The Effect of Weighting in Counting Sunspots

Leif Svalgaard

HEPL, Stanford University

2nd Sunspot Workshop, Brussels 2012

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:

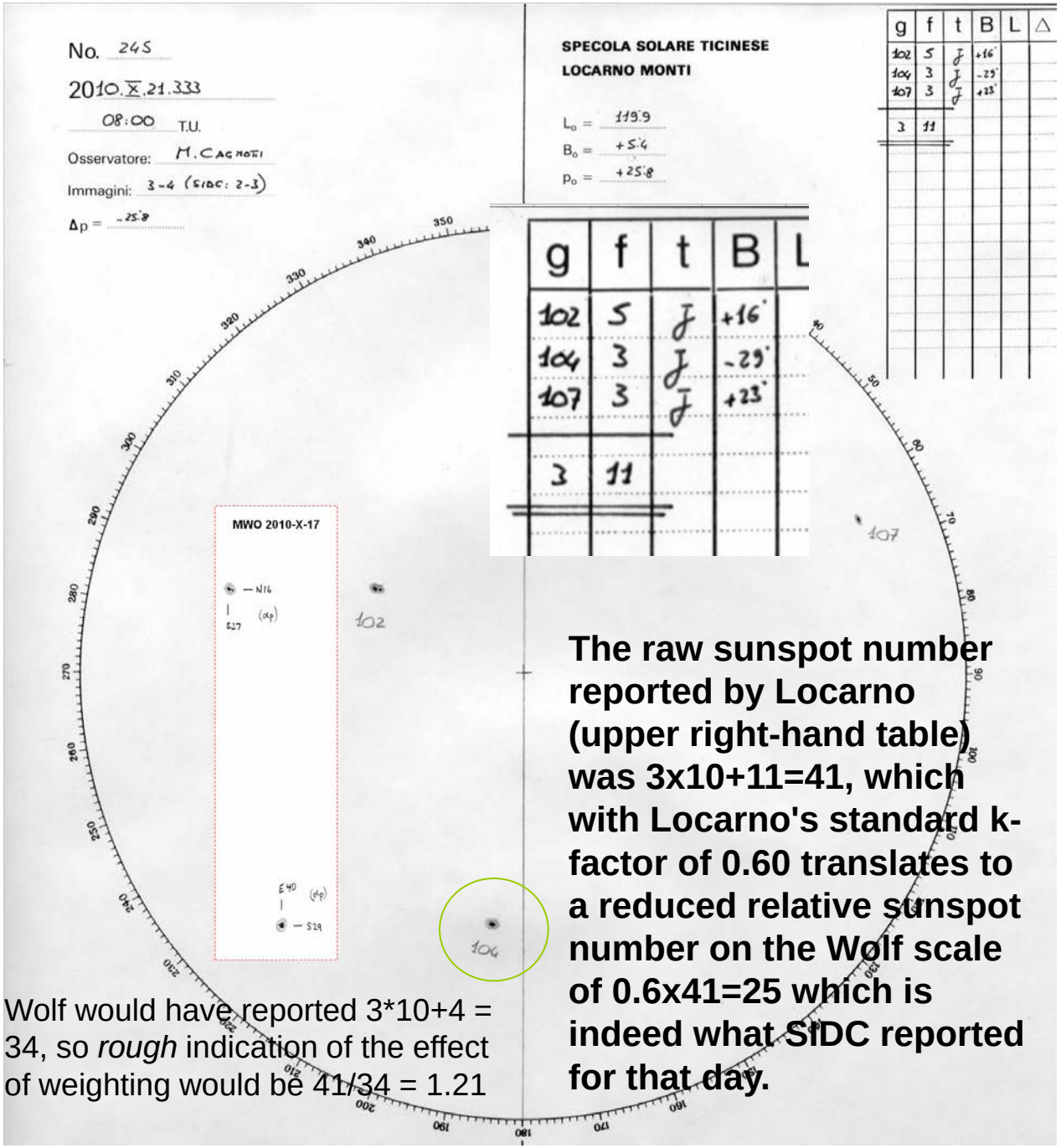
CHANGES TO THE COUNTING METHOD

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]..



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.

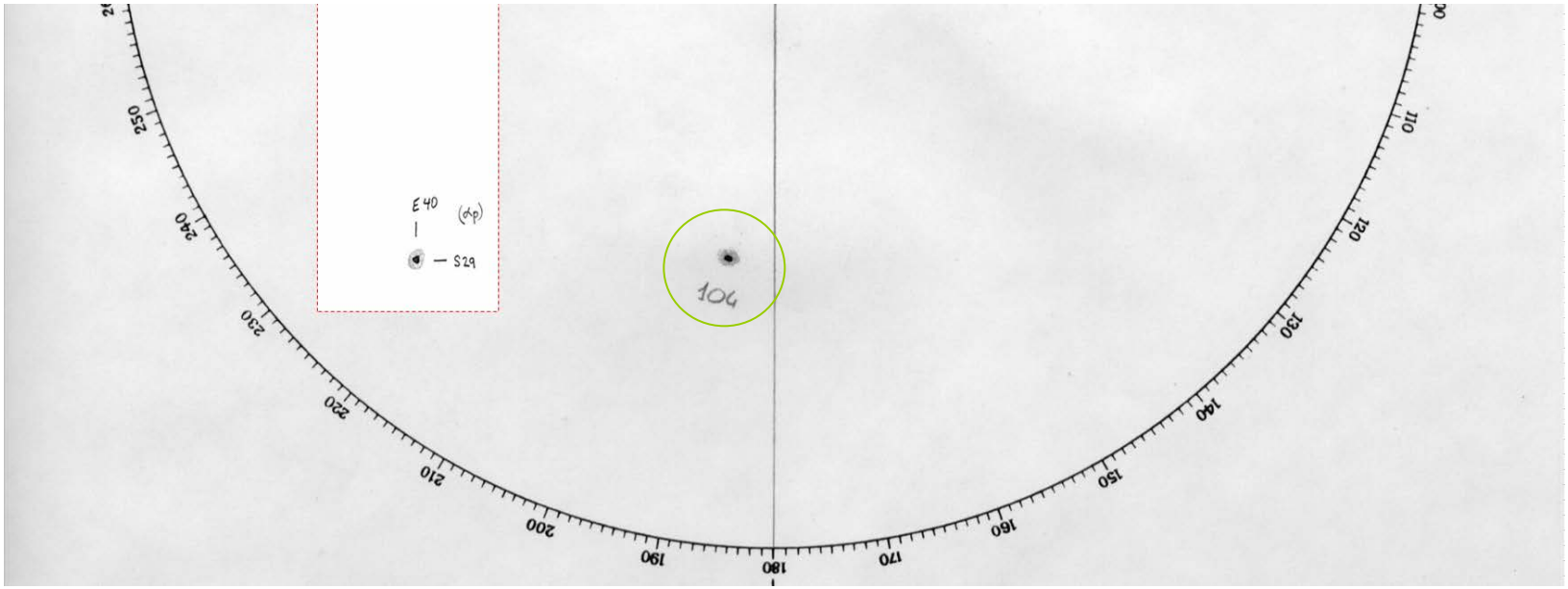
Wolf would have reported 3*10+4 = 34, so *rough* indication of the effect of weighting would be 41/34 = 1.21

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"

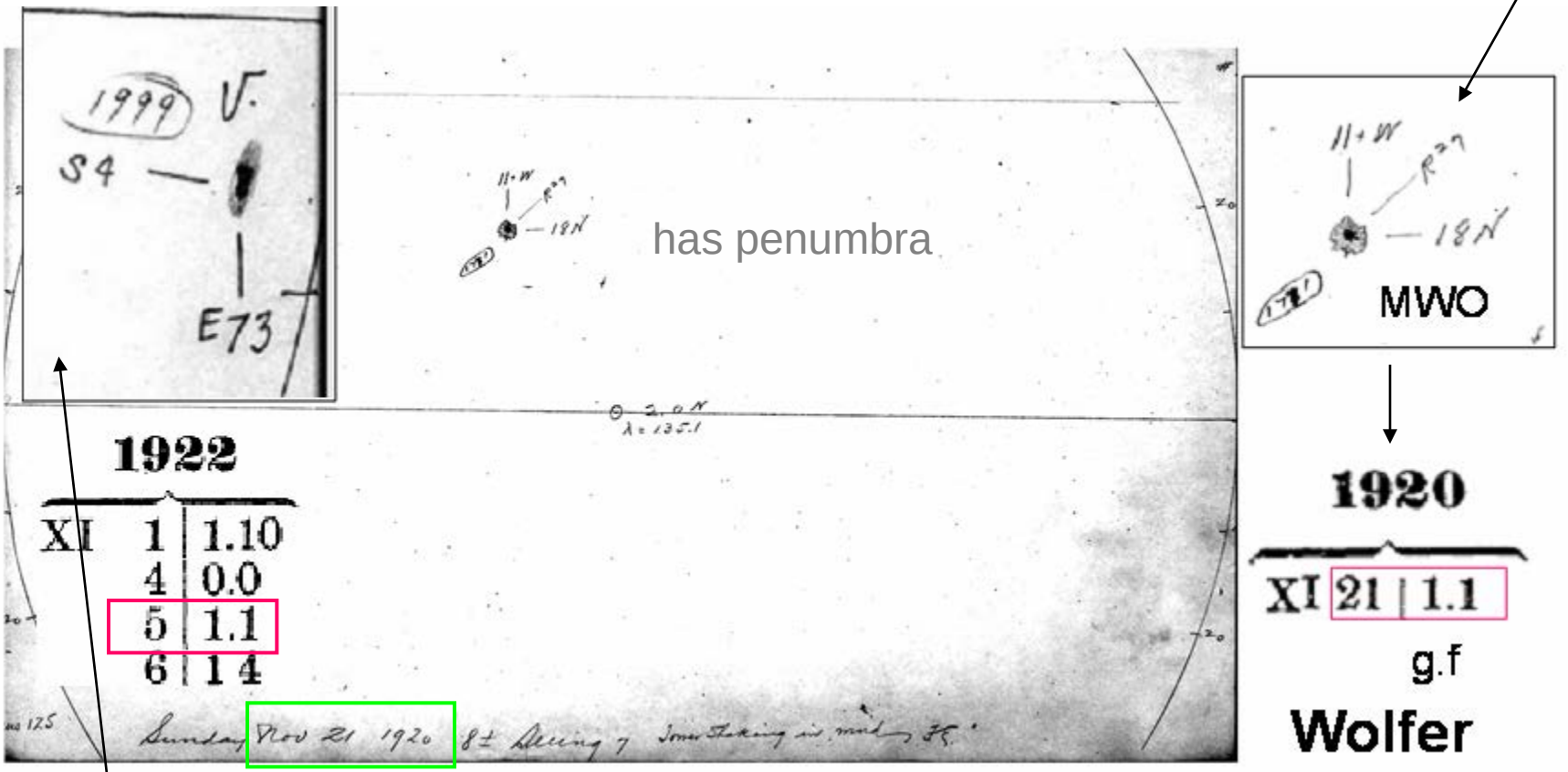
Sonnenfleckenbeobachtungen im Jahre 1849.

	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	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

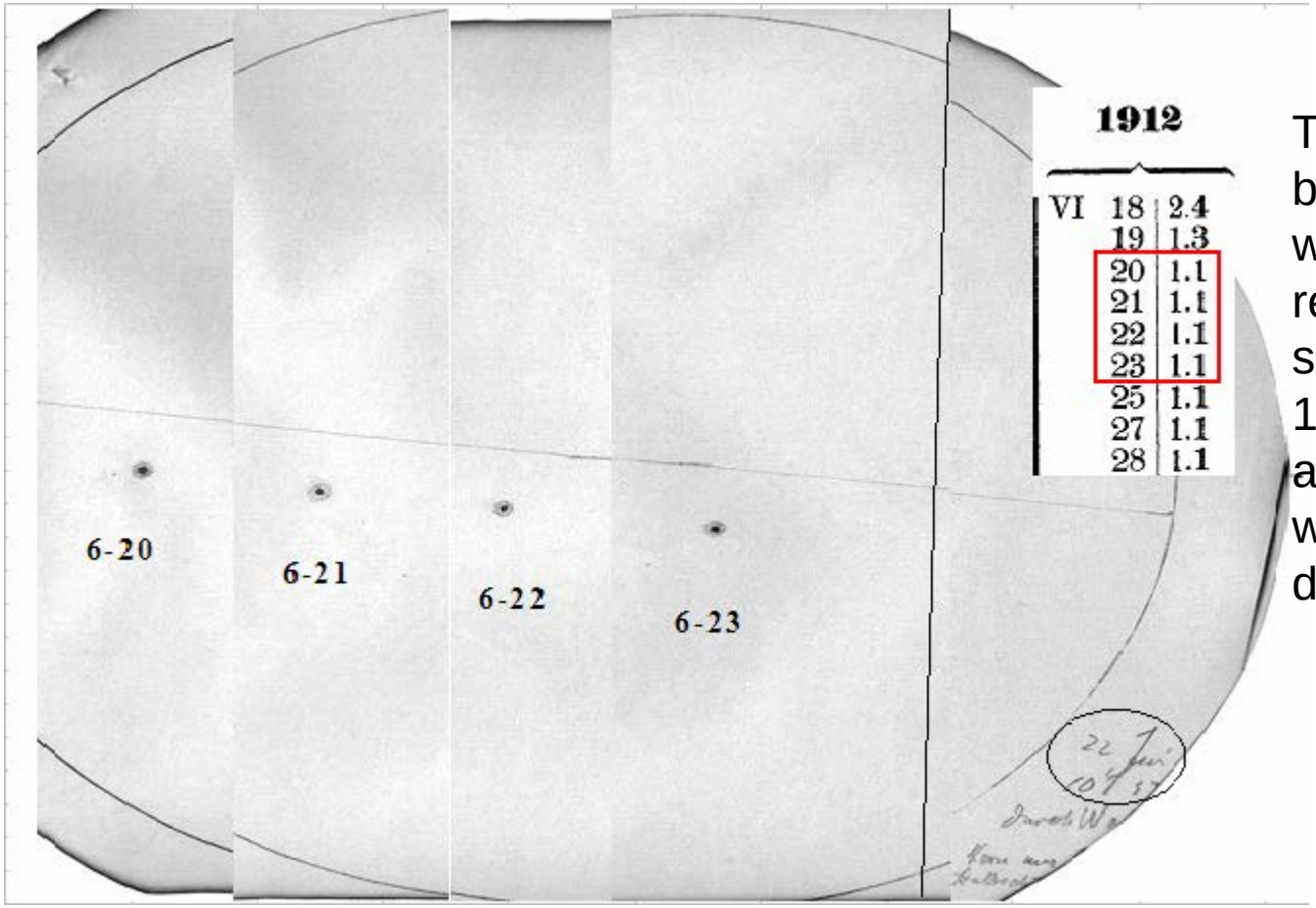
where the scale factor *k* is 1.00 for Wolf himself.

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).

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.

In addition, Wolfer himself writes explicitly in 1907 [Mitteilungen, 98]:
“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 $r = k(10g+f)$“

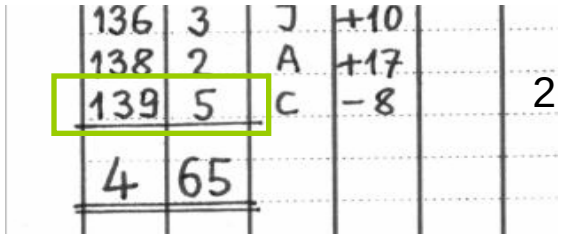
We thus consider it established that Wolfer did not apply the weighting scheme contrary to Waldmeier's assertion.

Estimating Unweighted Sunspot Count From Locarno Drawings

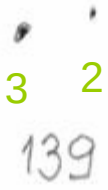
I look at the drawing of a group and from experience [I have looked at thousands of spots, 42025 at last count, on Locarno's drawings going back many years], assign a weight to each spot, then subtract the weight from the count given for the group and add 1 for the spot.

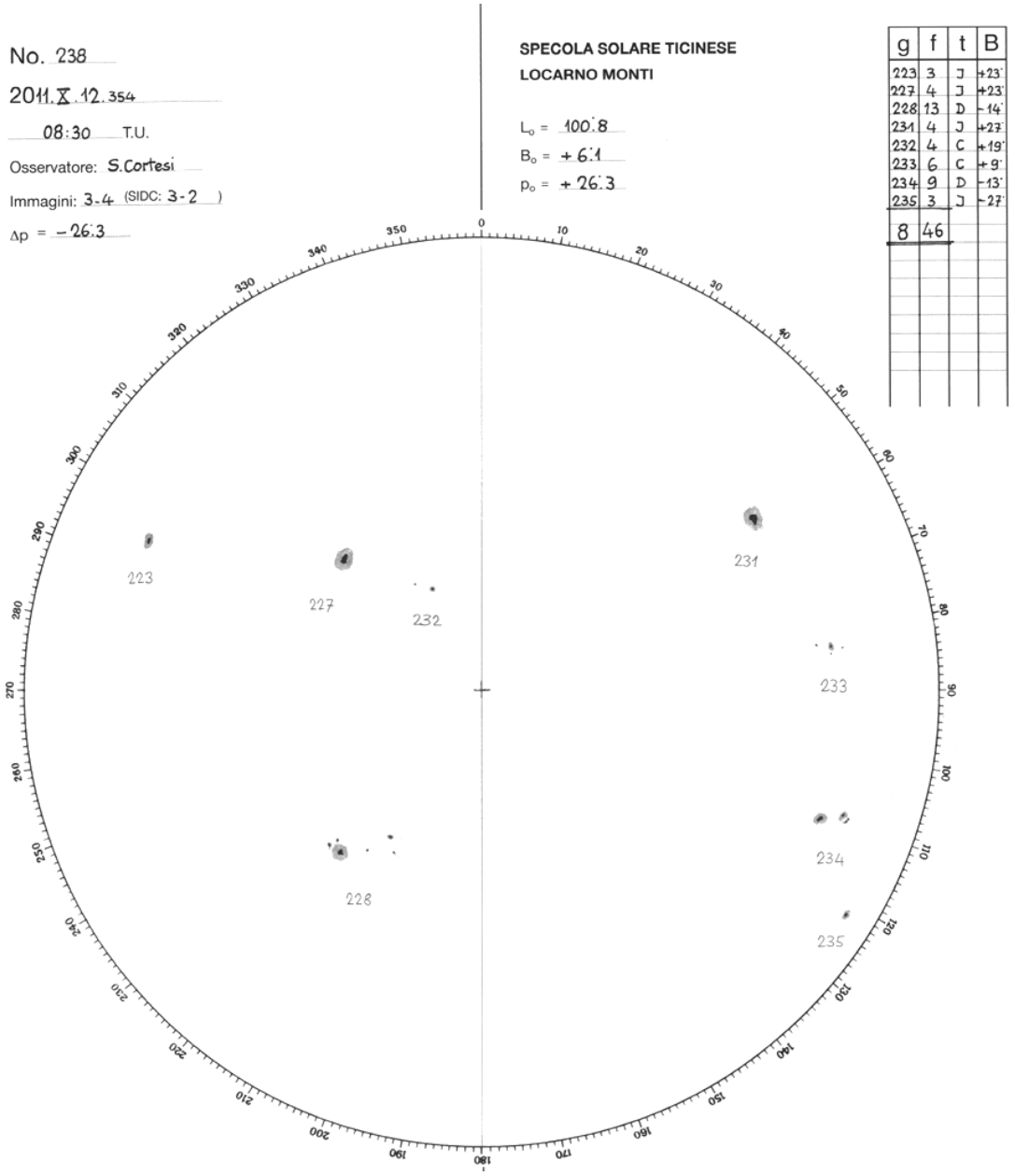
Example 1: A group has four spots on the drawing, one is large with weight 3, one is medium with weight 2 and two are small with weight 1. The total count given by Locarno was 6. That tells me that one of the small spots was not counted [otherwise the total would have been 3+2+1+1 = 7]. So, I subtract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



2004-8-12





Oct. 12 2011

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

Double-Blind Test

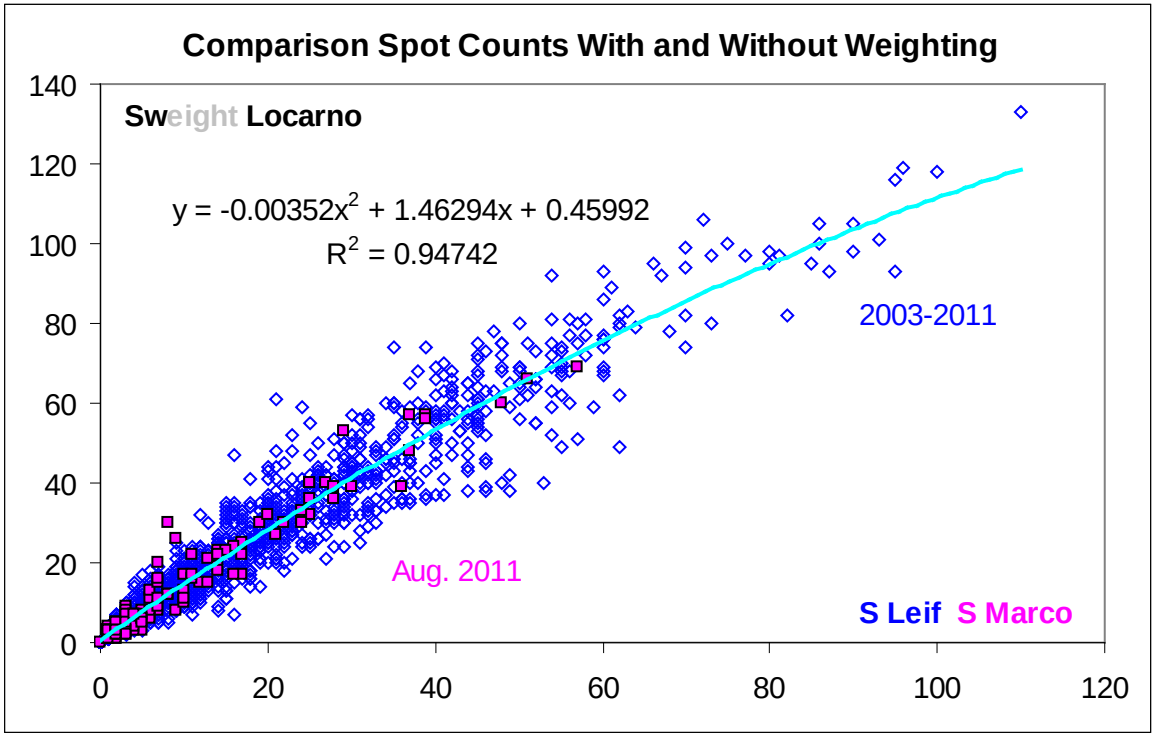
Email from Leif Svalgaard

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.

Current Status of the Test



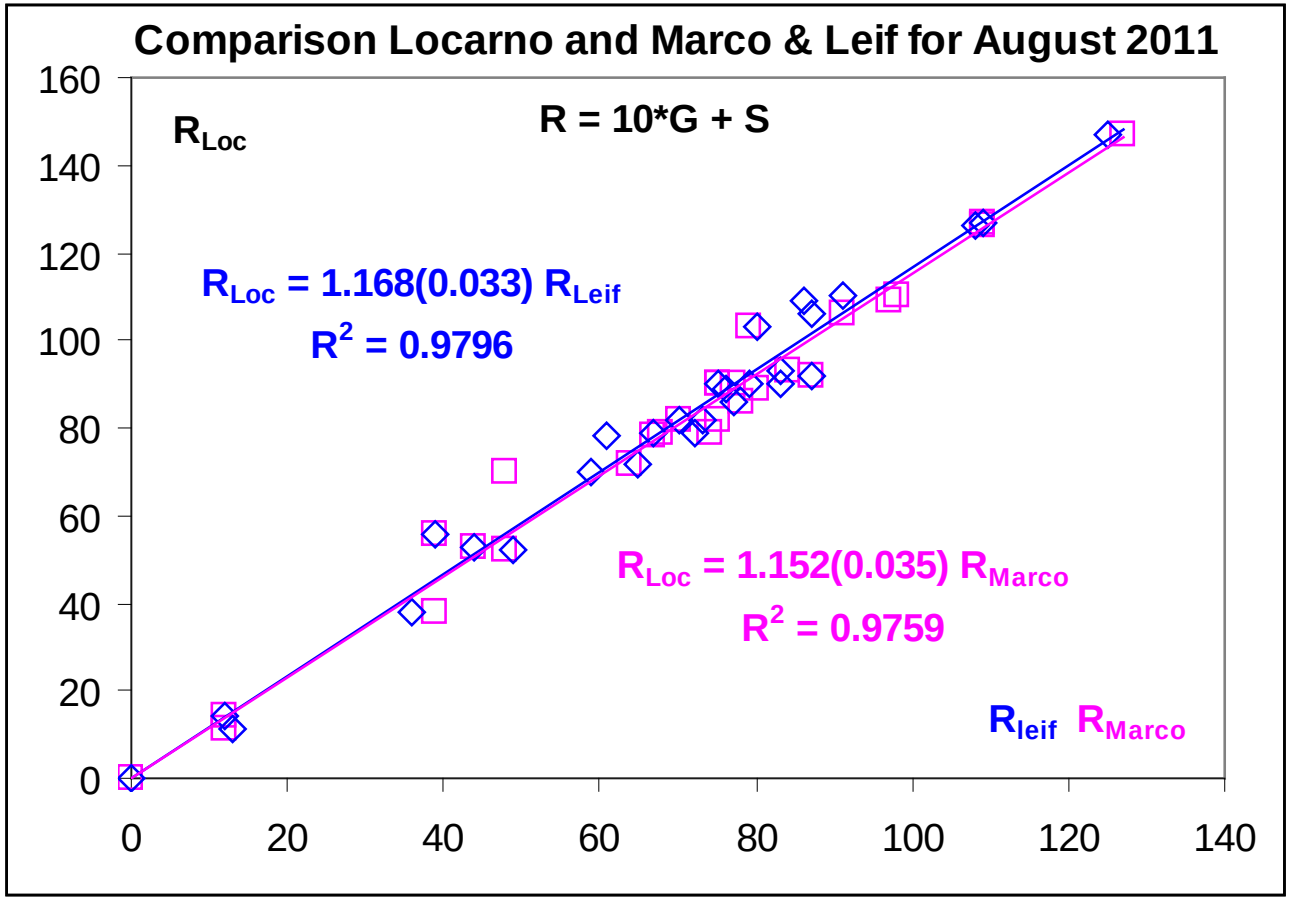
2nd degree fit

S	Sw	Sw/S
10	14.74	1.4737
25	34.83	1.3933
50	64.81	1.2961
75	90.38	1.2051
100	111.55	1.1155

For typical number of spots the weighting increases the 'count' of the spots by 30-50%

For the limited data for August 2011 Marco Cagnotti and Leif Svalgaard agree quite well with no significant difference. The test has continued since then 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.

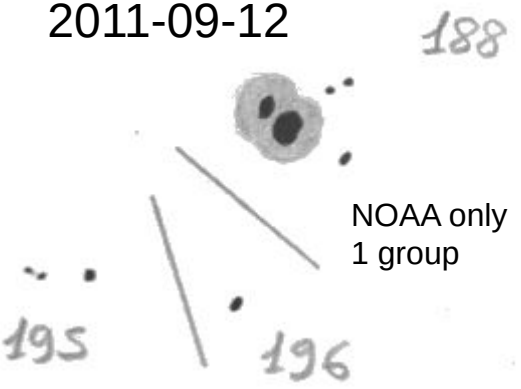
For Aug. 2011 the result is at left. There is no real difference between Marco and Leif.

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?

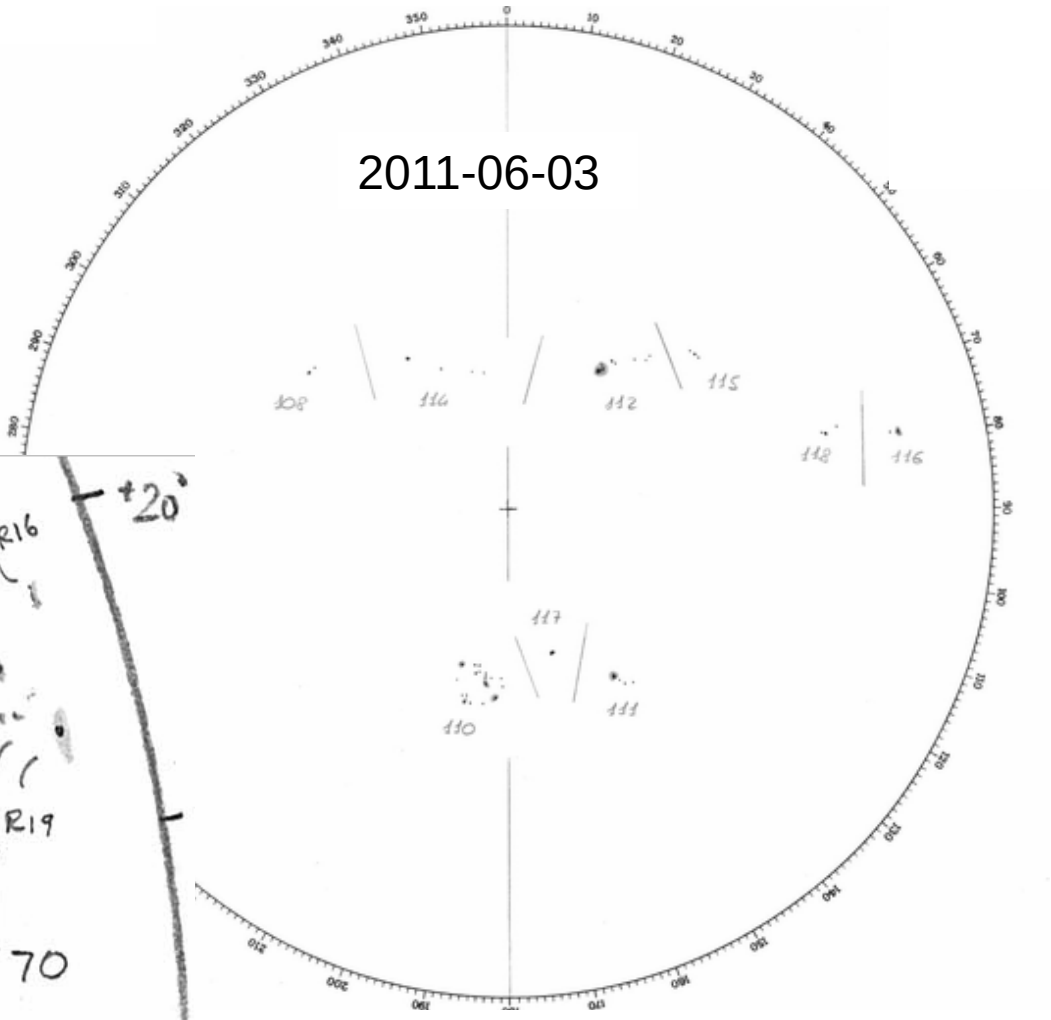
The Waldmeier Classification May lead to Better [larger] Determination of Groups

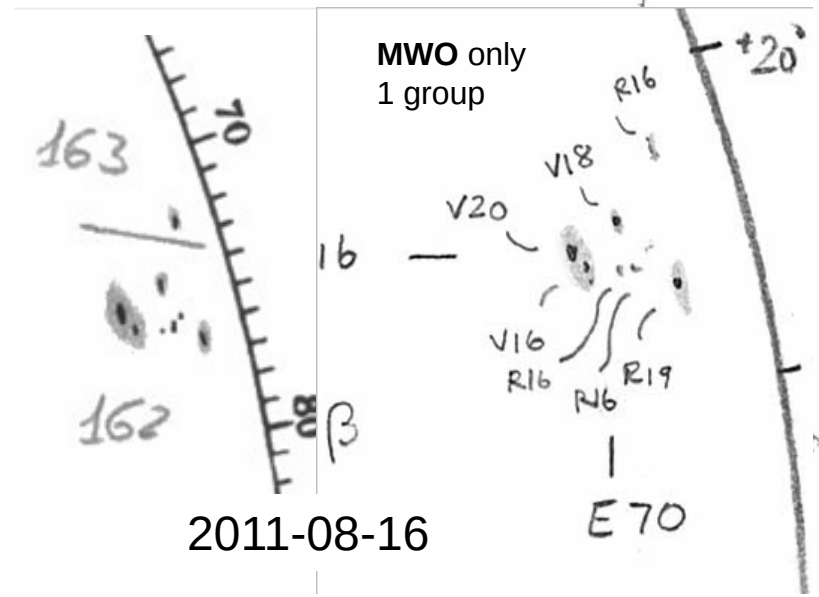
2011-09-12



NOAA only
1 group

2011-06-03





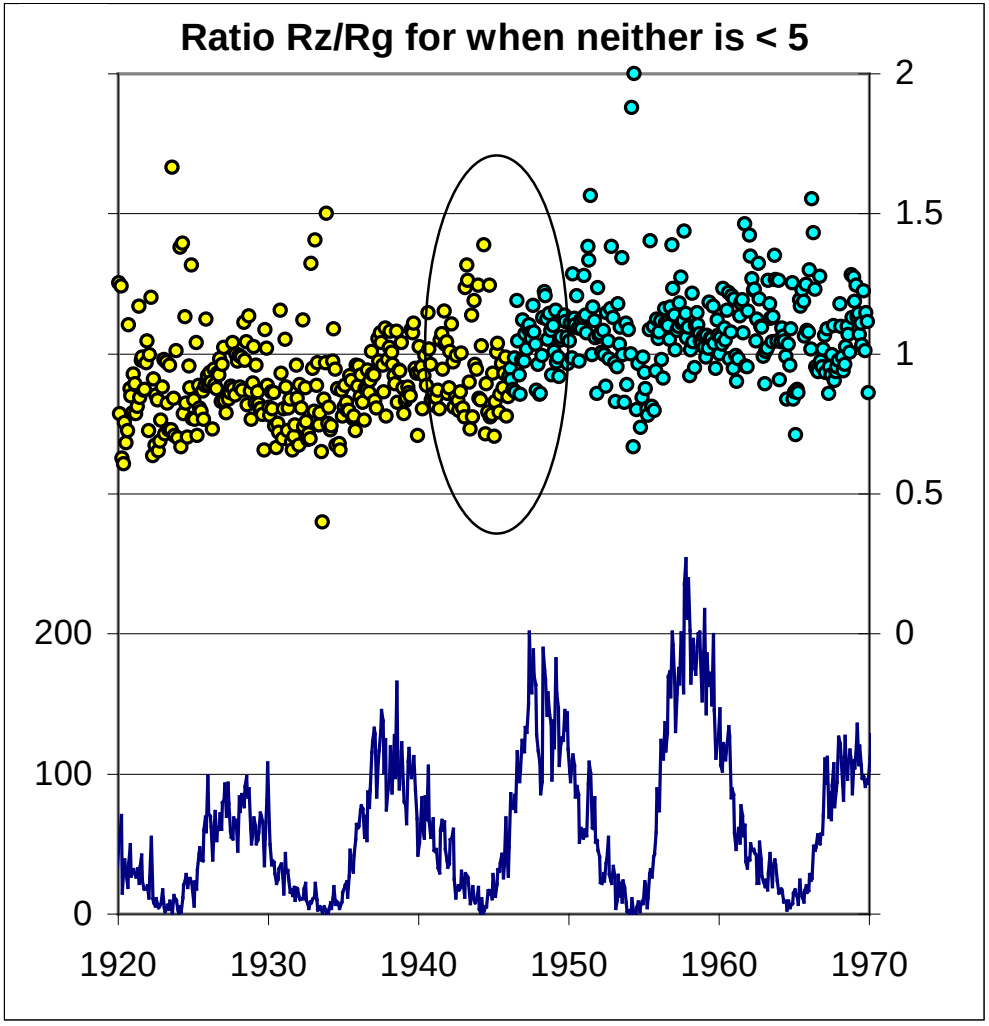
MWO only
1 group

2011-08-16

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% [?]
- This would increase the ‘Waldmeier Jump” to about 20%
- My suggested solution is to increase all pre-Waldmeier SSNs by 20%, rather than decrease the modern counts which may be used in operational programs

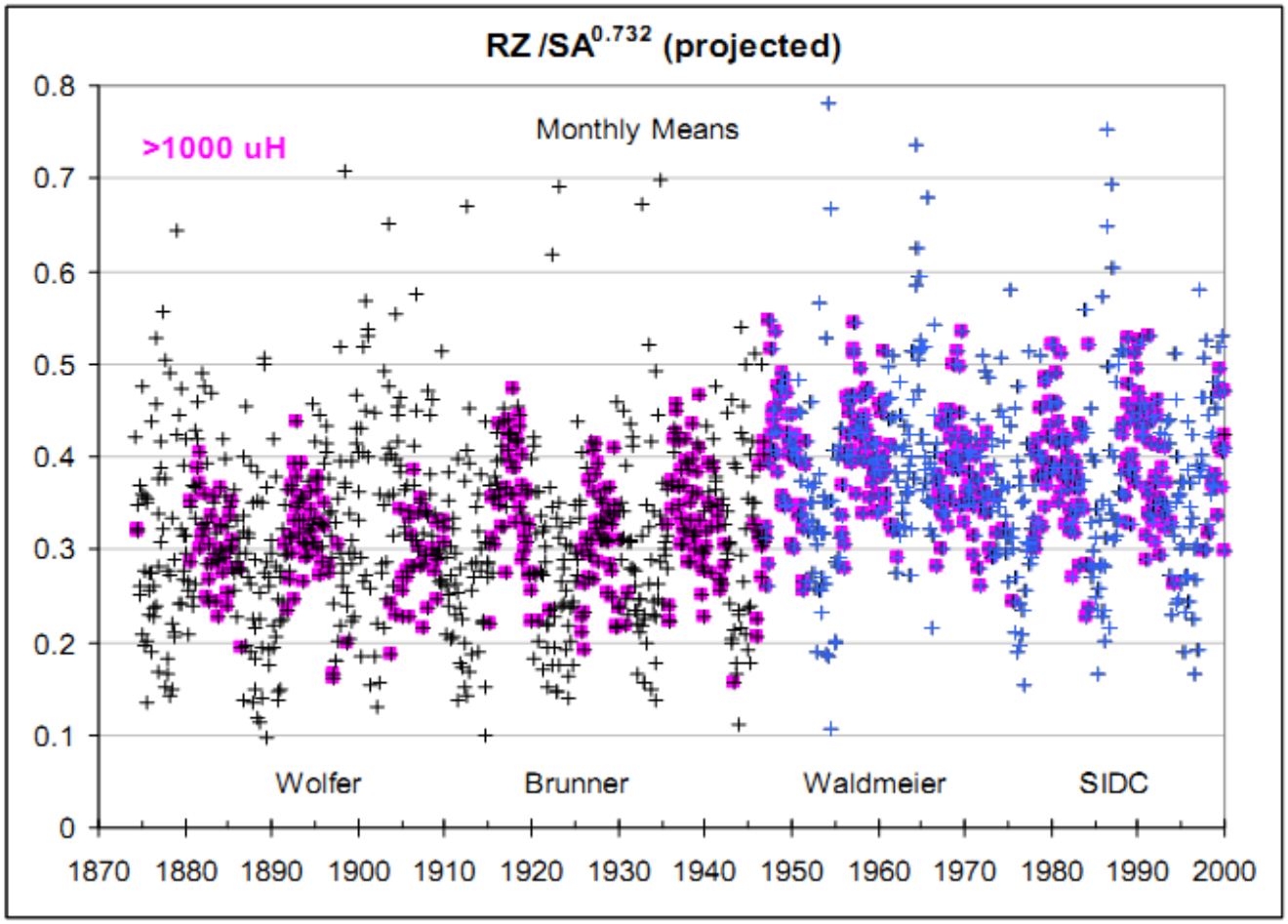
Can we see the Effect in the Data?



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

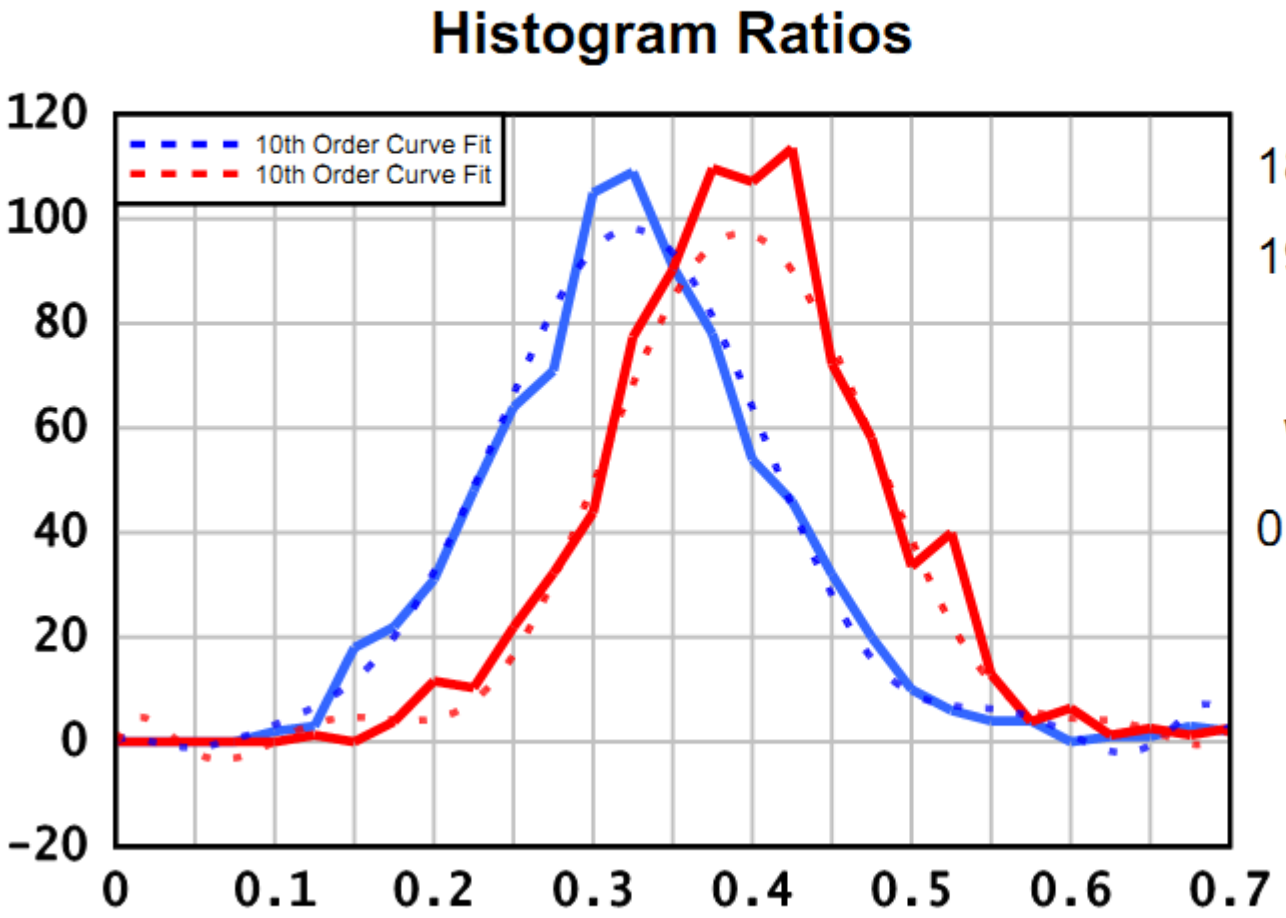


The relationship between sunspot number and sunspot area [SA, Balmaceda] is not linear, but can be made linear raising SA to the power of 0.732. Then taking the ratio makes sense.

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

Clear change in the relationship around 1945

Quantifying the Waldmeier 'Jump'



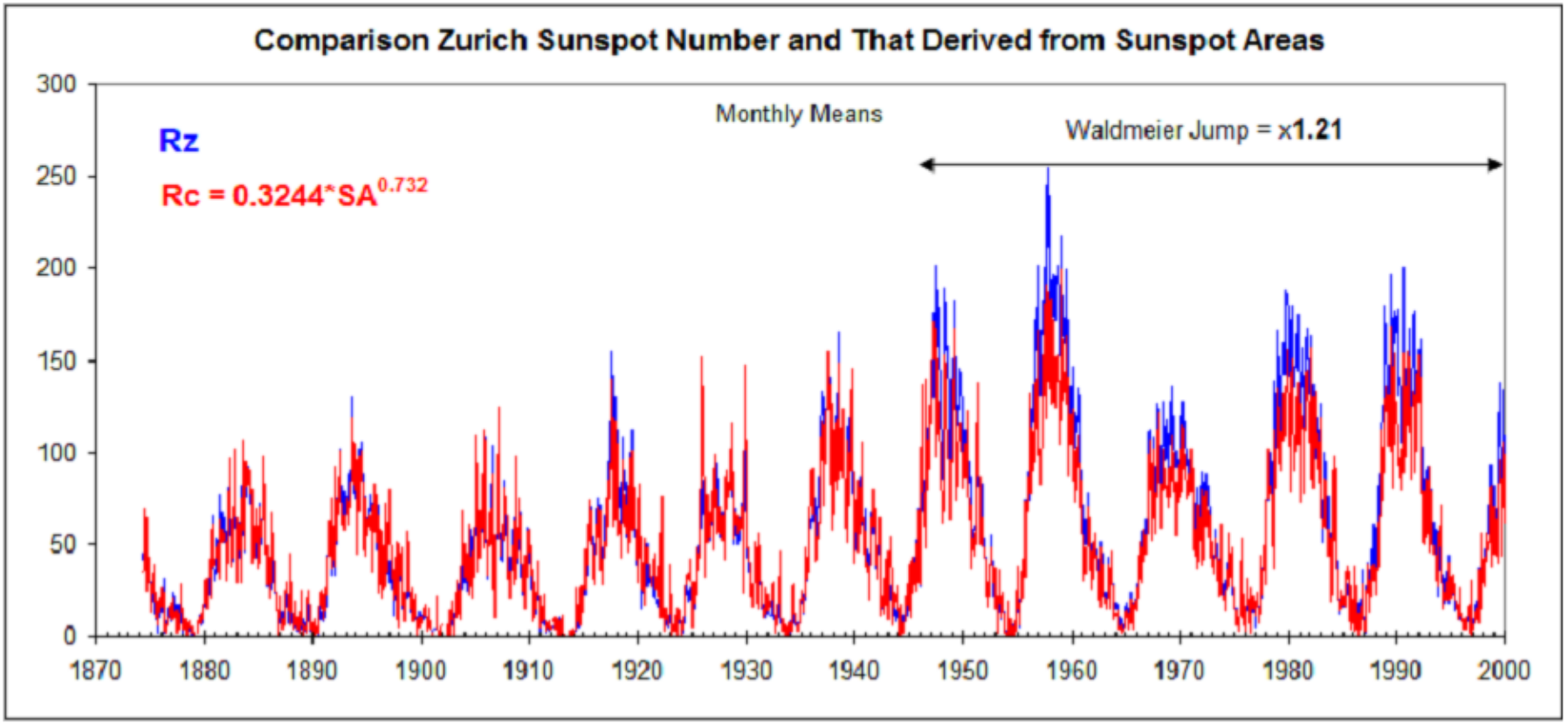
1874-1944 0.3244

1945-2000 0.3921

Waldmeier Jump

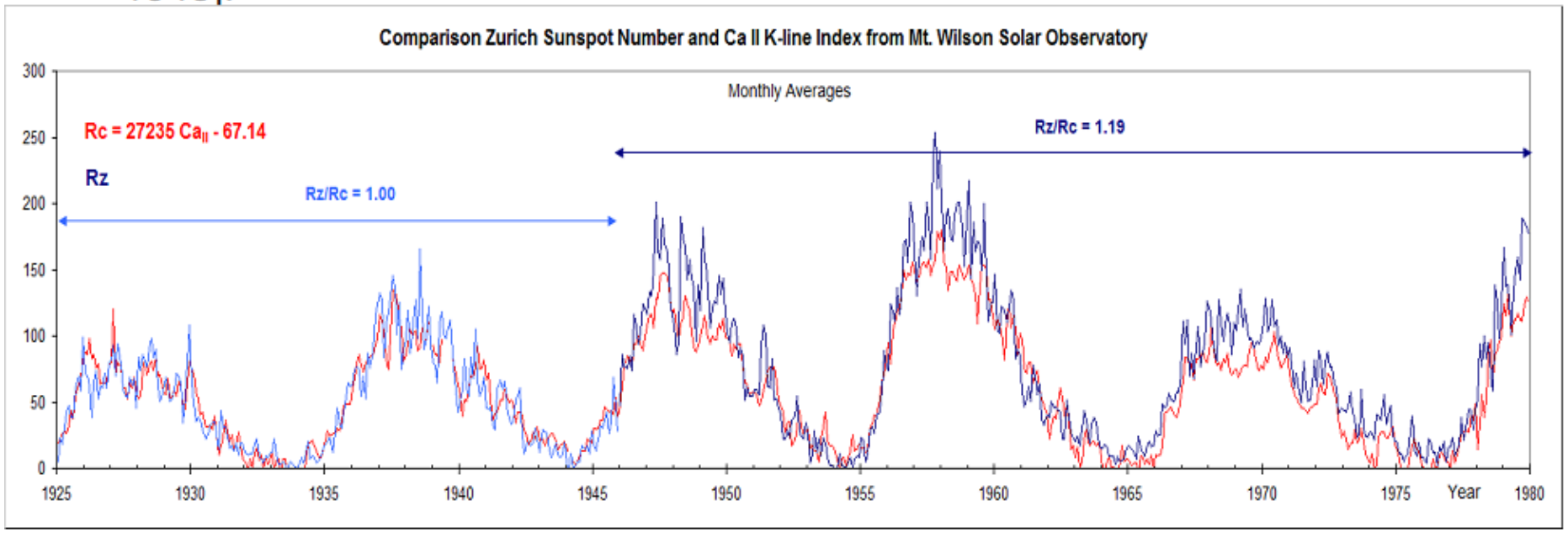
0.3921/0.3244 = **1.212**

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



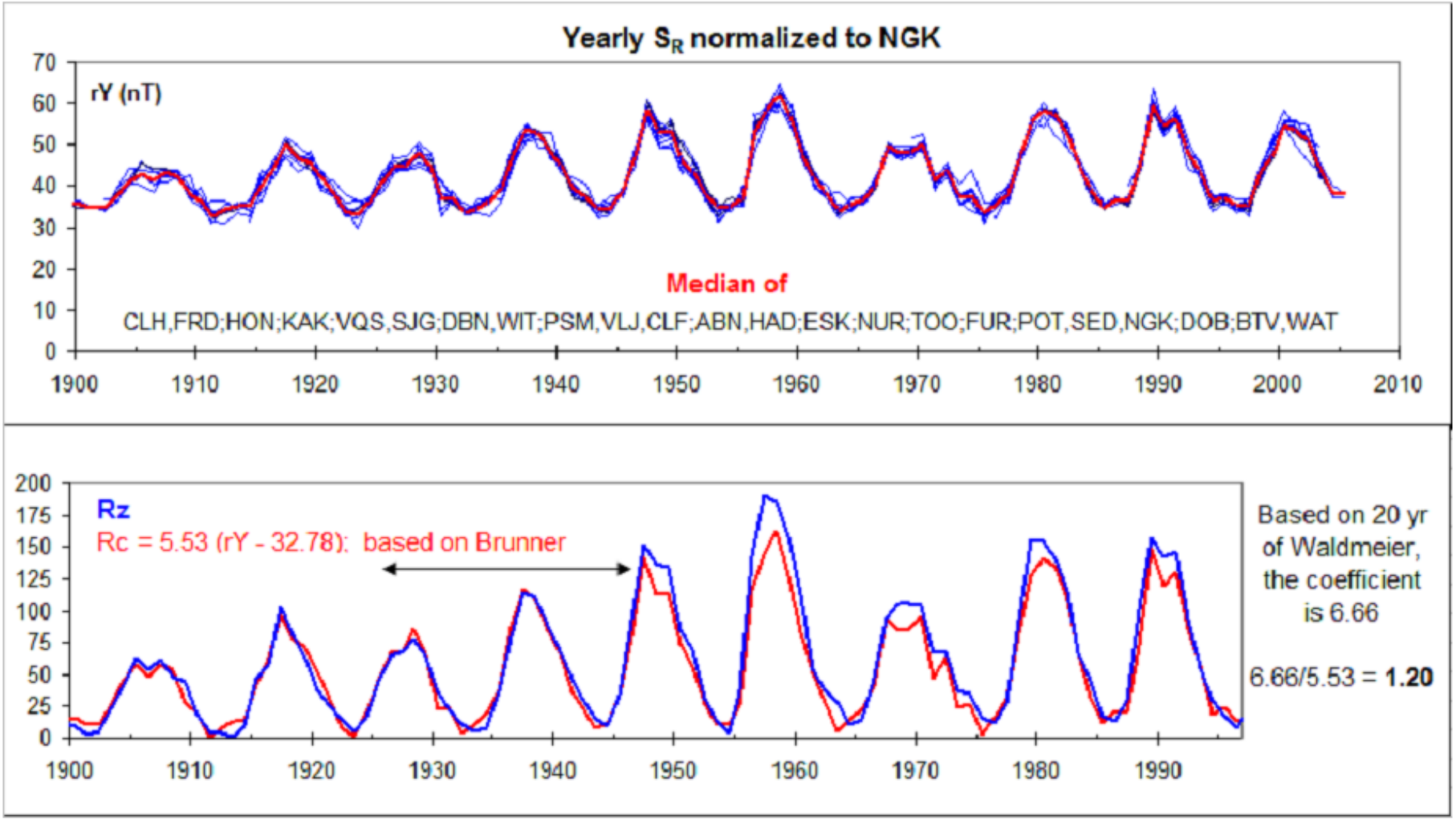
Ca II K-line Data Scaled to Rz shows similar Jump in Rz Sunspot Number after 1945

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



Brunner Comment on Weighting

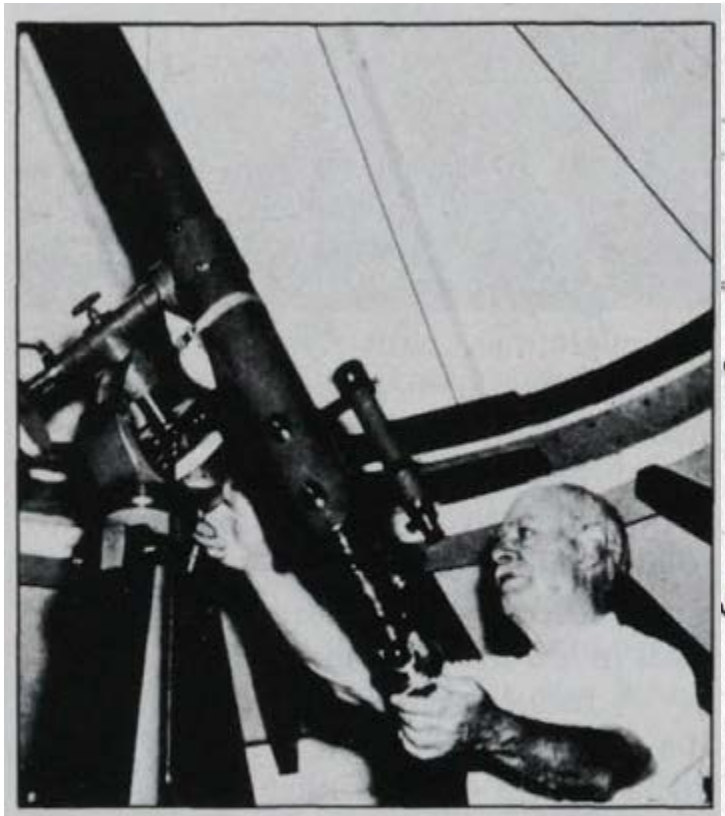
Terr. Magn. Atmosph. Elect. Vol 41 (2), p 210, 1936:

The subjective method of counting may also have an influence. In large centers of activity one is inclined—and this perhaps rightly—to give some single spots according to their sizes a different weight. In the spot-statistics, introduced for our Observatory by Rudolf Wolf 80 years ago, all these circumstances have been considered as far as possible by introducing a reduction-factor on Wolf's unit. The latter is determined by comparison of corresponding observations. In determining the Wolf relative-number a weight of ten is given for the groups of spots and a weight of one for the number of single spots or nuclei.

EIDGEN. STERNWARTE,
Zürich, Switzerland

W. BRUNNER

H. B. Rumrill, 1923-1951



Harry Barlow Rumrill, president of the Rittenhouse Astronomical Society in 1932, with his 4-inch Brashear refractor. From *History of the Rittenhouse Astronomical Society*, courtesy Joy Crist.

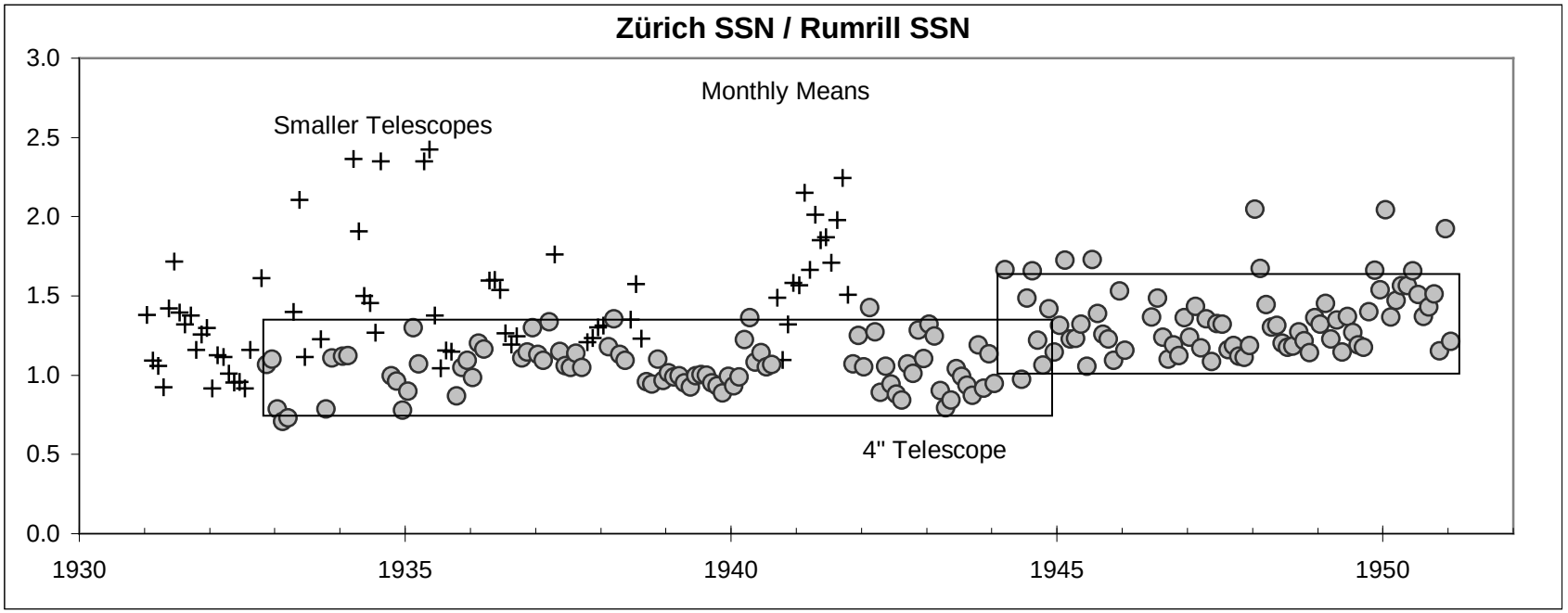
BERWYN, PENNSYLVANIA

Sun Spots and Faculae 256

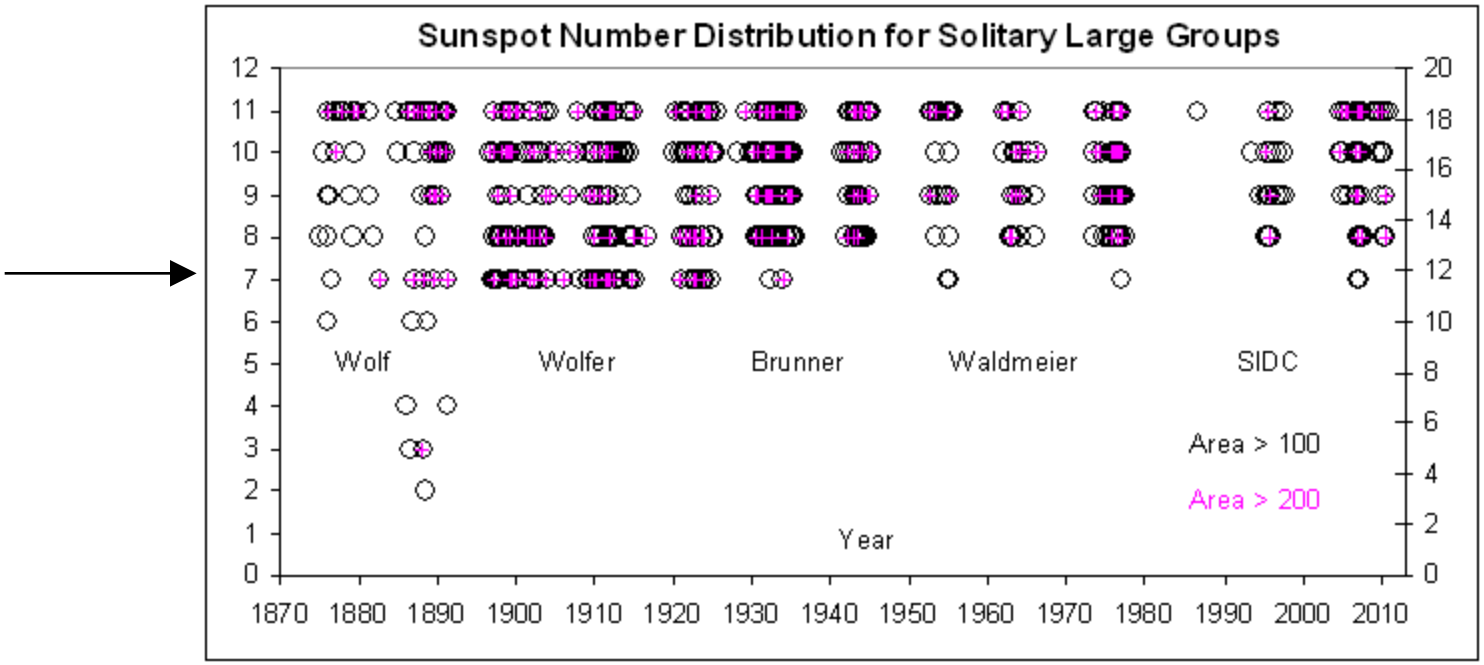
1939		Time	New Groups	TOTAL Groups	TOTAL Spots	Groups Faculae	Definition
June	27	8^{30} a	– Much cloud	6	33	2	Fair
	28	8^{30} a	1 Much cloud. New group near eastern limb.	6	37	4	Poor
	30	10 a	–	4	32	4	Good
July	1	7^{30} a	1 Probably should be reckoned as 6 groups.	5	39	3	Good
	2	7^{30} a	–	6	35	5	Good
	3	7^{15} a	4	9	23	5	Good
	4	8^{45} a	– The faculae especially fine.	9	36	5	Beautiful
	6	7^{30} a	2 Much cloud	6	51	2	Good
	8	7^{30} a	1 A magnificent exhibition	5	77 +	2	Good

Sky & Telescope, Jan. 1989

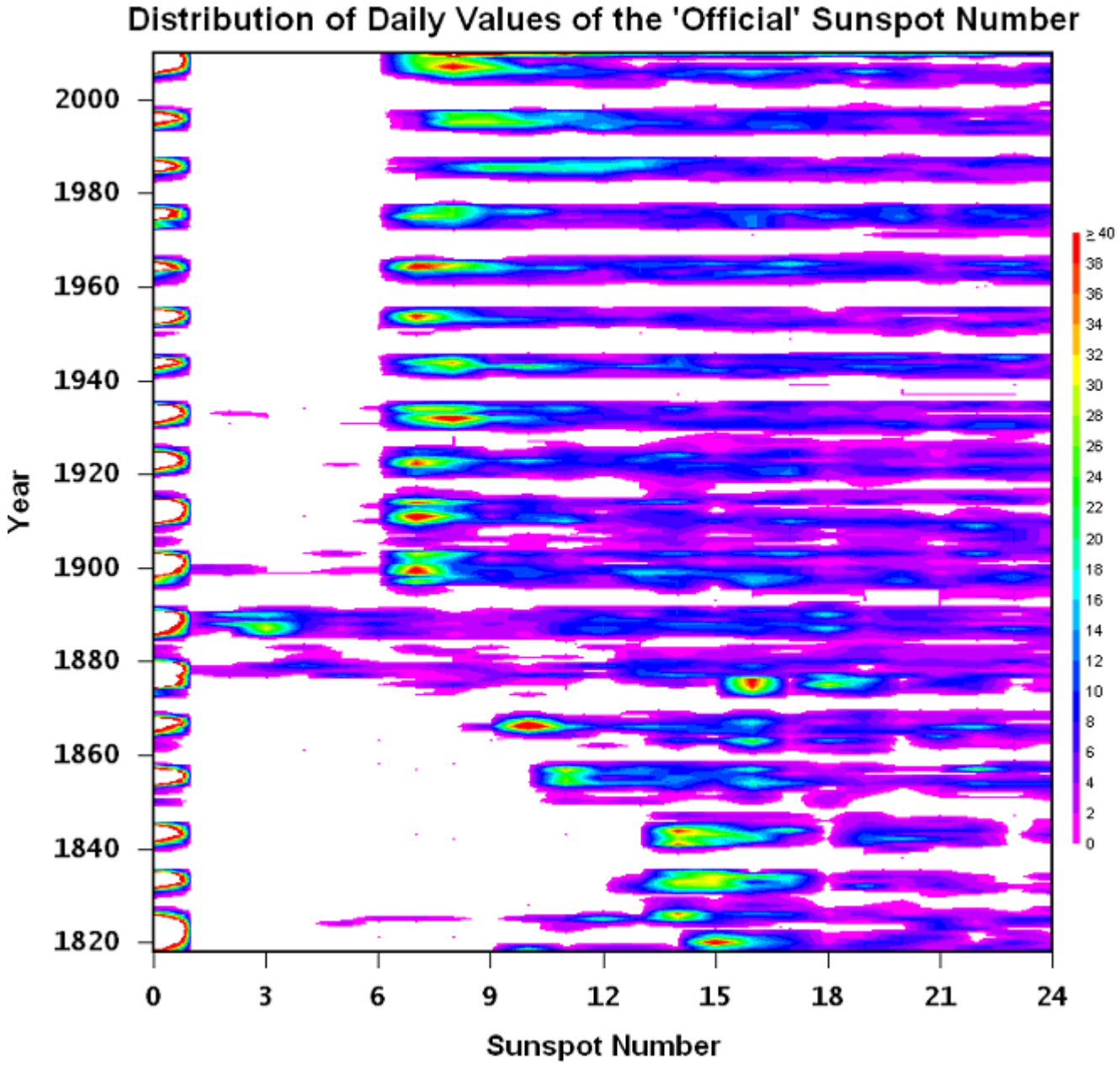
Zurich vs. Rumrill



Large Solitary Groups



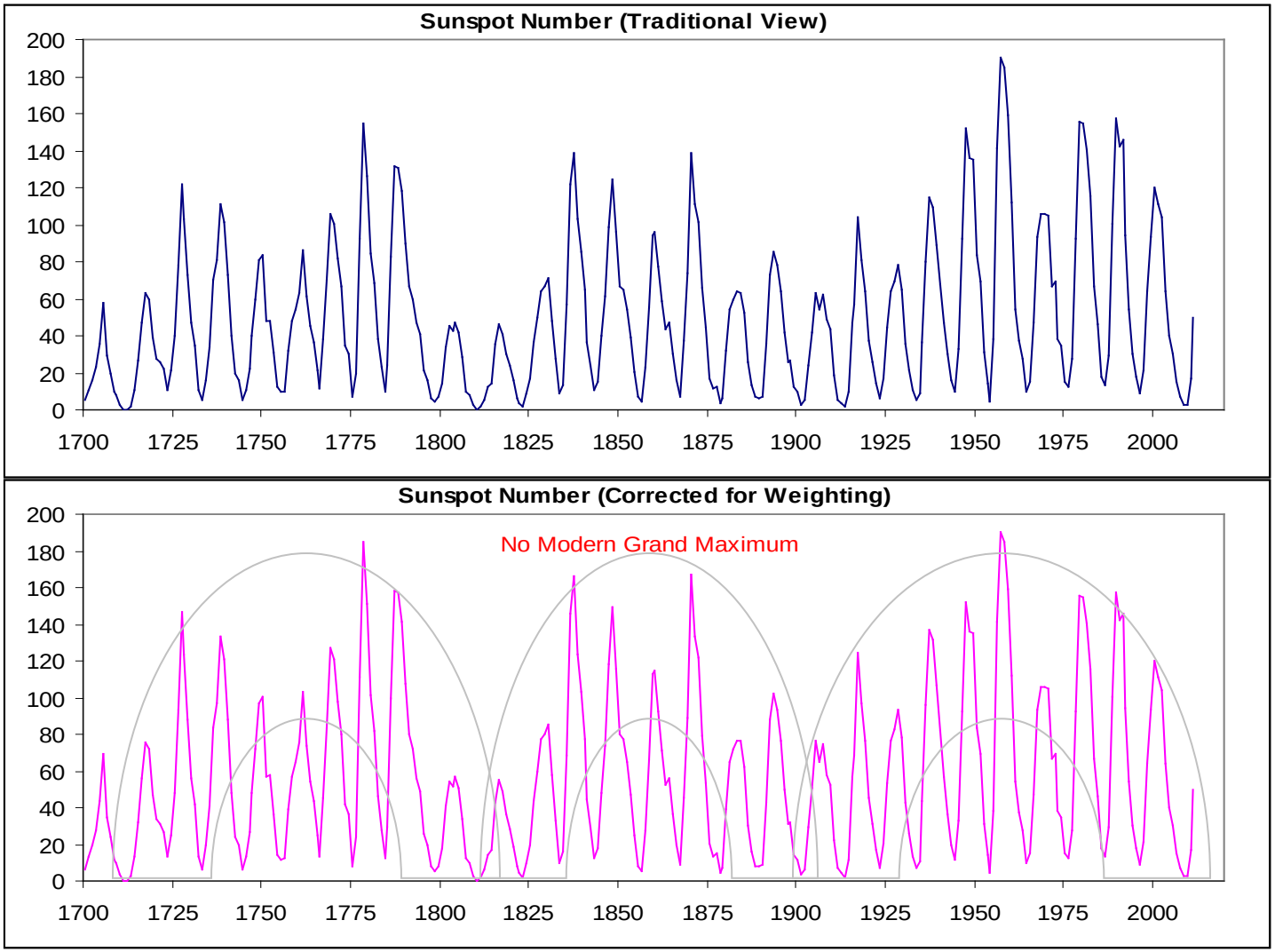
Daily Values



Averages of assistants included

adjustment of 25% for Schwabe

The Effect on the Sunspot Curve



No long-term trend the last 300 years