counting every spot that could be seen
- This, of course, introduces a discontinuity 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



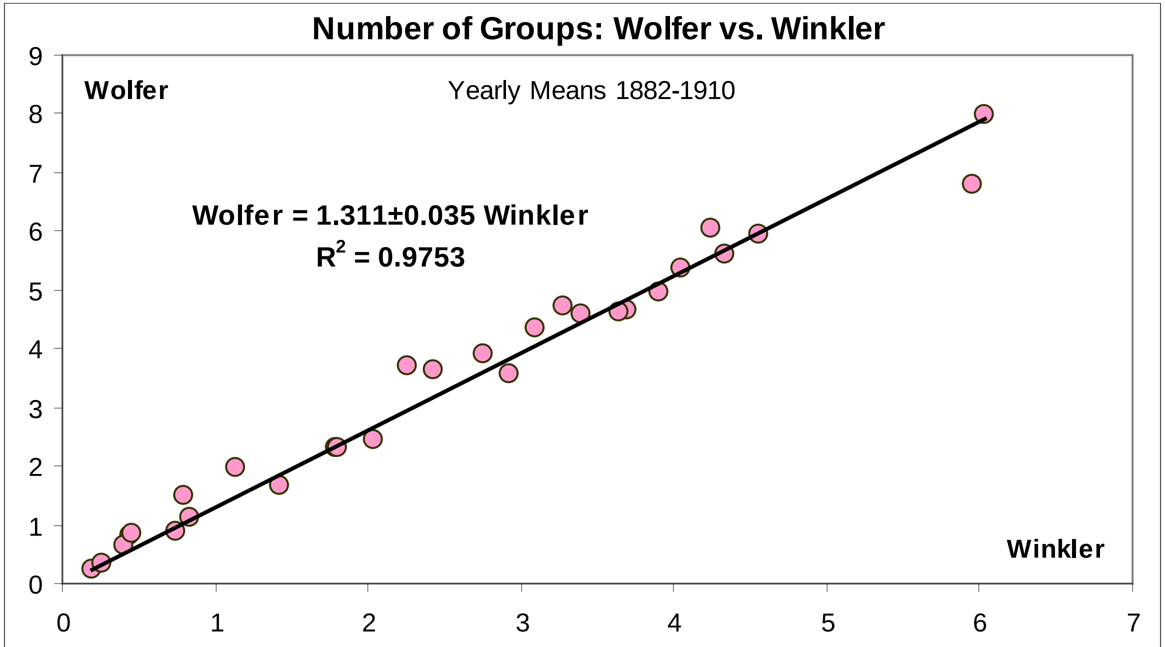


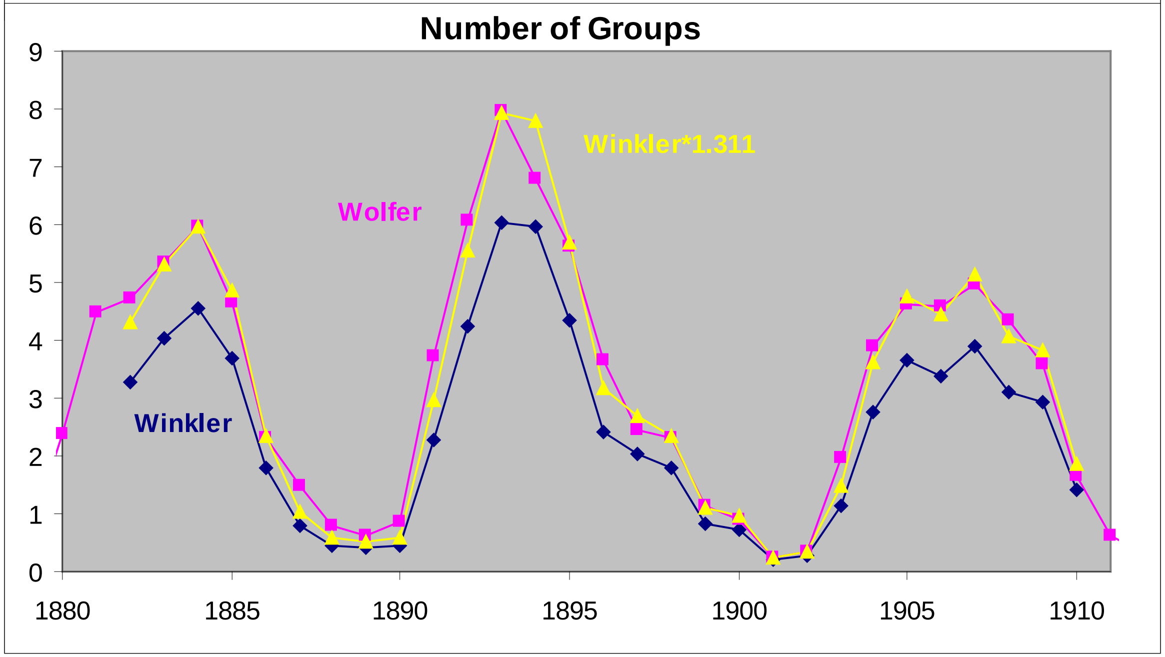




The K-factor shows in daily values too

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**

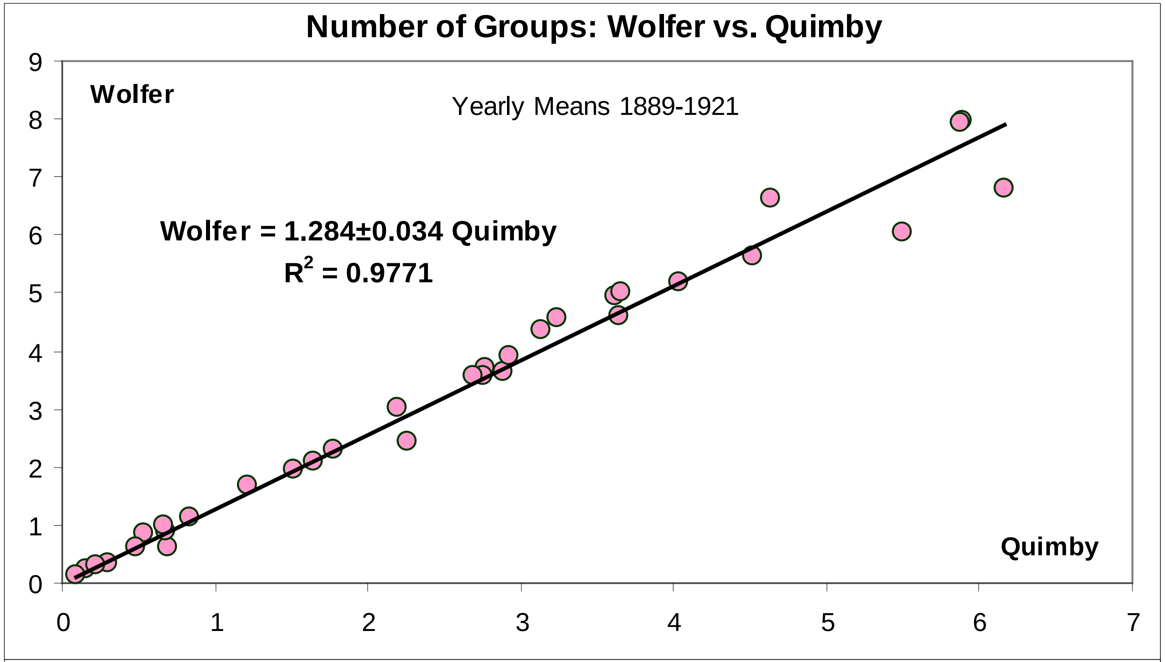


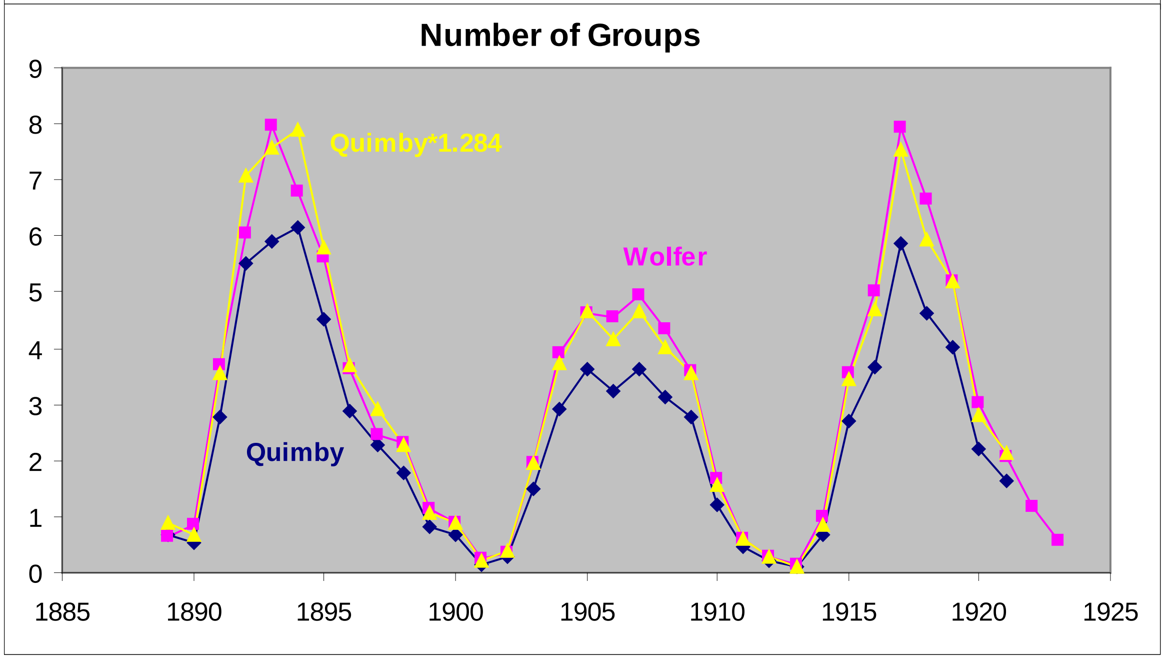


We can make the same type of comparison between observers Winkler and Wolfer

Again, we see a strong correlation indicating homogenous data

Again, scaling by the slope yields a good fit





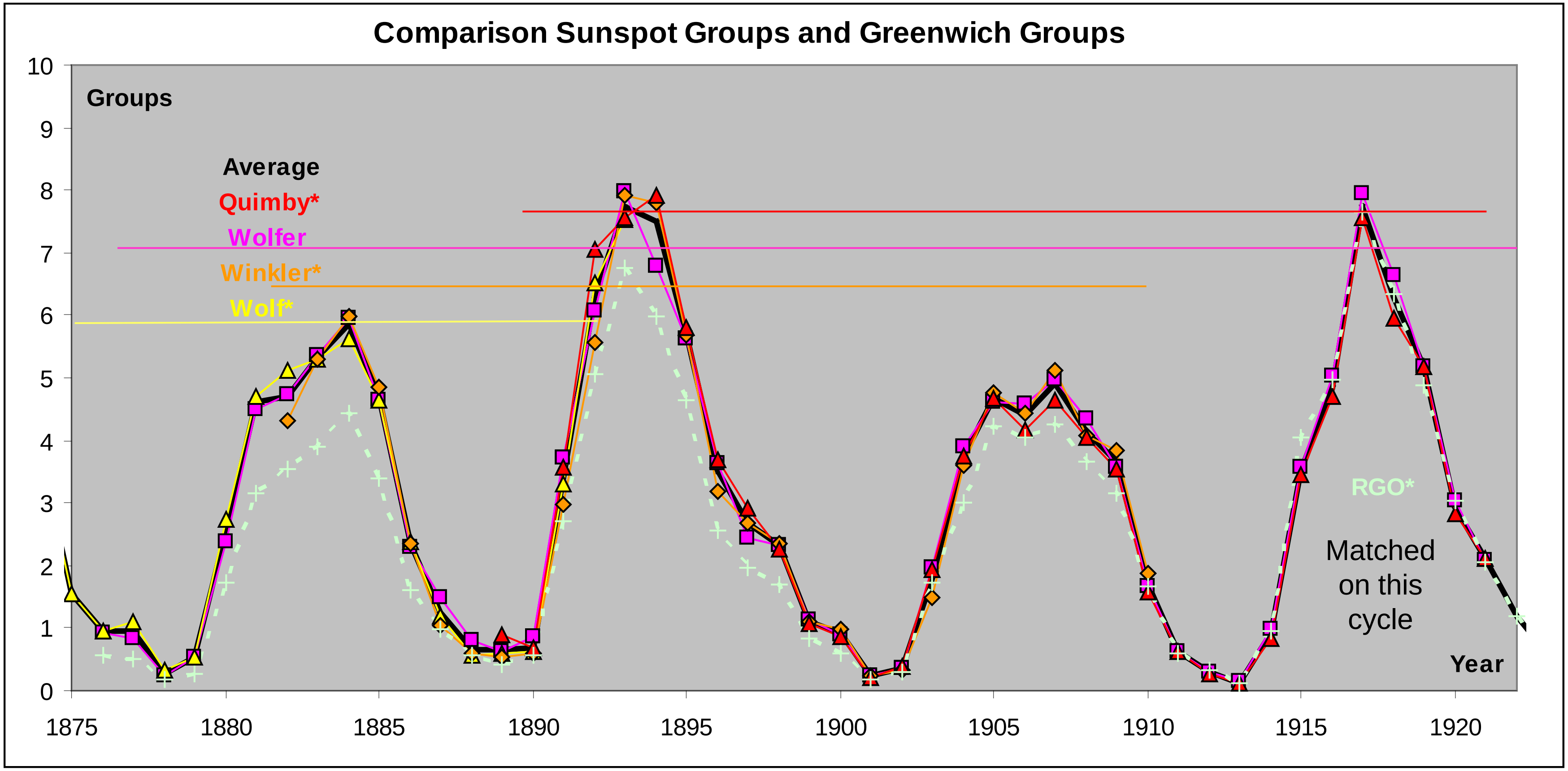
And between Rev. A. Quimby [Philadelphia] and Wolfer

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.

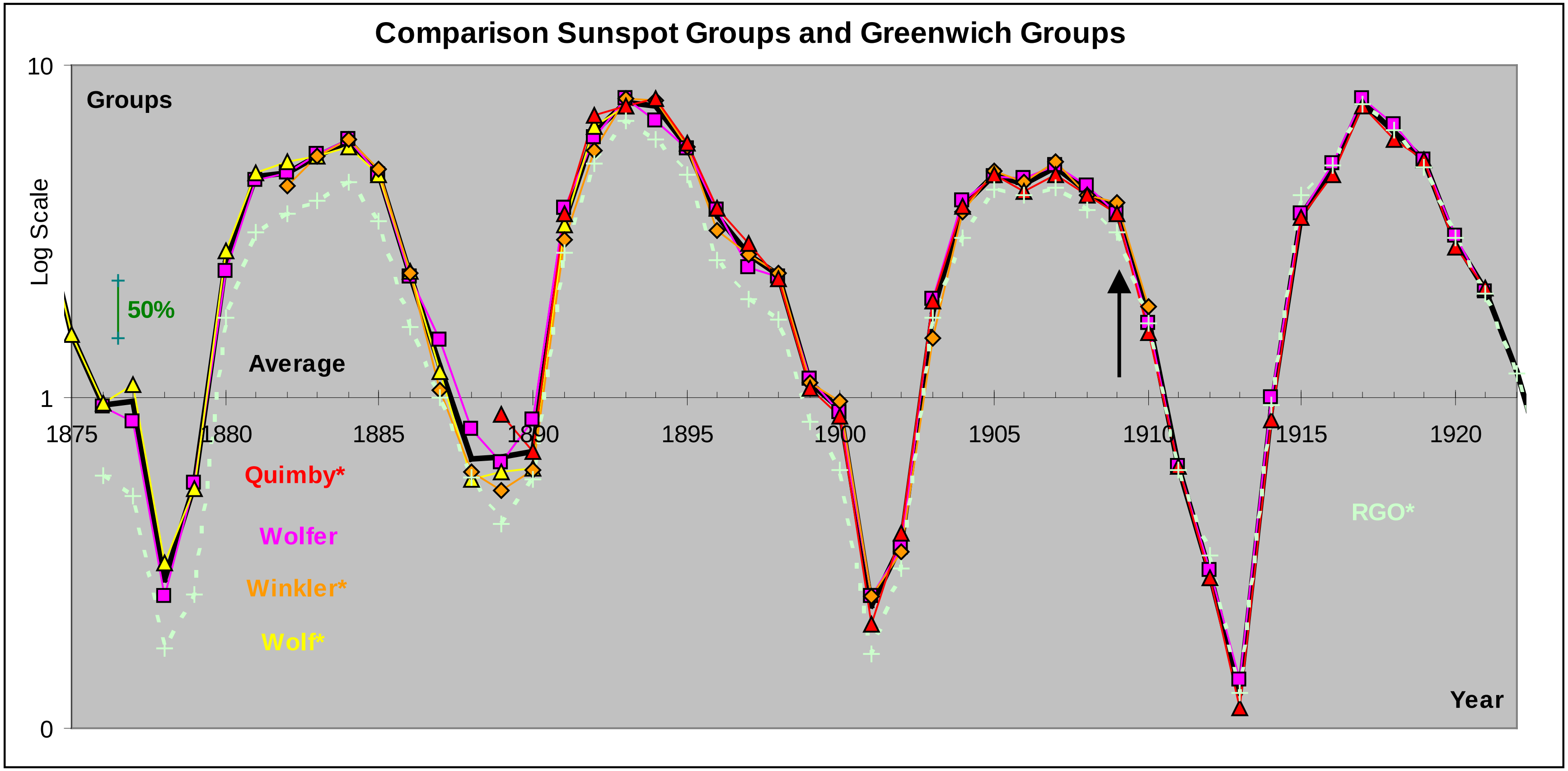
The Rumrill data has been considered lost, but I have just recently found the person that has all the original data.

Making a Composite



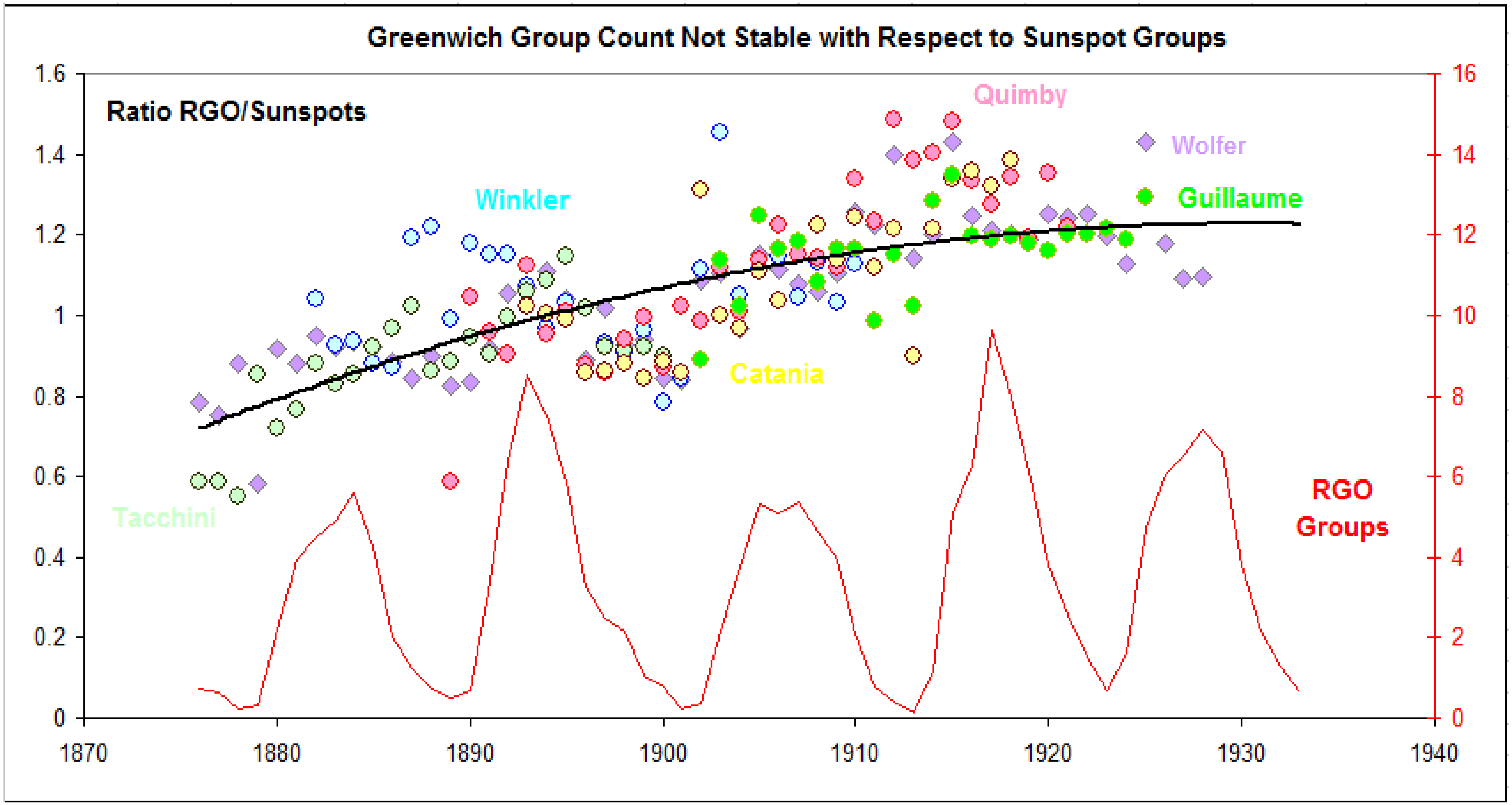
Compare with group count from RGO [dashed line] and note its drift

Composite on Logarithmic scale



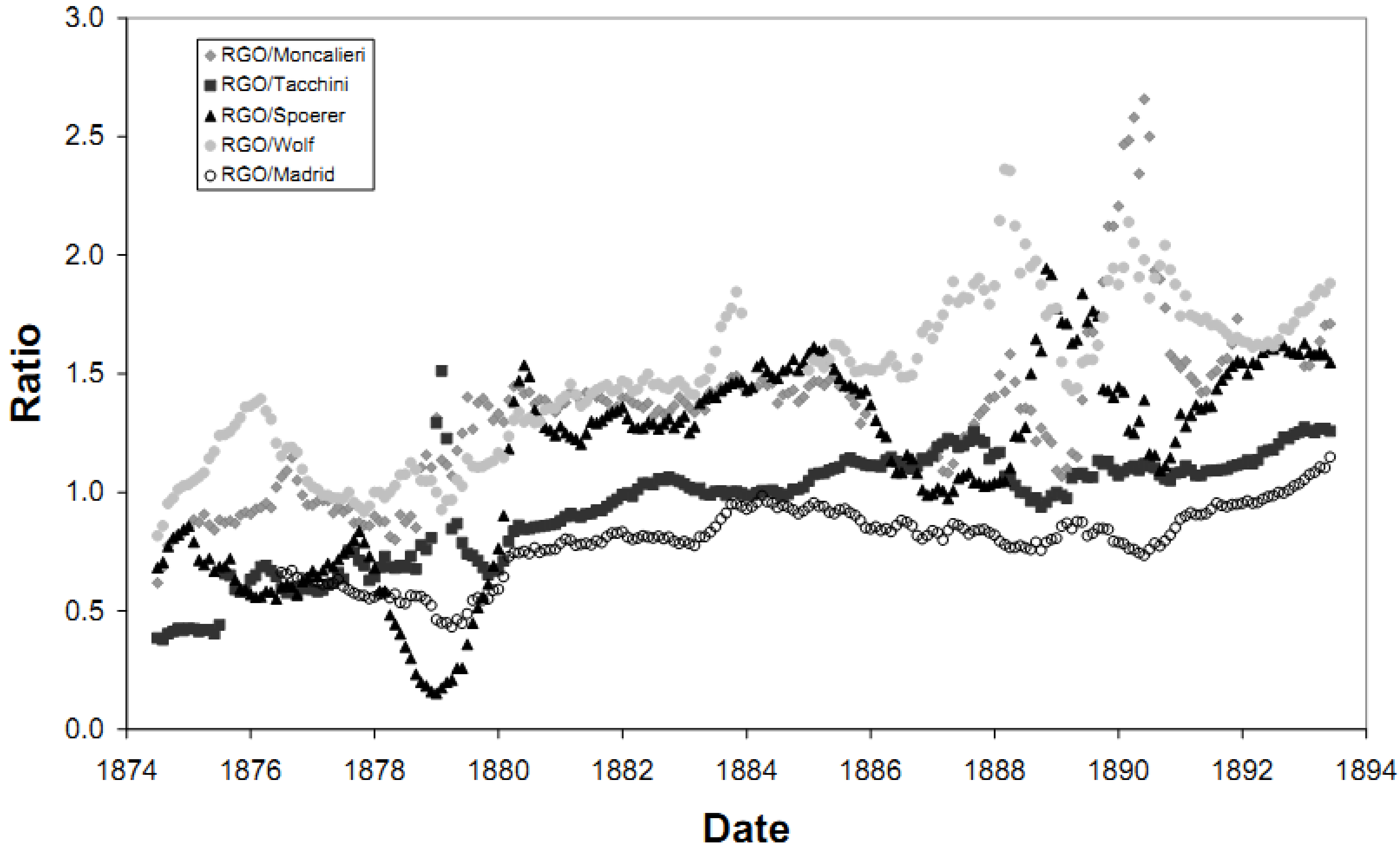
Note that the discrepancy between the composite and RGO approaches 50%

RGO Groups/Sunspot Groups



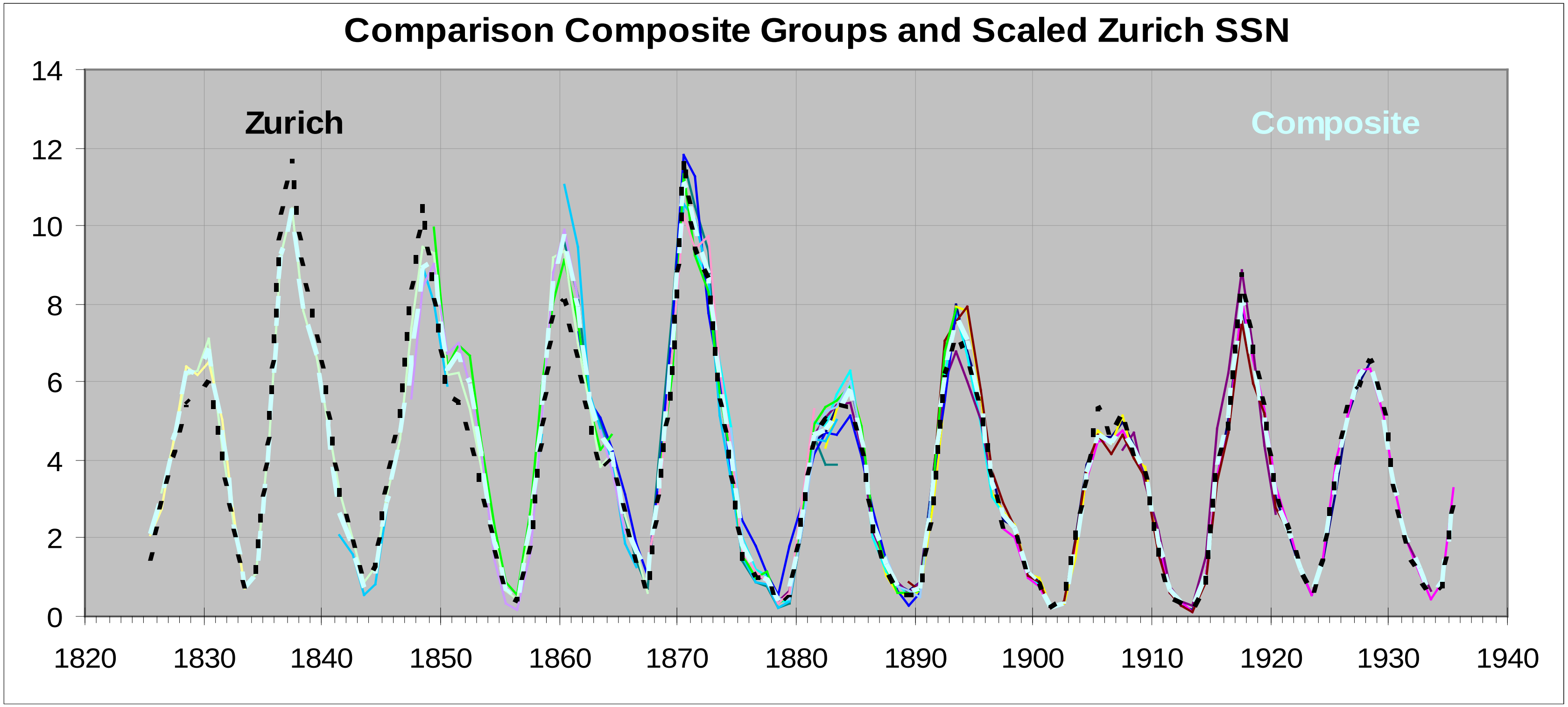
Early on RGO count fewer groups than the Sunspot Observers. There was a significant fraction of days with no observations. H&S count these days as having a group count of zero

Confirmed by José Vaquero



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:



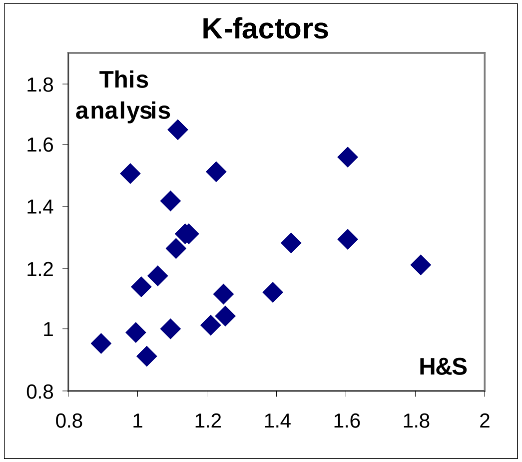
There is now no systematic difference between the Zurich SSN and a Group SSN constructed by not involving RGO.

Why are these so different?

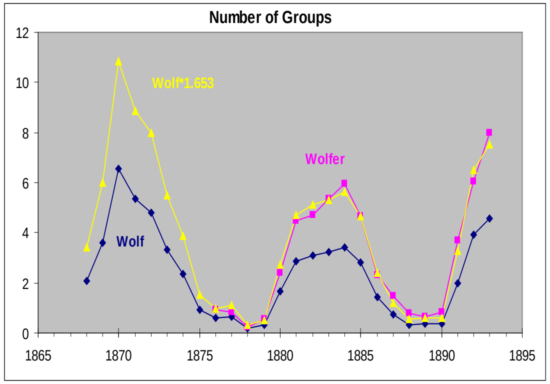
K-Factors

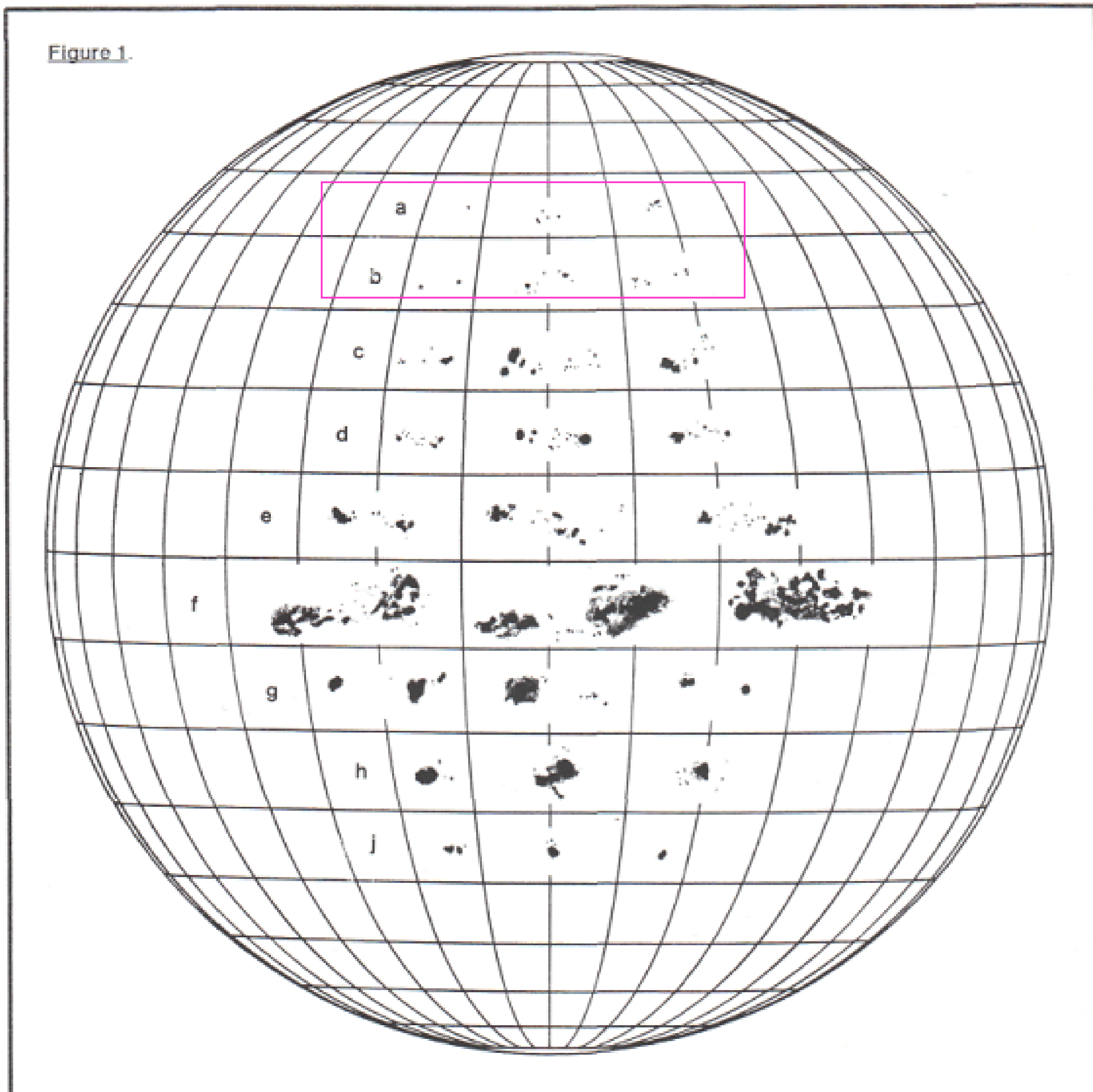
2% diff.

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, 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

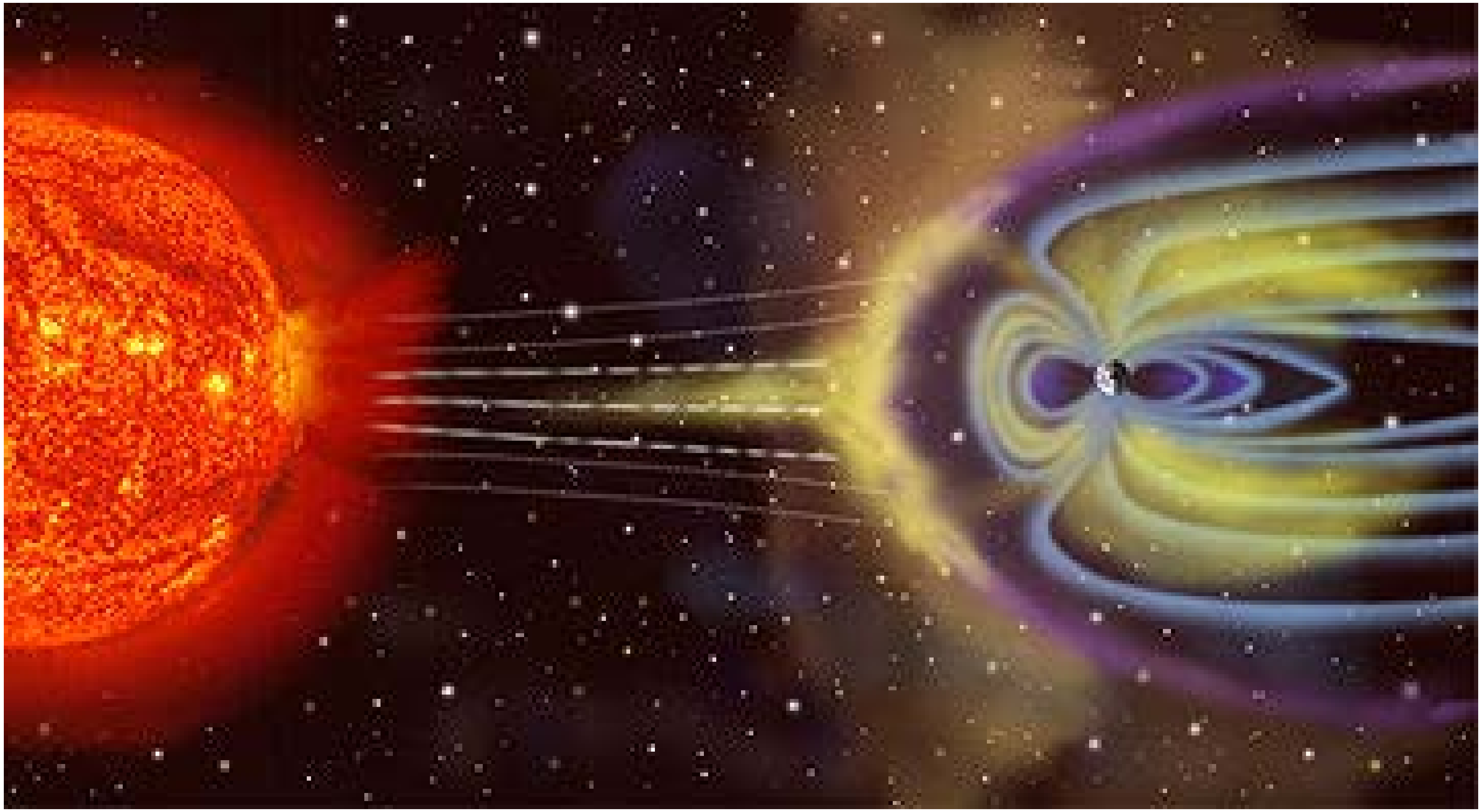
- H&S calculated their K-factor for an observer to RGO using only days when there was at least one spot seen by the observer
- This systematically removes about the lower half of the distribution for times of low solar activity
- Thus skews the K-factors
- This is the main reason for the discrepancy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

Geomagnetic Calibration of Sunspot Numbers

Wolf’s Several Lists of SSNs

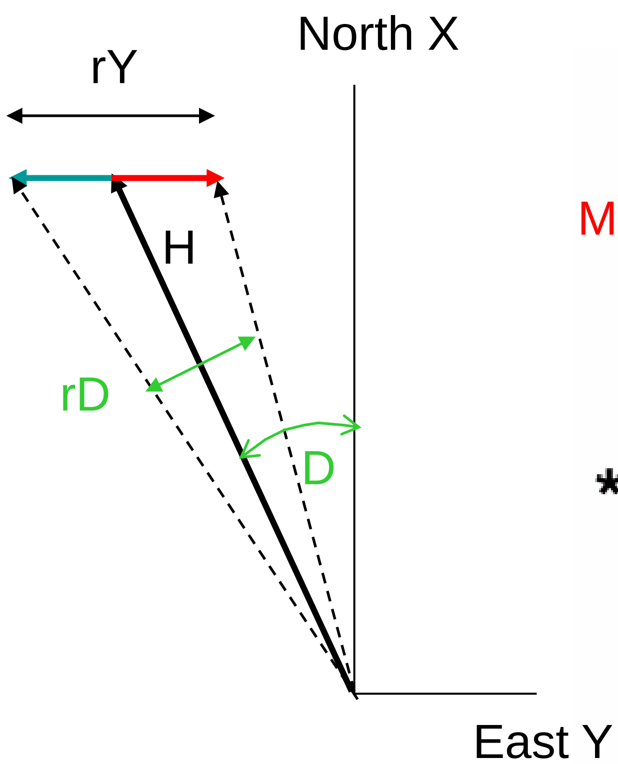
- During his life Wolf published several lists of his ‘Relative Sunspot Number’:
- 1857 Using Sunspot Drawings By Staudacher 1749-1799 as early SSNs
- 1861 Doubling Staudacher’s Numbers to align with the large variation of the Magnetic ‘Needle’ in the 1780s
- 1874 Adding newer data and published list
- 1880 Increasing all values before his own series [beginning 1849] by ~25% based on Milan Declination
- 1902 [Wolfer] reassessment of cycle 5 reducing it significantly, obtaining the ‘Definitive’ List in use today

Geomagnetic Regimes



1) Solar FUV maintains the ionosphere and influences the daytime field.
2) Solar Wind creates the magnetospheric tail and influences the nighttime field

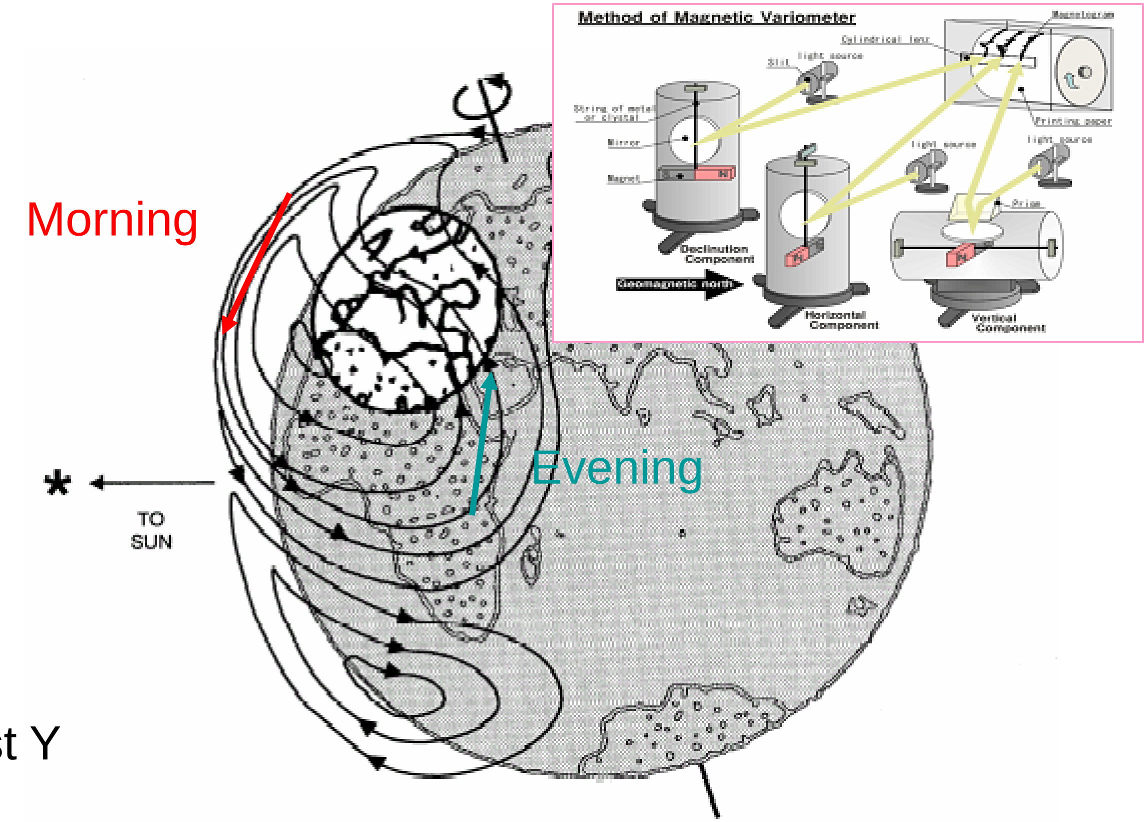
Justification of the Adjustments rests on Wolf's Discovery: $rD = a + b\ R_W$



$$Y = H \sin(D)$$

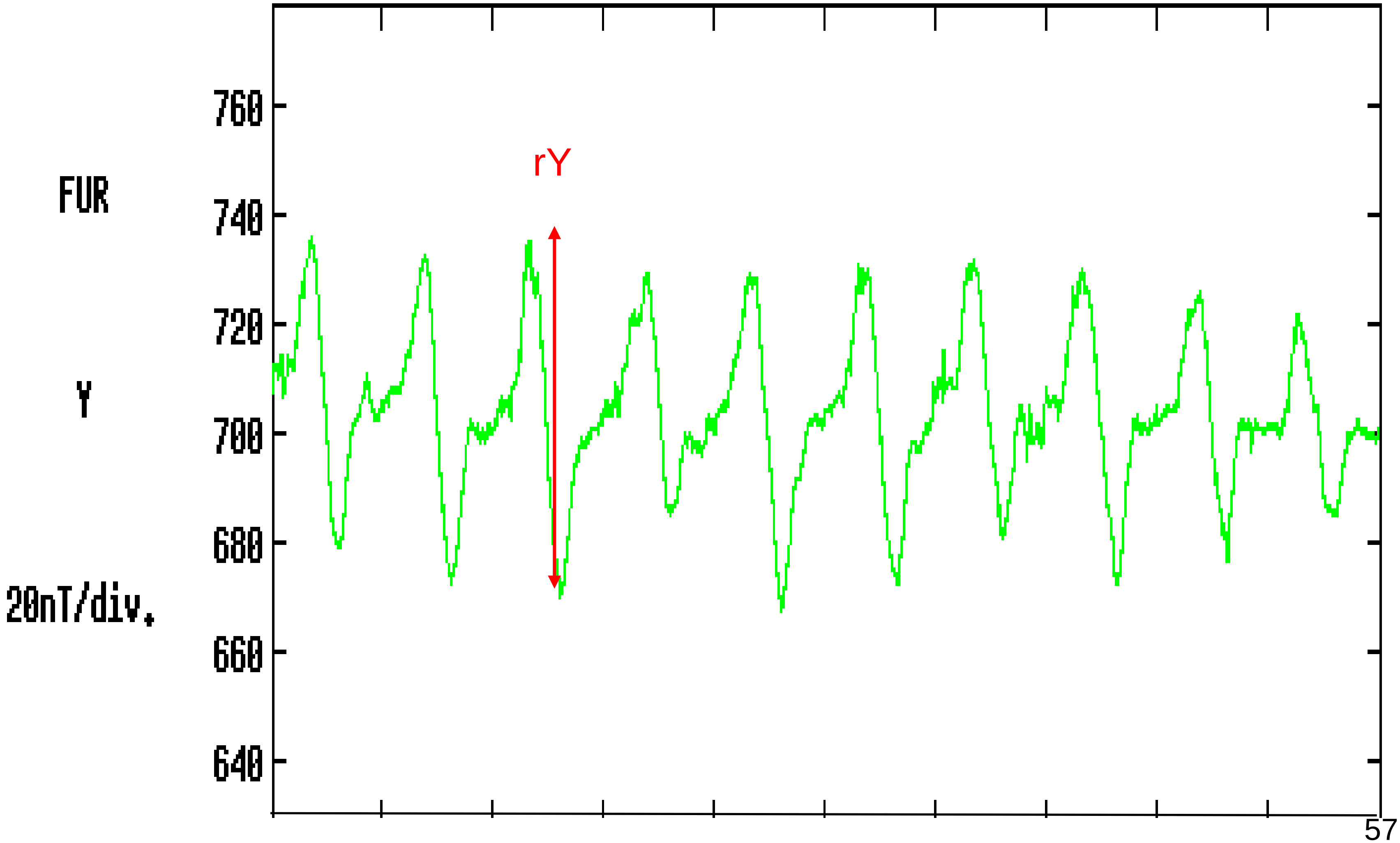
$$dY = H \cos(D)\ dD$$

For small D, dD and dH

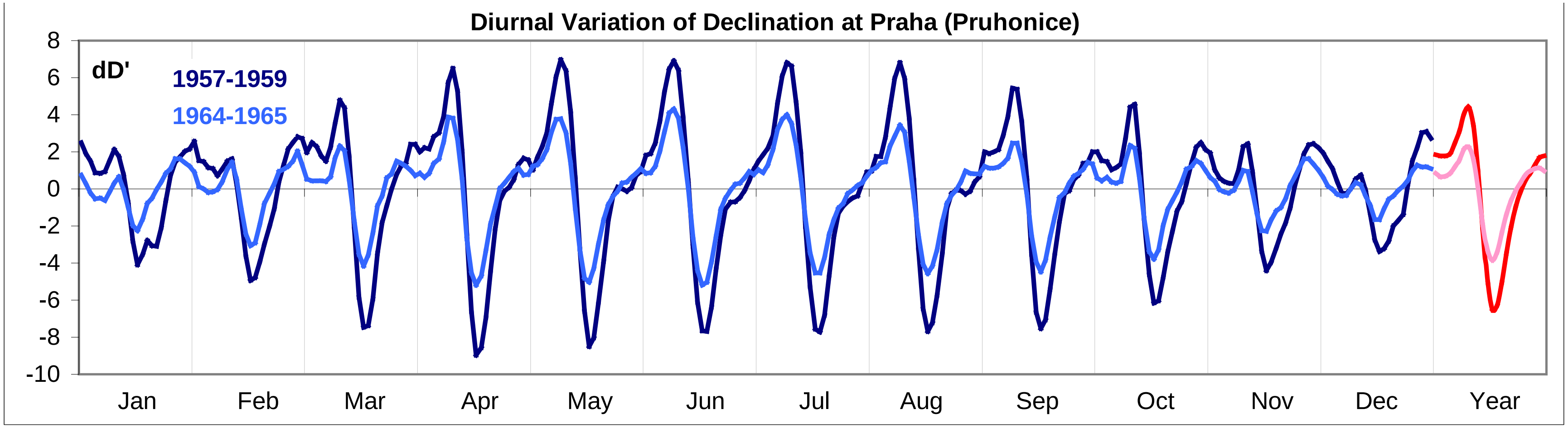


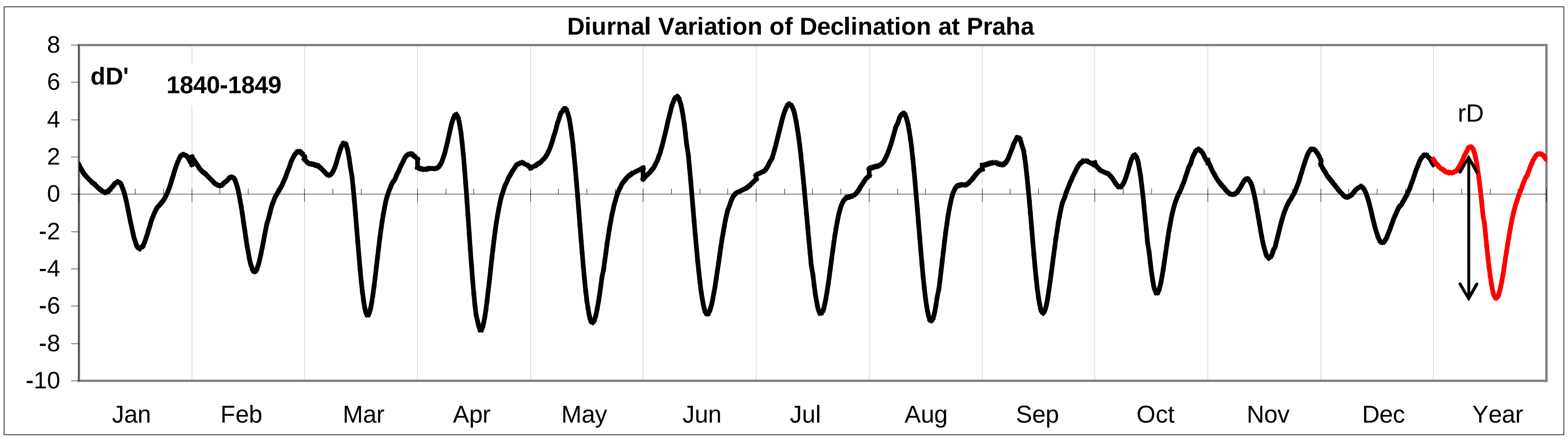
A current system in the ionosphere [E-layer] is created and maintained by solar FUV radiation. Its magnetic effect is measured on the ground.

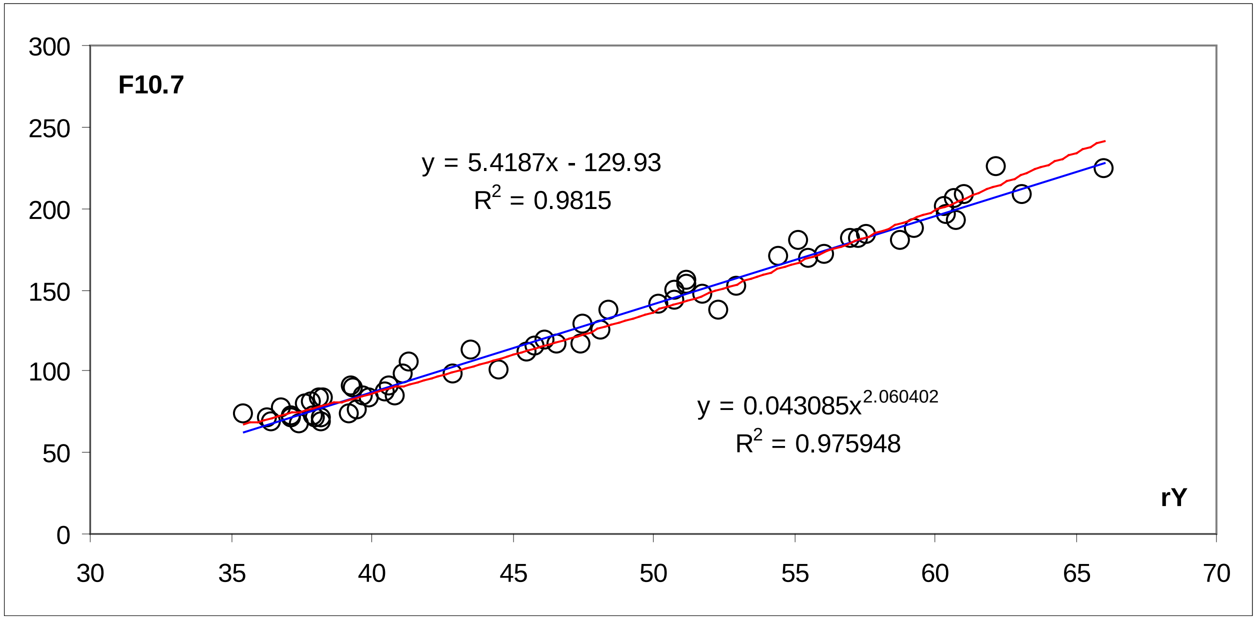
10 Days of geomagnetic variations



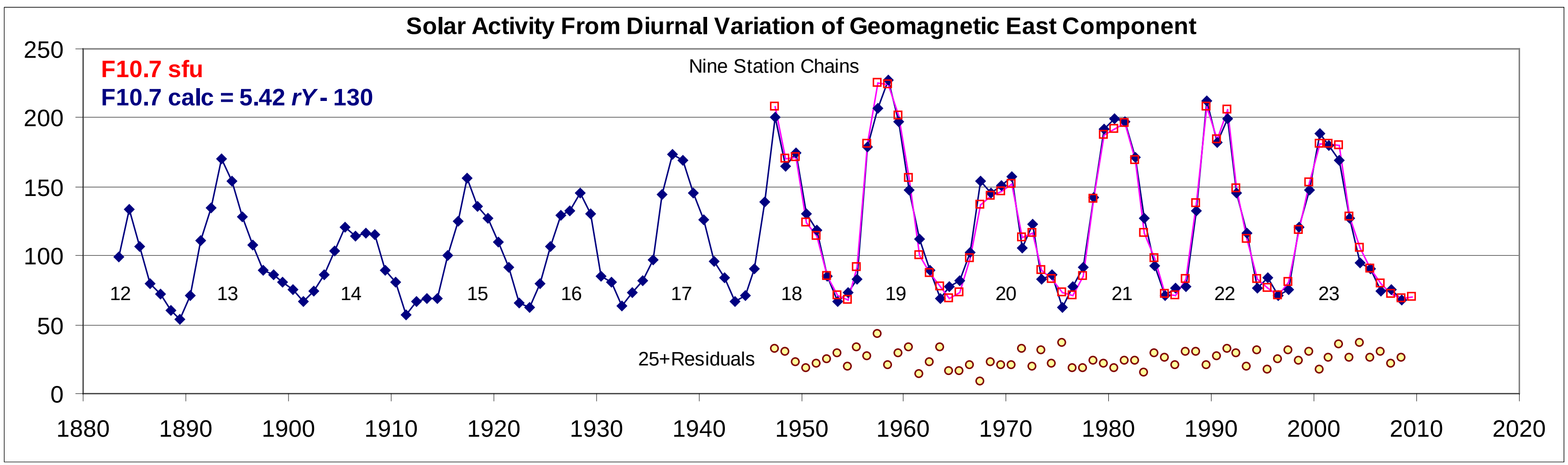
The Diurnal Variation of the Declination for Low, Medium, and High Solar Activity





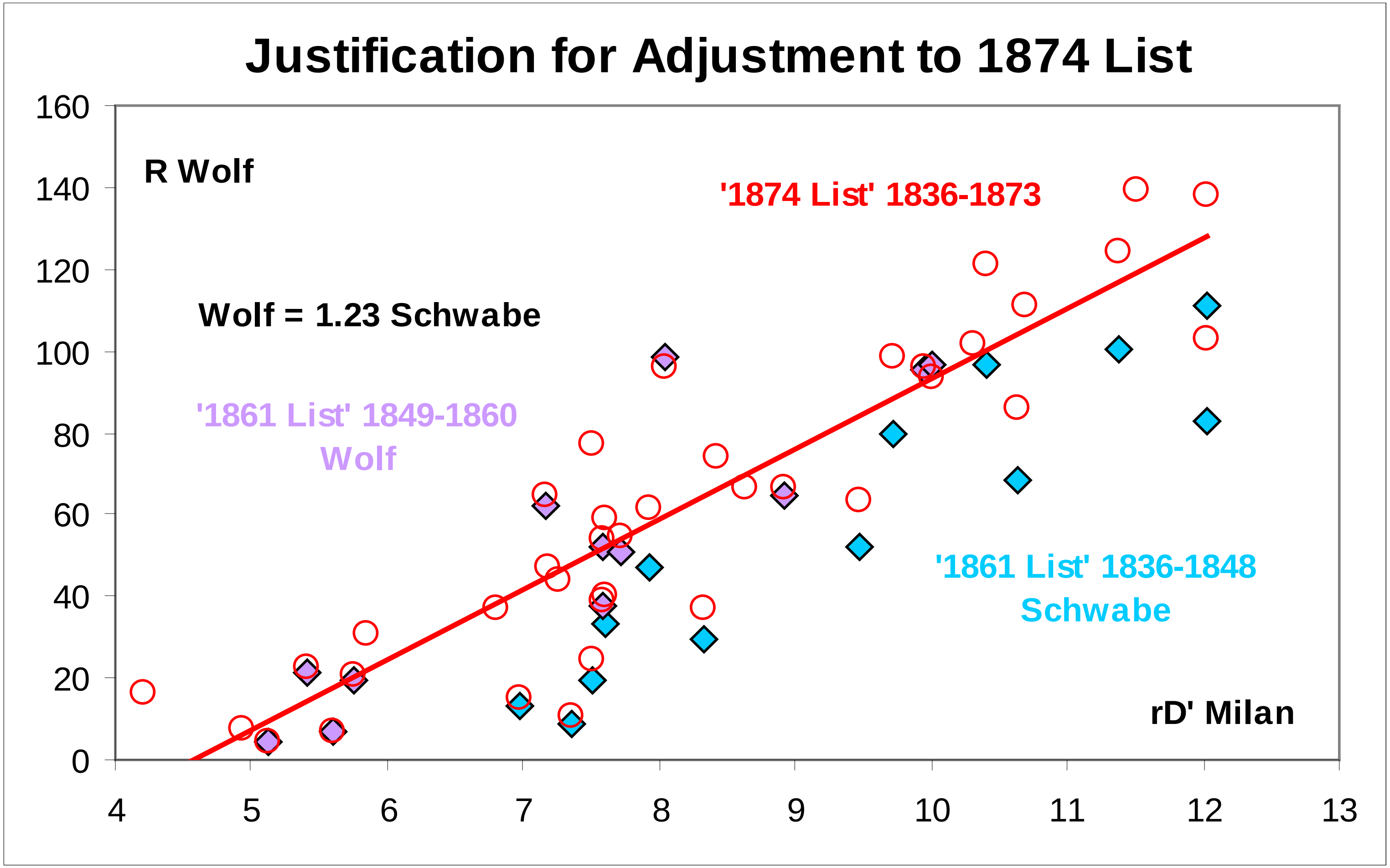


Using *rY* from nine 'chains' of stations we find that the **correlation** between *F10.7* and *rY* is extremely good (more than 98% of the variation is accounted for)



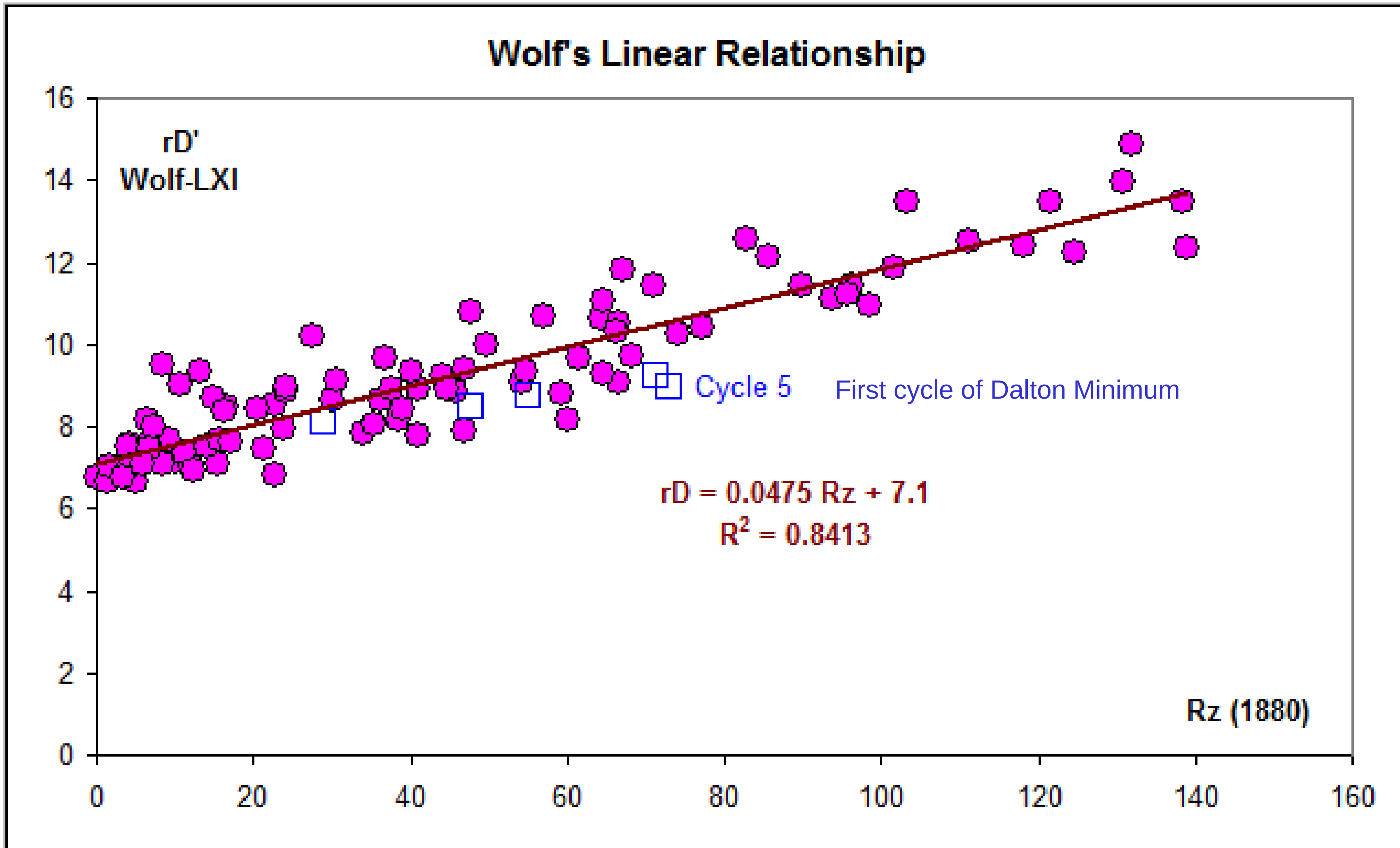
This establishes that Wolf's procedure and calibration are physically sound

Wolf got Declination Ranges for Milan from Schiaparelli and it became clear that the pre-1849 SSNs were too low



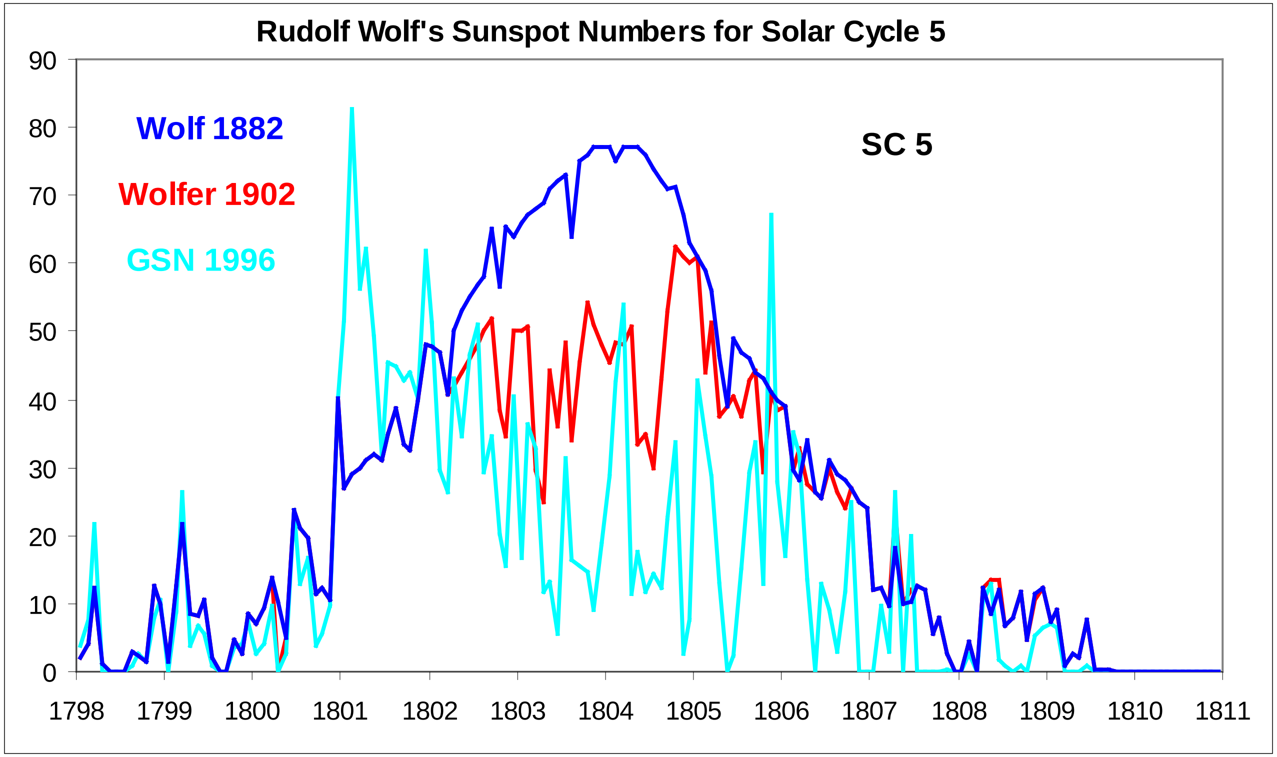
The ‘1874’ list included the 25% [Wolf said 1/4] increase of the pre-1849 SSN

Wolf’s SSN was thus now consistent with his many-station compilation of the diurnal variation of Declination 1781-1880



It is important to note that the relationship is *linear* for calculating averages

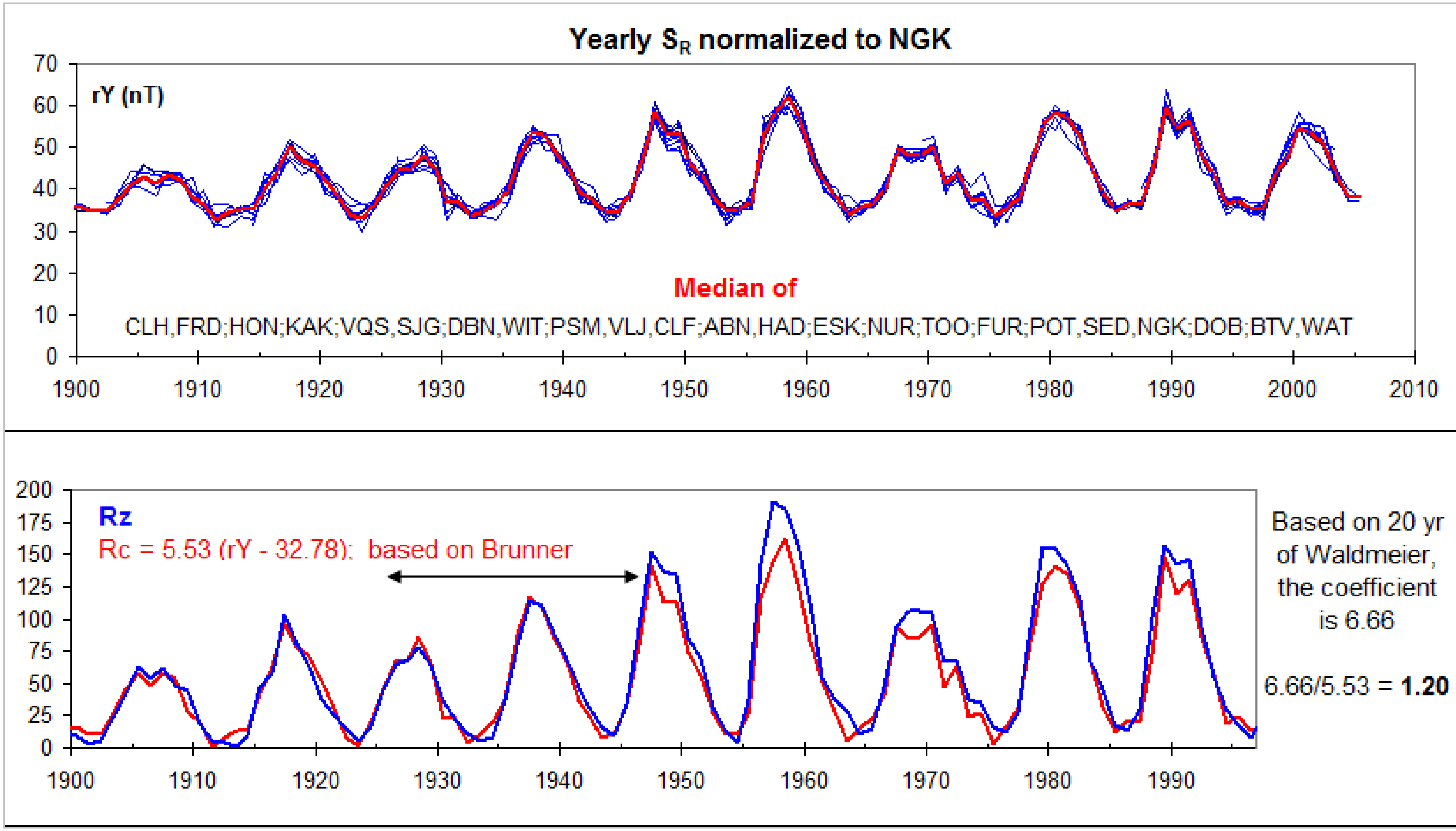
Wolfer's Revision of Solar Cycle 5 Based on Observations at Kremsmünster



Alfred Wolfer became Wolf's Assistant in 1876 and Used a Different Counting Method

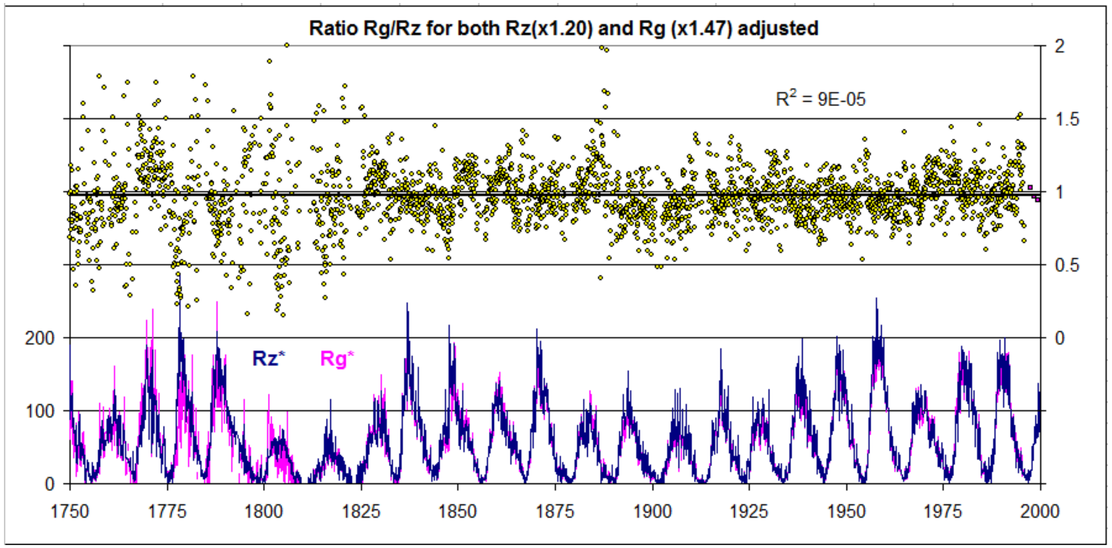
- Wolf did not [with the 80mm] count small spots and pores that could only be observed under good 'seeing'
- With the smaller Handheld Telescope this was really not an issue because those small spots could not been seen anyway
- Wolfer insisted on counting ALL the spots that could be seen as clearly black with the 80mm Standard Telescope [this has been adopted by all later observers]
- During 16 years of simultaneous observations with Wolf, it was determined that a factor of 0.6 could be applied to Wolfer's count to align them with Wolf's [actually to 1.5 times the 'Handheld' values]
- All subsequent observers have adopted that same 0.6 factor to stay on the original Wolf scale for 1849-~1860

The Amplitude of the Diurnal Variation, *rY*, [from many stations] shows the same Change in Rz ~1945



The Early ~1882 Discrepancy

- Since the sunspot number has an arbitrary scale, it makes no difference for the calibration if we assume Rg to be too 'low' before ~1882 or Rz to be too 'high' after 1882



By applying Wolf's relationship between Rz and the diurnal variation of the Declination we can show that it is Rg that is too low

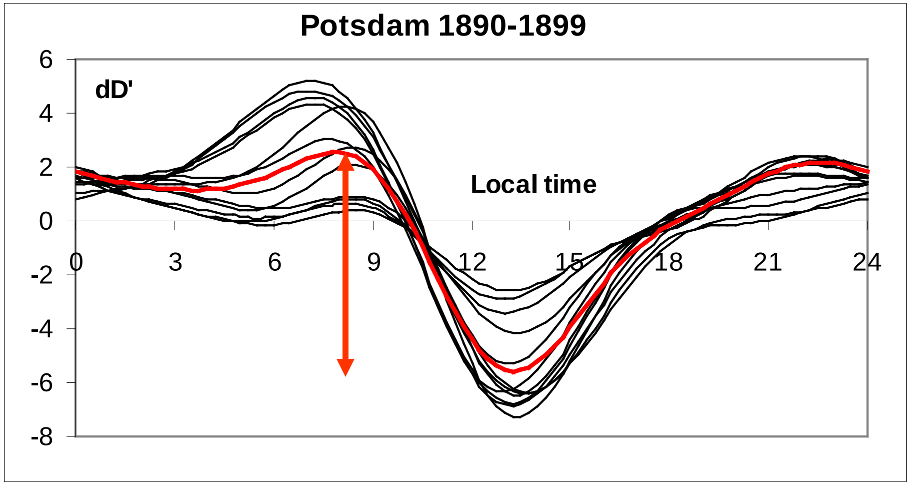
Comparing Diurnal Ranges

- A vast amount of hourly [or fixed-hours] measurements from the mid-19th century exists, but is not yet digitized
- We often have to do with second-hand accounts of the data, e.g. the monthly or yearly averages as given by Wolf, so it is difficult to judge quality and stability
- Just measuring the daily range [e.g. as given by Ellis for Greenwich] is not sufficient as it mixes the regular day-side variation in with night-time solar wind generated disturbances

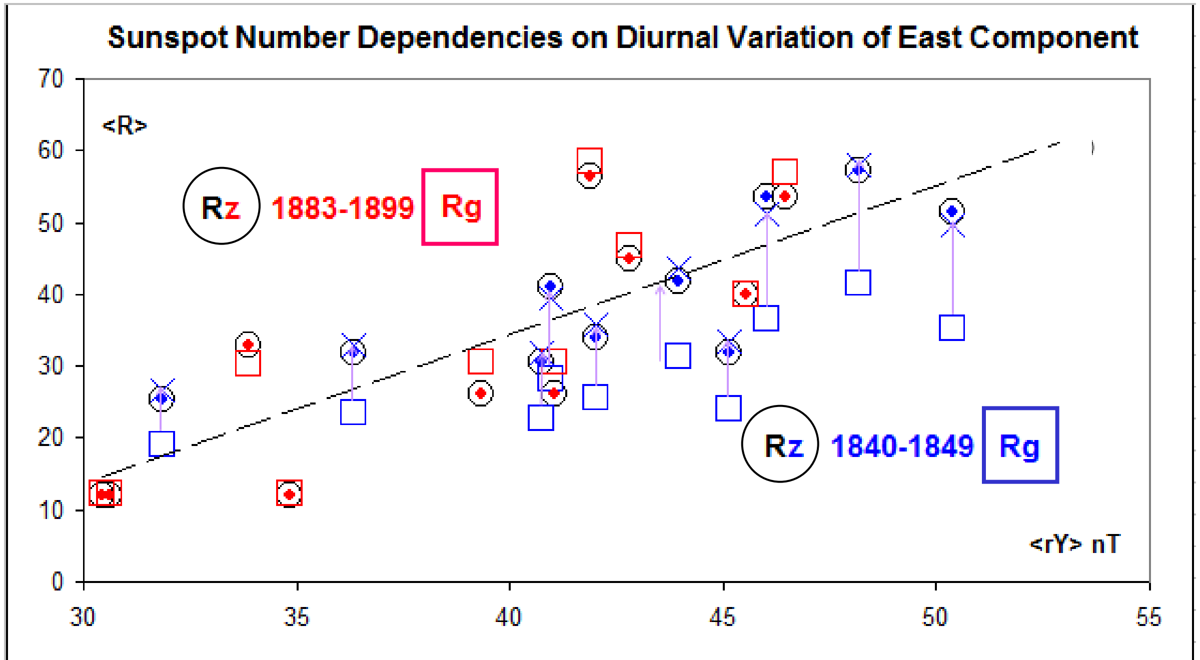
Adolf Schmidt's (1909) Analysis

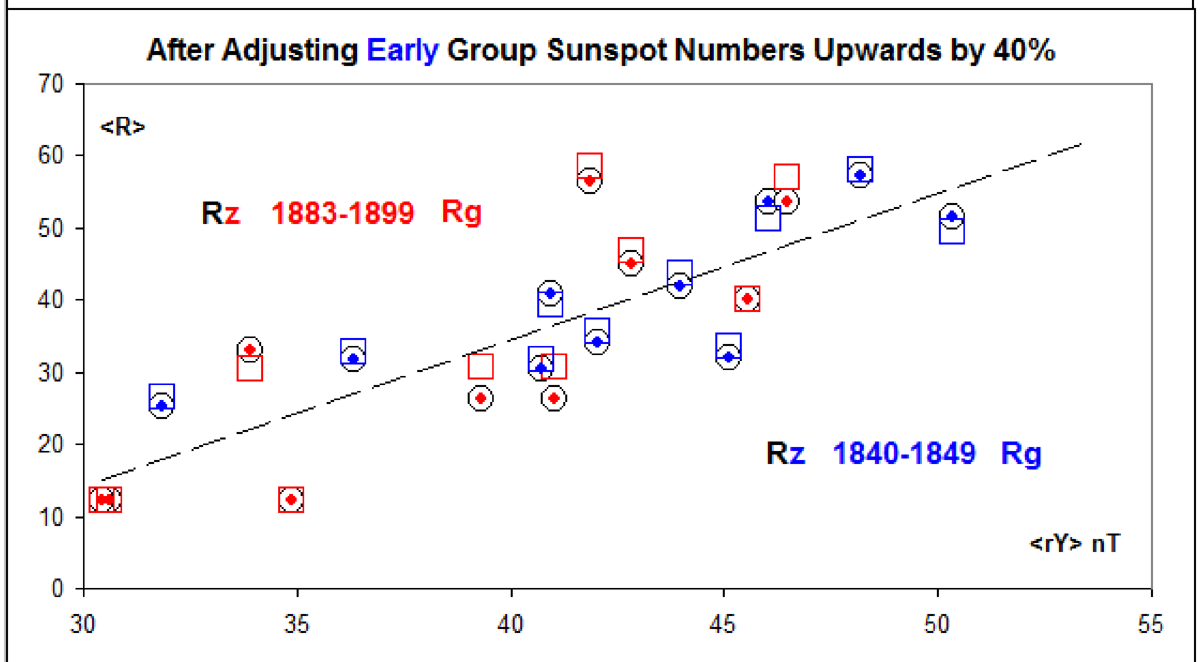
Schmidt collected raw hourly observations and computed the first four Fourier components [to 3-hr resolution] of the observed Declination in his ambitious attempt to present what was then known in an 'einheitlicher Darstellung' [uniform description]

Observatory	Years	Lat	Long
Washington DC	1840-1842	38.9	282.0
Dublin	1840-1843	53.4	353.7
Philadelphia	1840-1845	40.0	284.8
Praha	1840-1849	50.1	14.4
Muenschen	1841-1842	48.2	11.6
St. Petersburg	1841-1845	60.0	30.3
Greenwich	1841-1847	51.5	0.0
Hobarton	1841-1848	-42.9	147.5
Toronto	1842-1848	43.7	280.6
Makerstoun	1843-1846	55.6	357.5
Greenwich	1883-1889	51.4	0.0
P. Saint-Maur	1883-1899	48.8	0.2
Potsdam	1890-1899	52.4	13.1
København	1892-1898	55.7	12.6
Utrecht	1893-1898	52.1	5.1
Odessa	1897-1897	46.4	30.8
Tokyo	1897-1897	35.7	139.8
Bucarest	1899-1899	44.4	26.1
Irkutsk	1899-1899	52.3	194.3
Zi-ka-wei	1899-1899	31.2	121.2



Engelenburg and Schmidt calculated the average variation over the interval for each month and determined the amplitude and phase for each month. From this we can reconstruct the diurnal variation and the yearly average amplitude, dD [red curve].

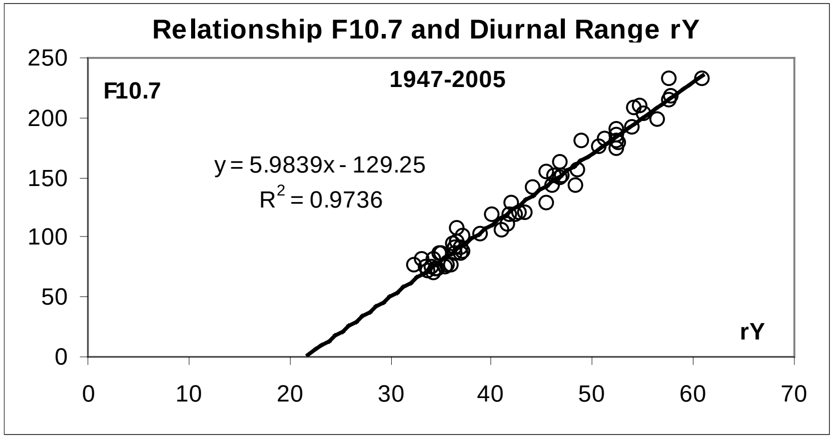




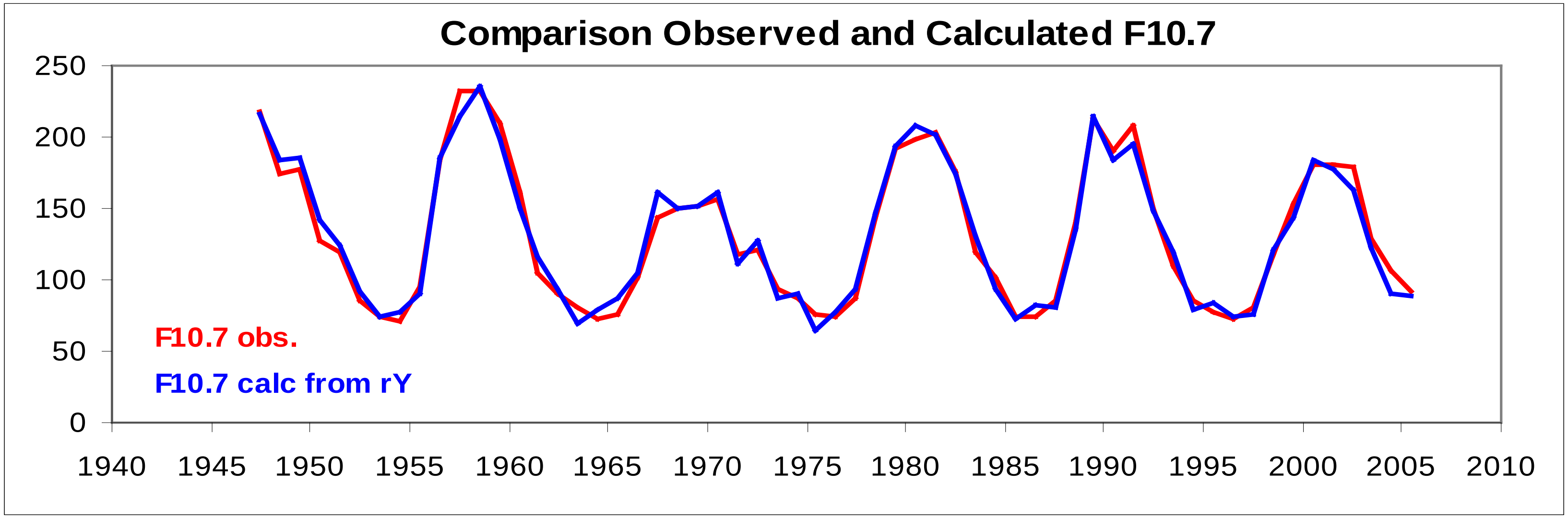
Procedure:
For each station we now compute the averages over the interval of <Rz>, <Rg>, and of the diurnal range [converted to force units, nT, from arc minutes] and plot <Rz> against the range <rY> (calculated from dD) as the black circles with a color dot at the center. The color is blue for the early interval and red for the later interval.

The Group Sunspot Numbers <Rg> is plotted as blue and red squares. It is clear that <Rg>s for the early interval fall significantly and systematically below corresponding <Rz>s. Increasing the early <Rg>s by 40% [the arrows to the blue crosses] brings them into line with <Rz> before Waldmeier.

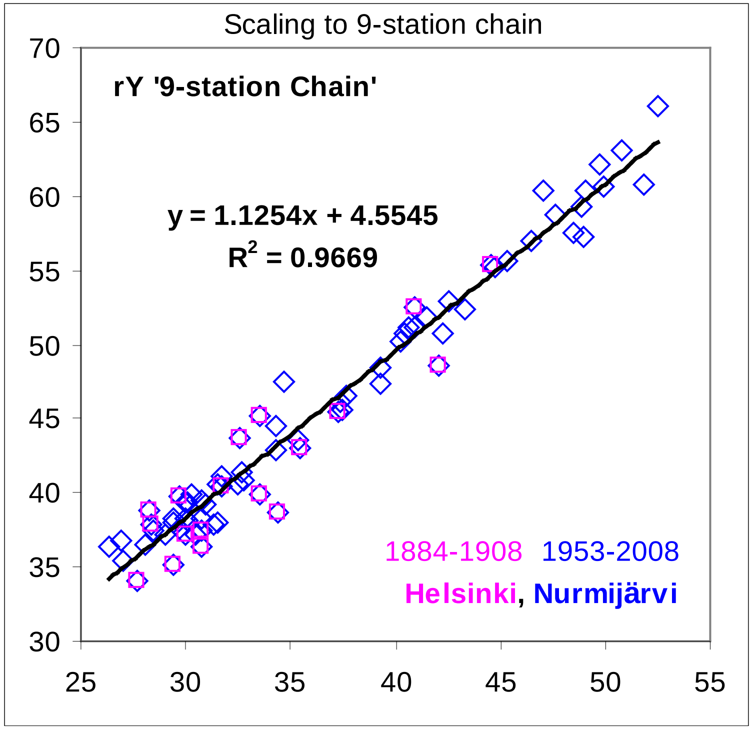
The Diurnal Range *rY* is a very good proxy for the Solar Flux at 10.7 cm



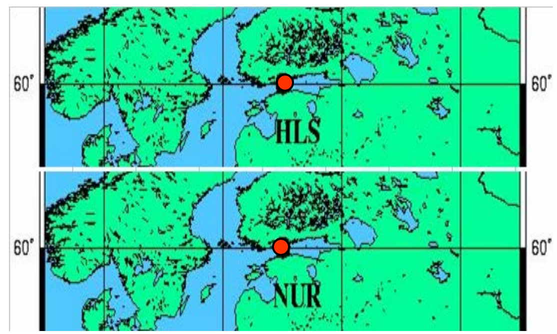
Which itself is a good proxy for solar Ultraviolet radiation and solar activity in general [what the sunspot number is trying to capture].

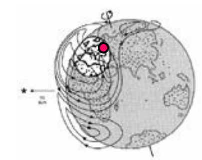


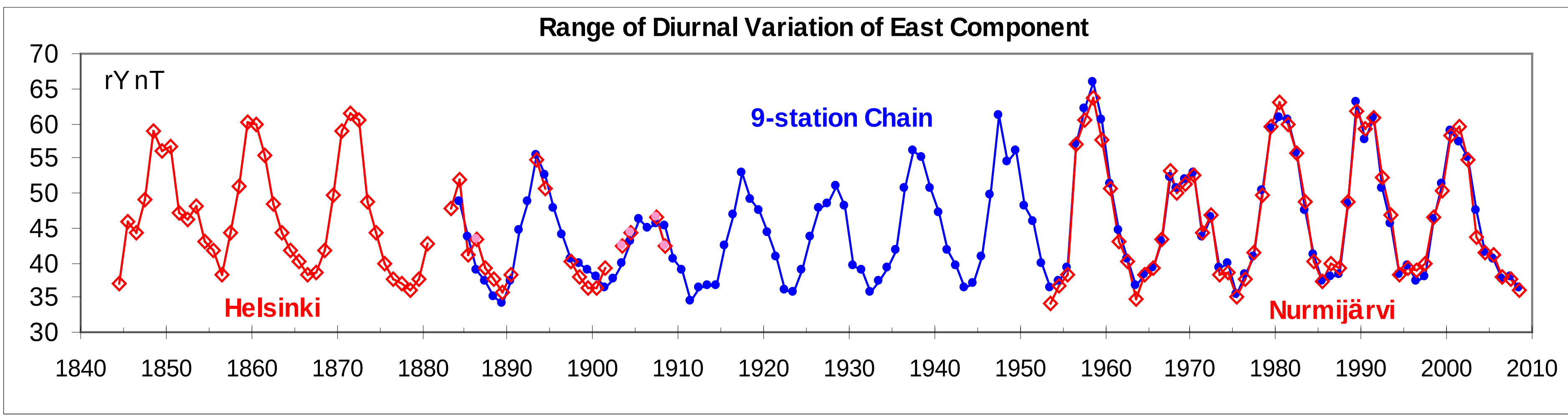
Helsinki-Nurmijärvi Diurnal Variation



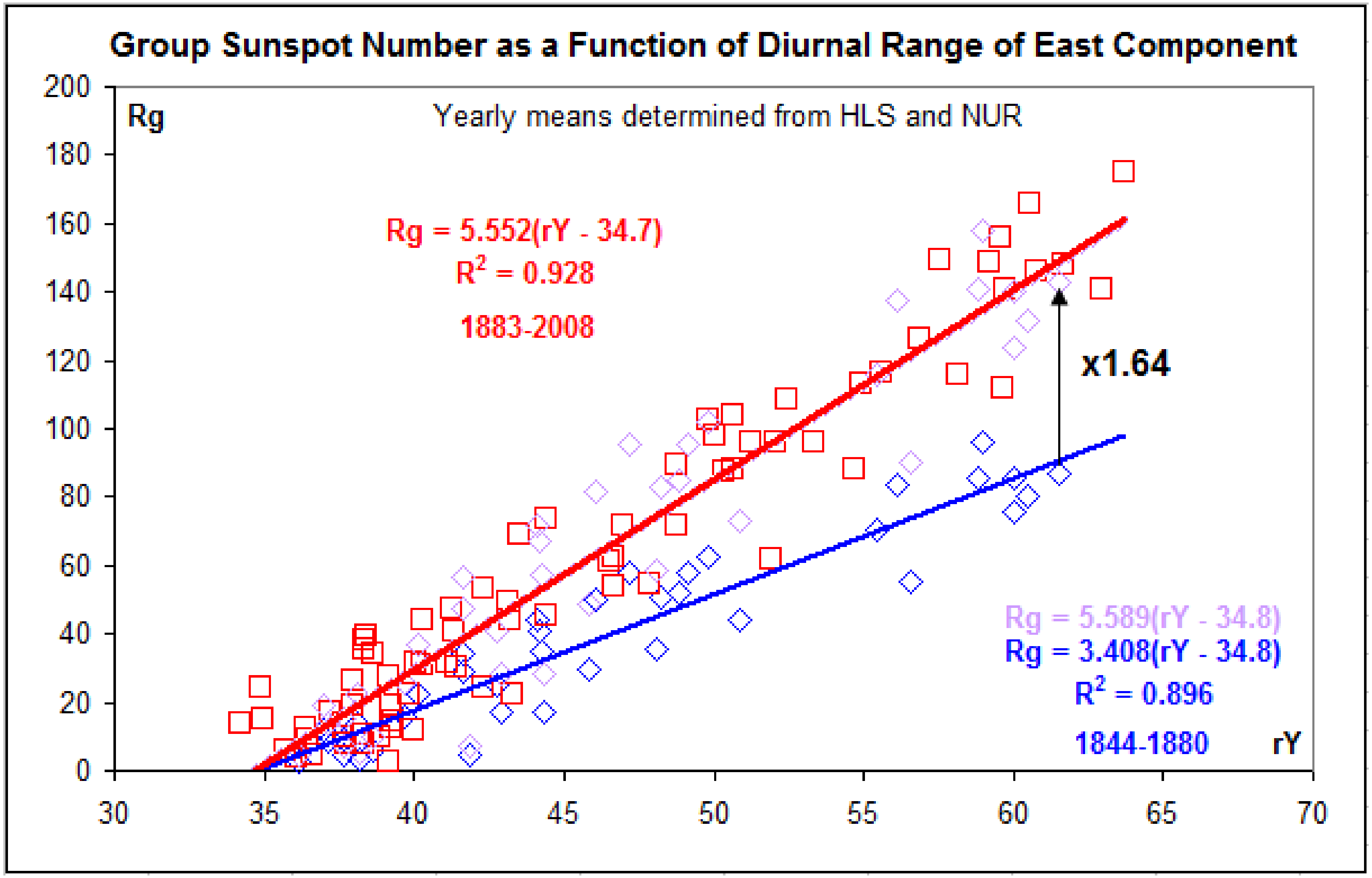
Helsinki and its replacement station Numijärvi scales the same way towards our composite of nine long-running observatories and can therefore be used to check the calibration of the sunspot number (or more correctly to reconstruct the F10.7 radio flux – see next slide)





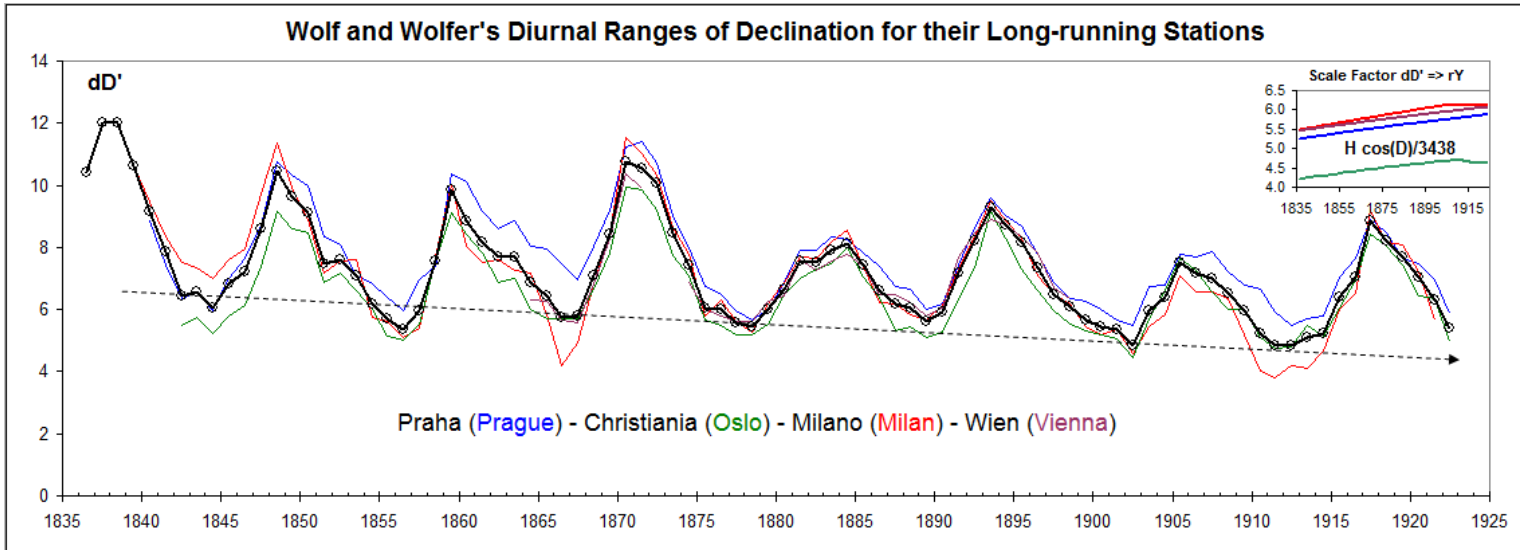


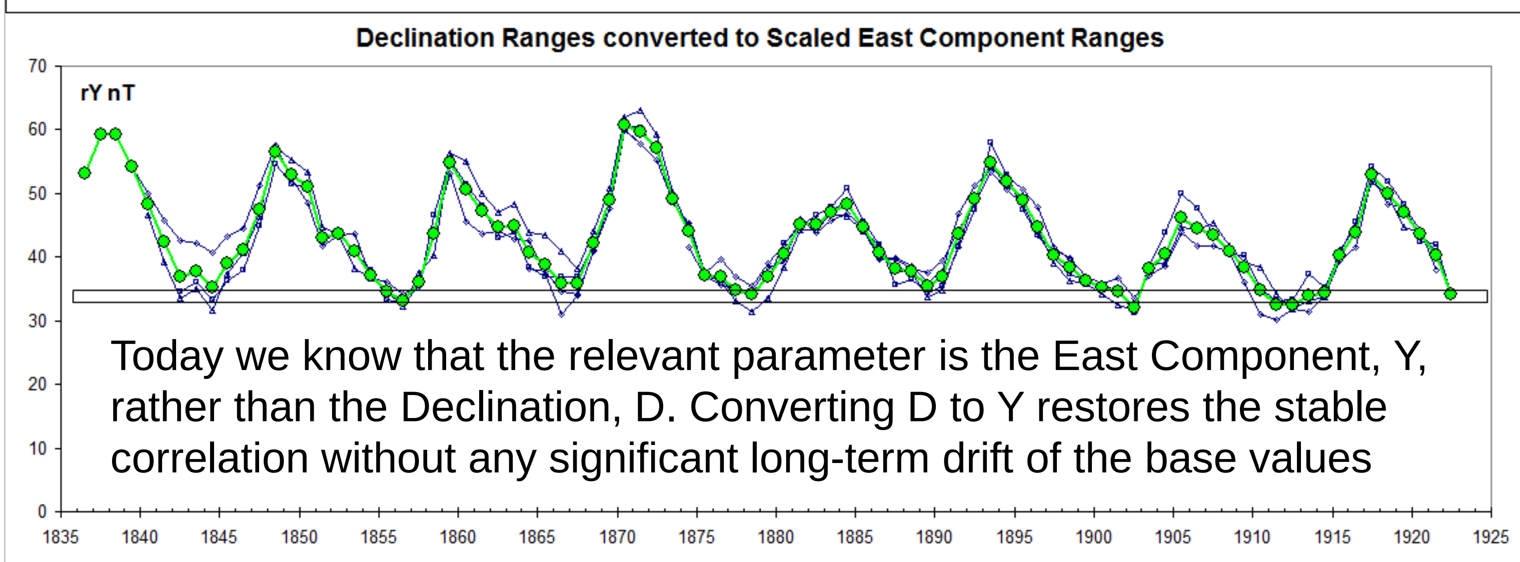
The HLS-NUR data show that the Group Sunspot Number before 1880 must be Increased by a factor 1.64±0.15 to match *rY* (F10.7)



This conclusion is independent of the calibration of the Zürich SSN, Rz

Wolf’s Geomagnetic Data

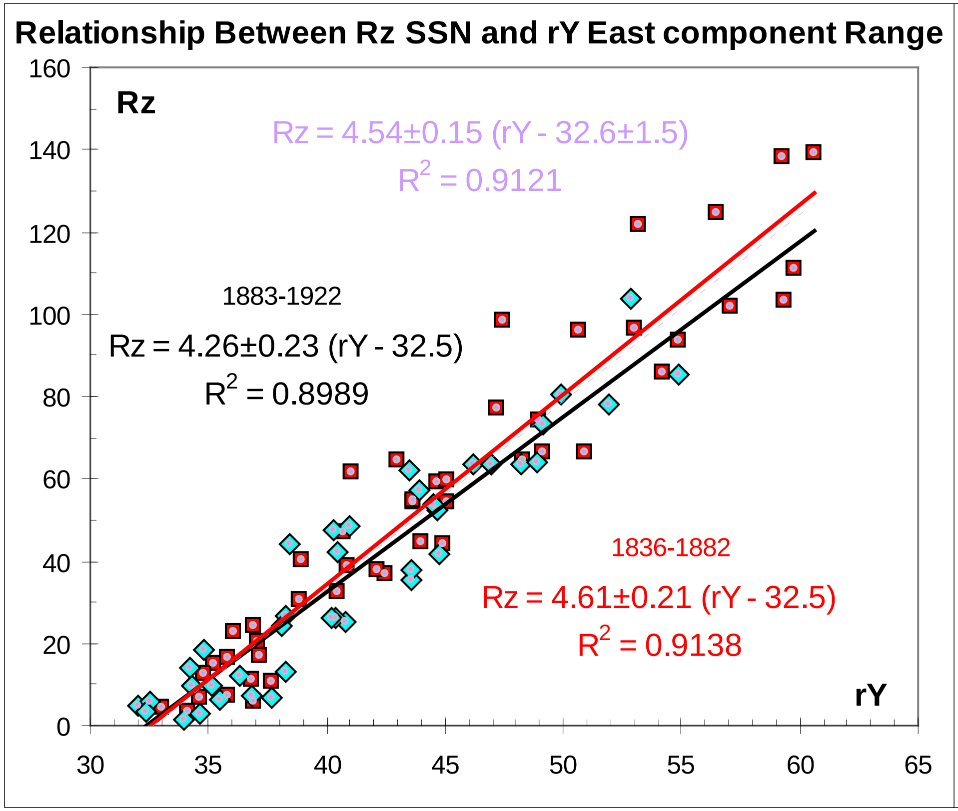


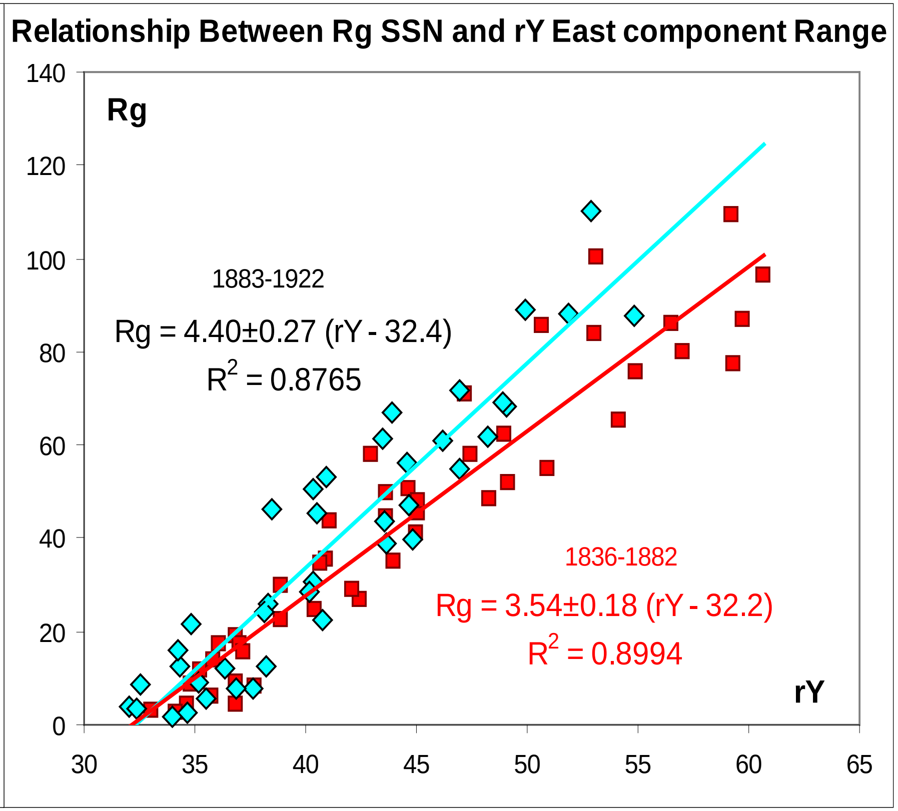


Wolf found a very strong correlation between his Wolf number and the daily range of the Declination.

Wolfer found the original correlation was not stable, but was drifting with time and gave up on it in 1923.

Using the East Component We Recover Wolf's Tight Relationship





The regression lines are identical within their errors before and after 1883.0. This means that likely most of the discordance with Rg ~1882 is not due to 'change of guard' or method at Zürich. It is also clear that Rg before 1883 is too low.

New paper on Eastward Component JGR, 2012

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, A05302, doi:10.1029/2012JA017555, 2012

The dependence of the coupled magnetosphere-ionosphere-thermosphere system on the Earth's magnetic dipole moment

Ingrid Cnossen,[1] Arthur D. Richmond,[1] and Michael Wiltberger[1]

[39] *Svalgaard* [2009] noted that in particular the eastward component of the daily Sq variation is a useful indicator of solar activity, and may be used as a tool to calibrate the long-term sunspot number record. Clearly, if geomagnetic data are to be used in this way, the effects of the decreasing dipole moment on Sq variation must be considered and corrected for. Our scaling relations will be a first tool to do so, although local changes in the magnetic field over specific stations could also be important. Further work with more

What to do about all this?

Credit line: *Dave Dooling, NSO/AURA/NSF*
©2011 NSO/AURA Inc.

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.

The first was in Sunspot, NM, Sept. 2011. The next in Brussels, Belgium, May 2012

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

Where do we go from here?

- Find and Digitize as many 19th century geomagnetic hourly values as possible
- Determine improved adjustment factors based on the above and on model of the ionosphere
- Co-operate with agencies producing sunspot numbers to harmonize their efforts in order to produce an adjusted and accepted sunspot record that can form a firm basis for solar-terrestrial relations, e.g. reconstructions of solar activity important for climate and environmental changes
- Follow-up Workshop in Brussels, May 2012

What to do about this?

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

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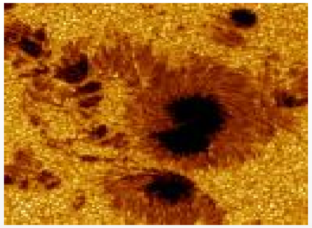

Added by Lsvalgaard

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

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
