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Reconciling Group and International Sunspot Numbers

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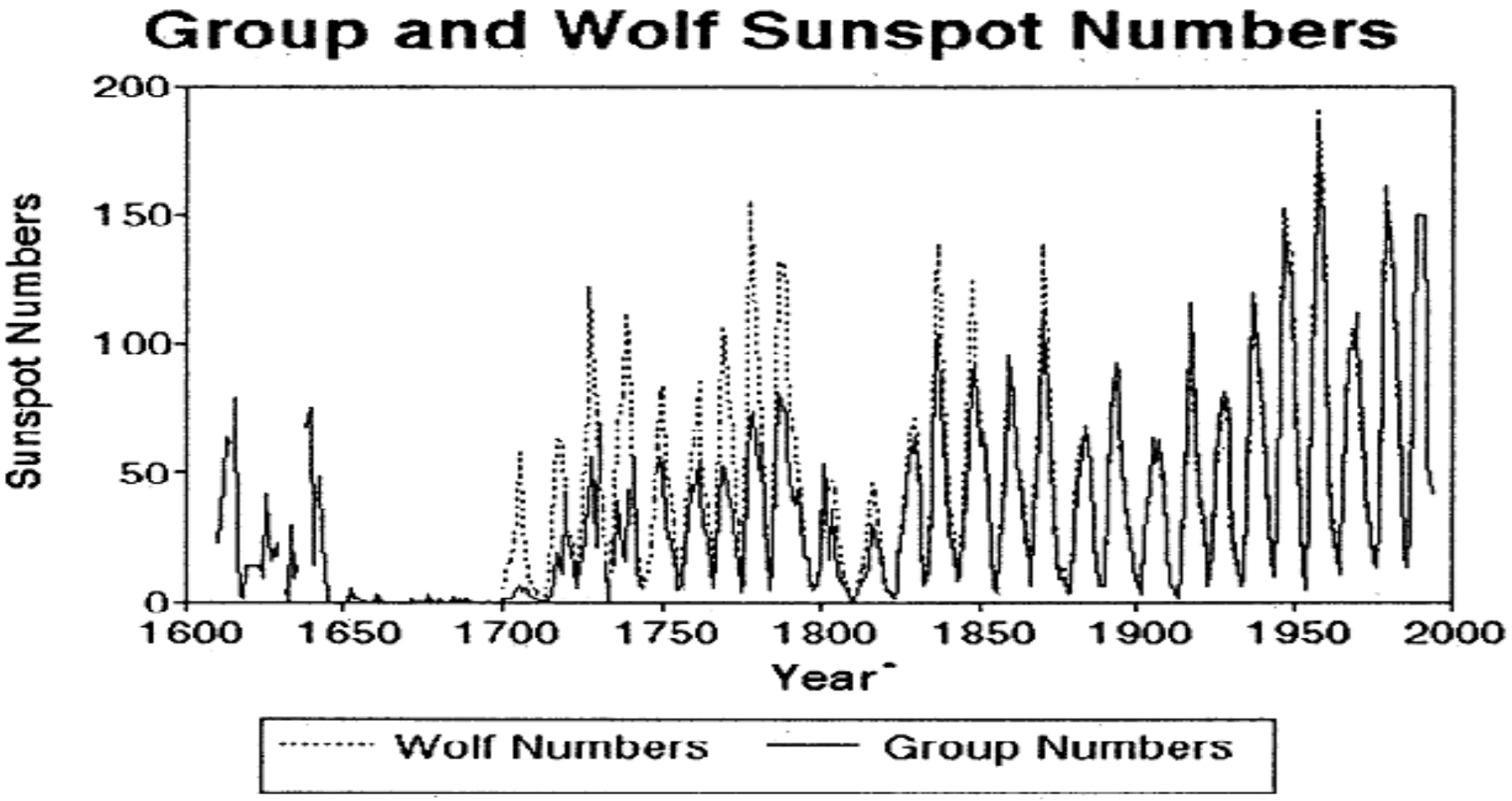
2 September 2012

Sunspot Number

- Primary time series in solar & solar-terrestrial physics: applications to dynamo studies and climate change

- Two SSN series that vary widely during the 19th Century



Hoyt & Schatten, GRL *21*, 1994

The Sunspot Number(s)

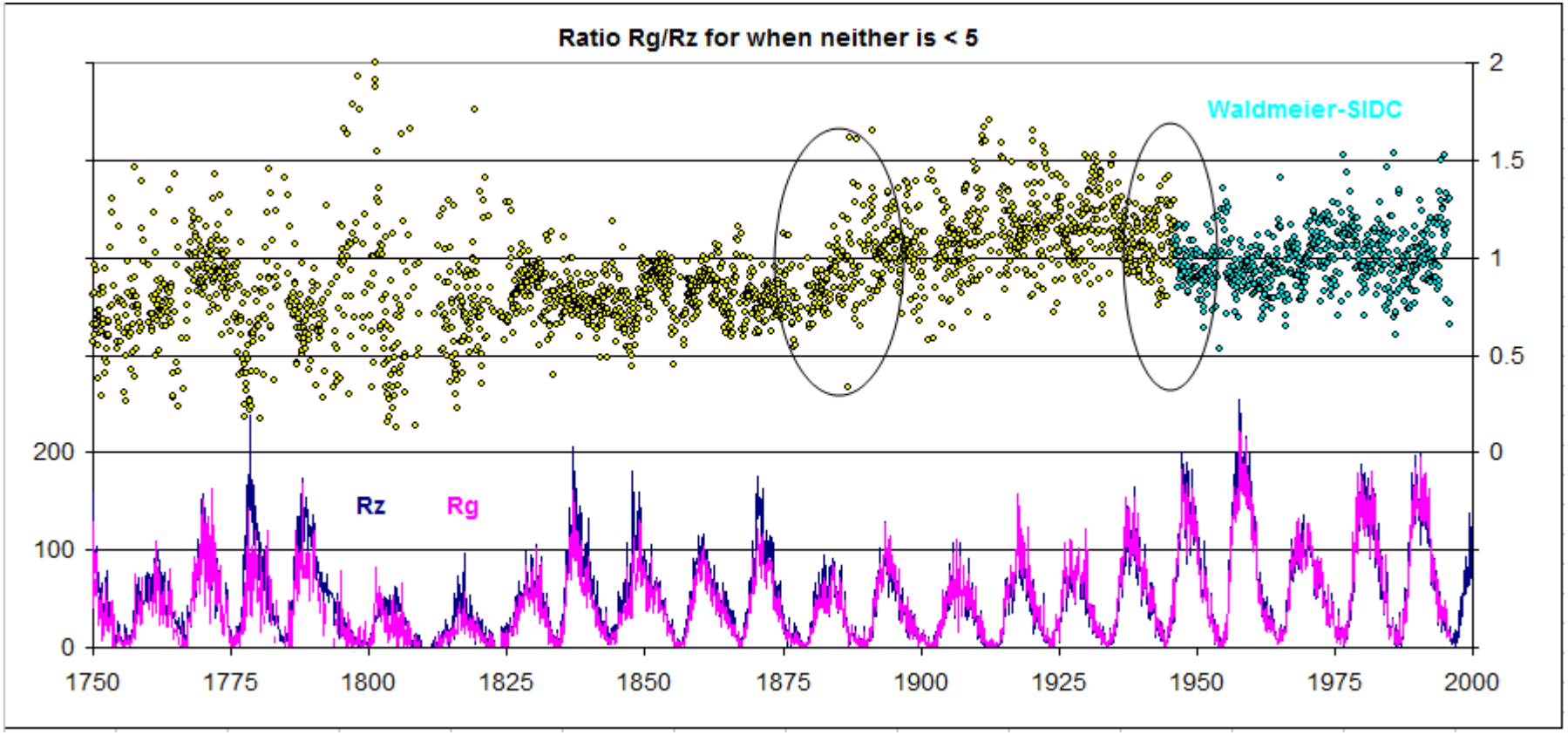
Rudolf Wolf (1816-1893)
Observed 1849-1893

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

- Group Number = 12 k_G G

Ken Schatten

The Ratio Group/Zurich SSN has Two Significant Discontinuities

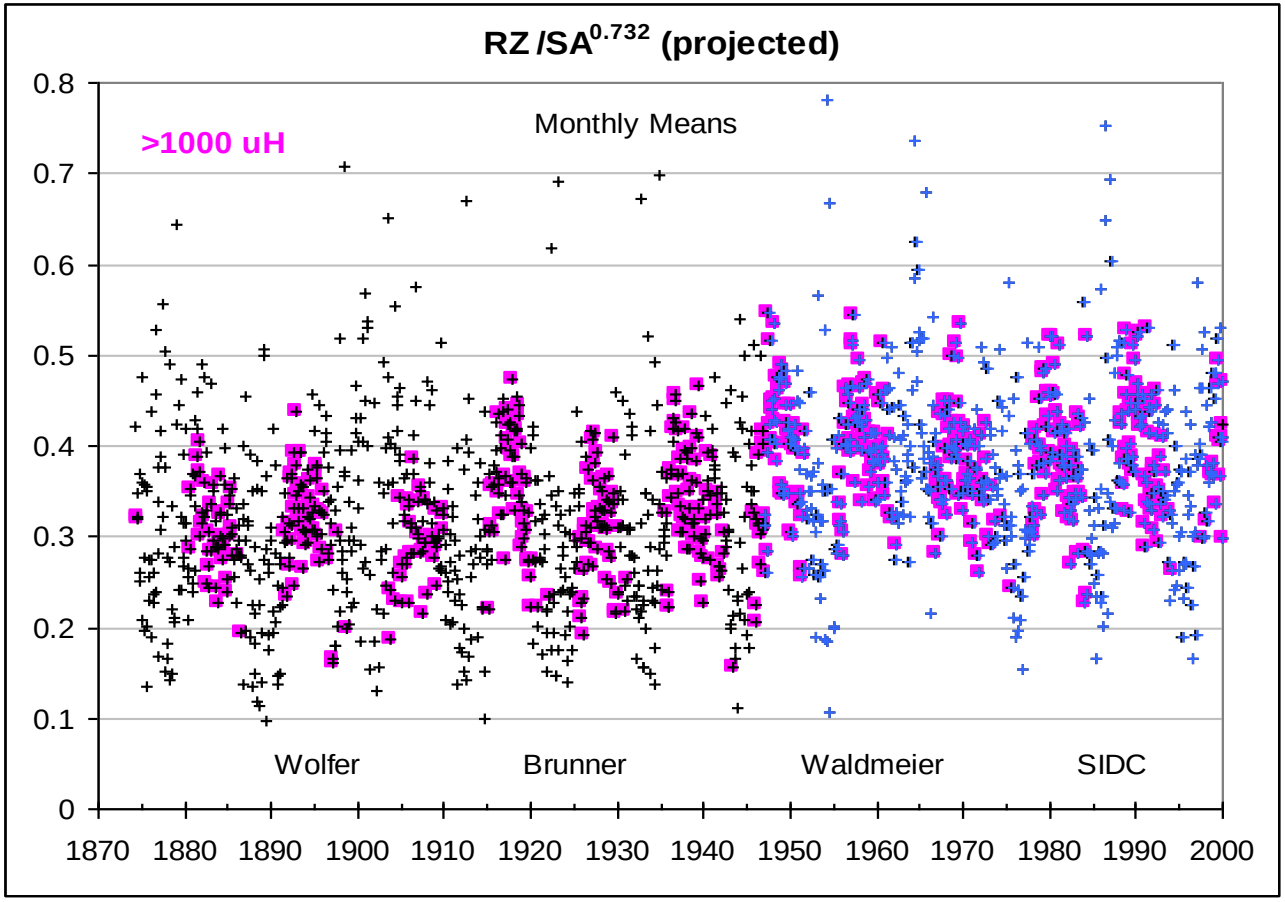


At ~1946 (after Max Waldmeier took over) and at ~1885

Corroborating Indications of the ‘Waldmeier Discontinuity’ ~1946

- SSN for Given Sunspot Area increased 21%
- SSN for Given Ca II K-line index up 19%
- SSN for Given Diurnal Variation of Day-side Geomagnetic Field increased by 20%
- Ionospheric Critical Frequency *foF2* depends strongly on solar activity. The slope of the correlation changed 20% between sunspot cycle 17 and 18

Sunspot Areas vs. Rz

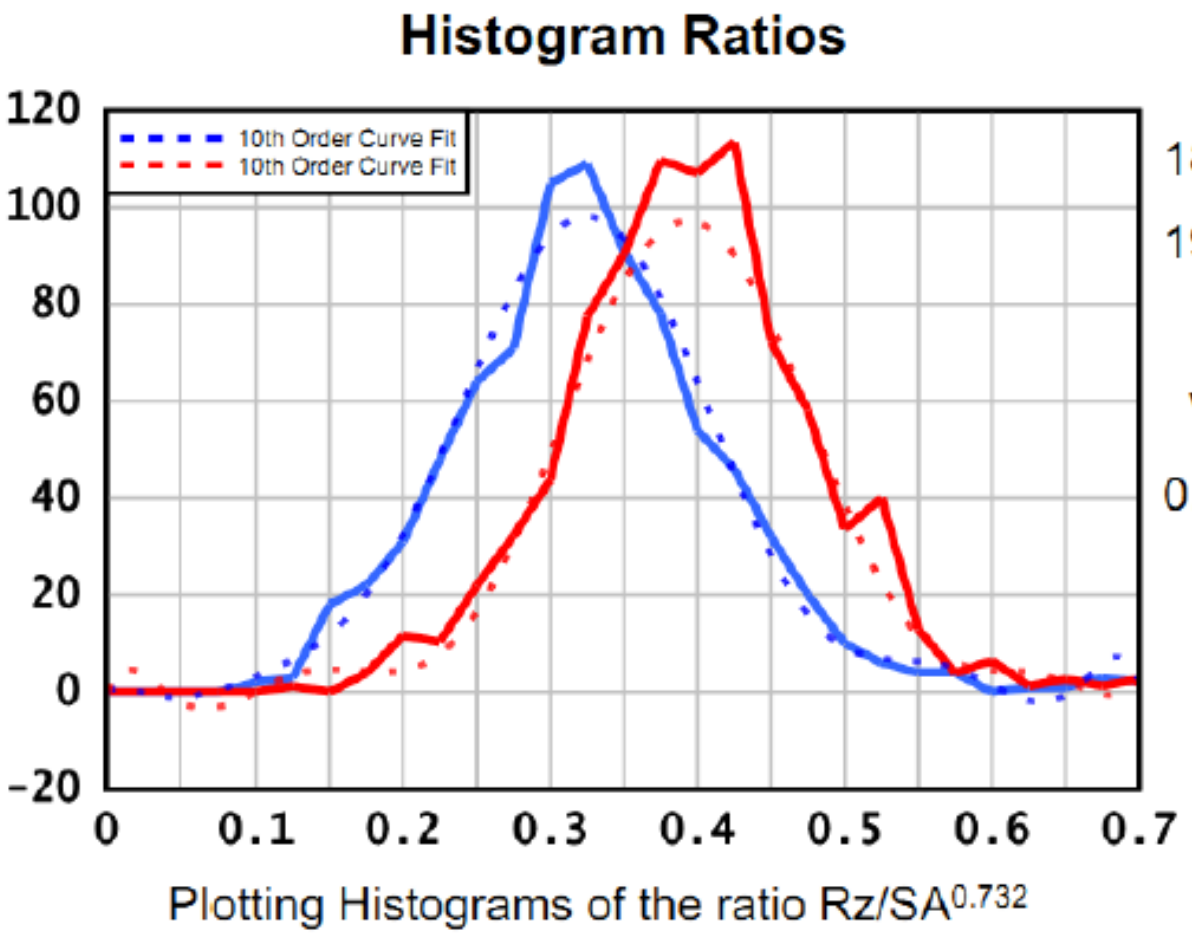


The relationship between SSN and sunspot area [SA, Balmaceda et al., 2009] is not linear, but can be made linear raising SA to the power of 0.732.

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

Clear change in the relationship around 1945

Quantifying the Waldmeier 'Jump'



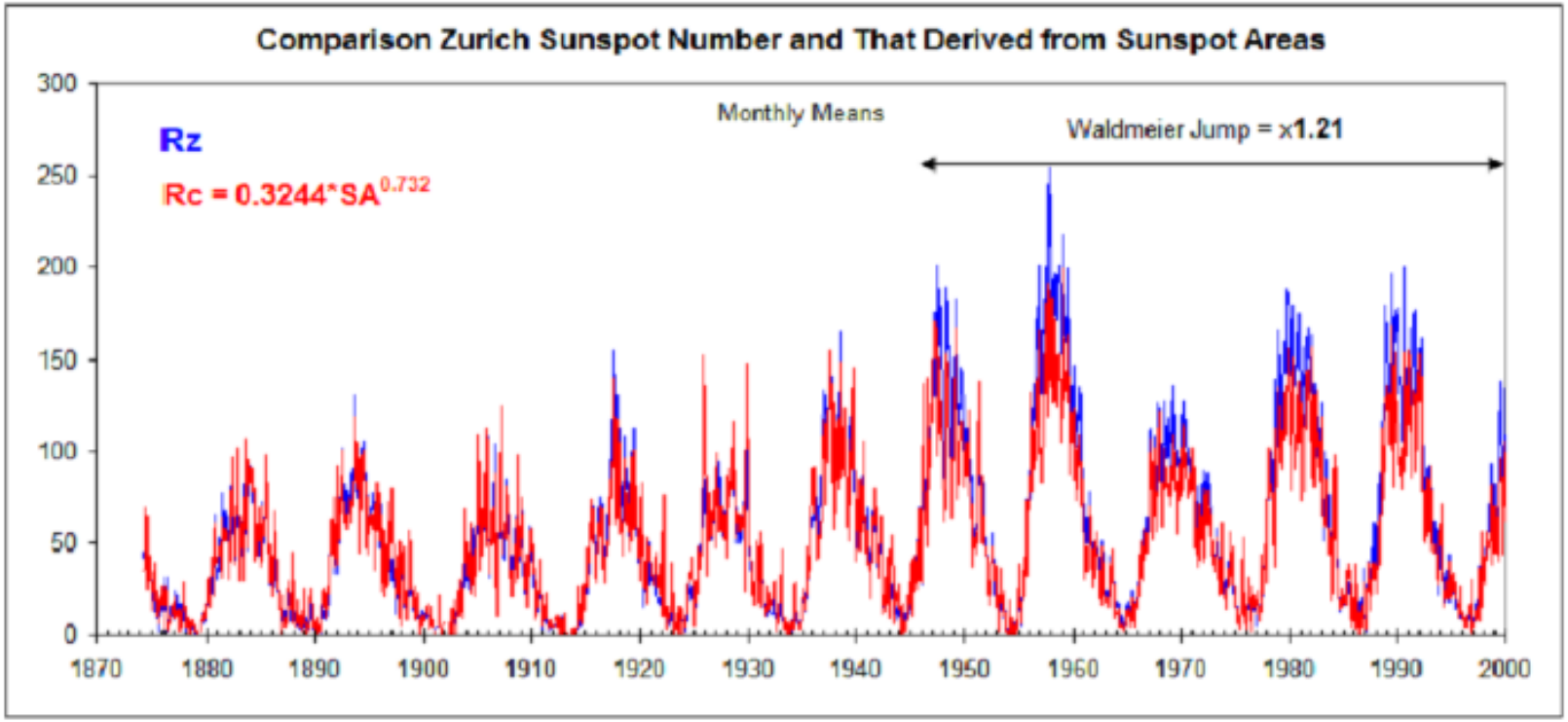
1874-1944 0.3244

1945-2000 0.3921

Waldmeier Jump

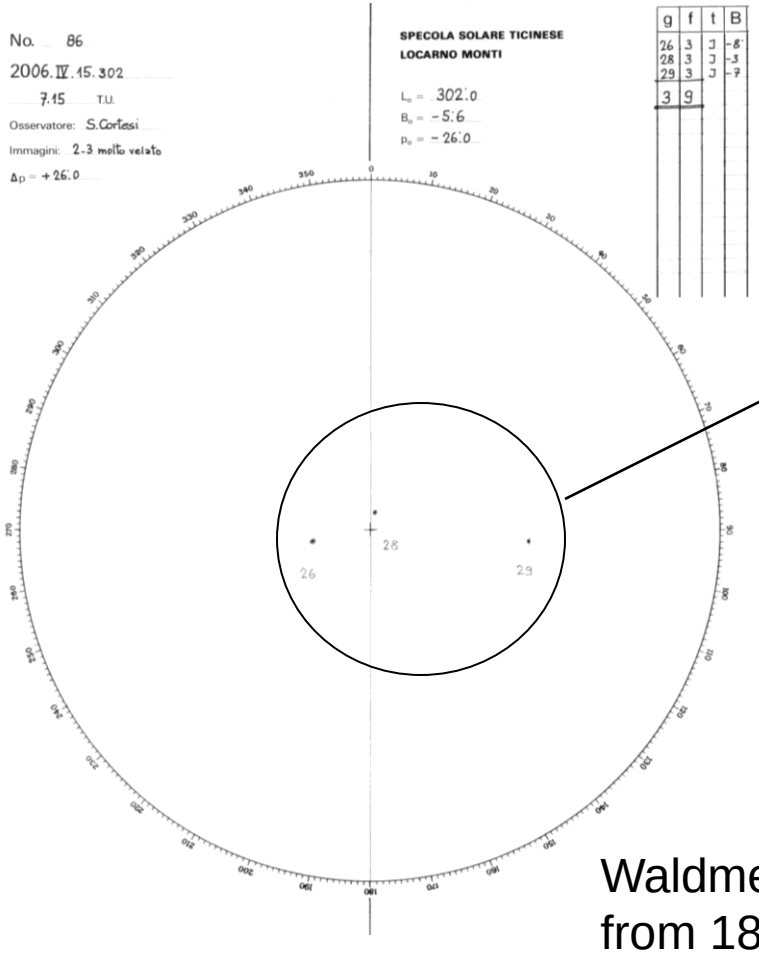
0.3921/0.3244 = **1.212**

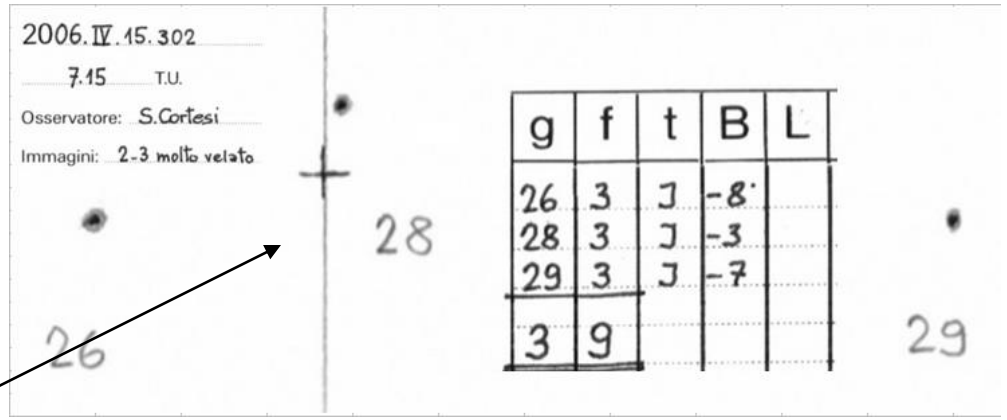
Illustrating that Observed Rz after 1945 is Higher than Deduced from Sunspot Areas



What caused the Waldmeier Discontinuity?

At some point during the 1940s the Zürich observers began to weight sunspots in their count

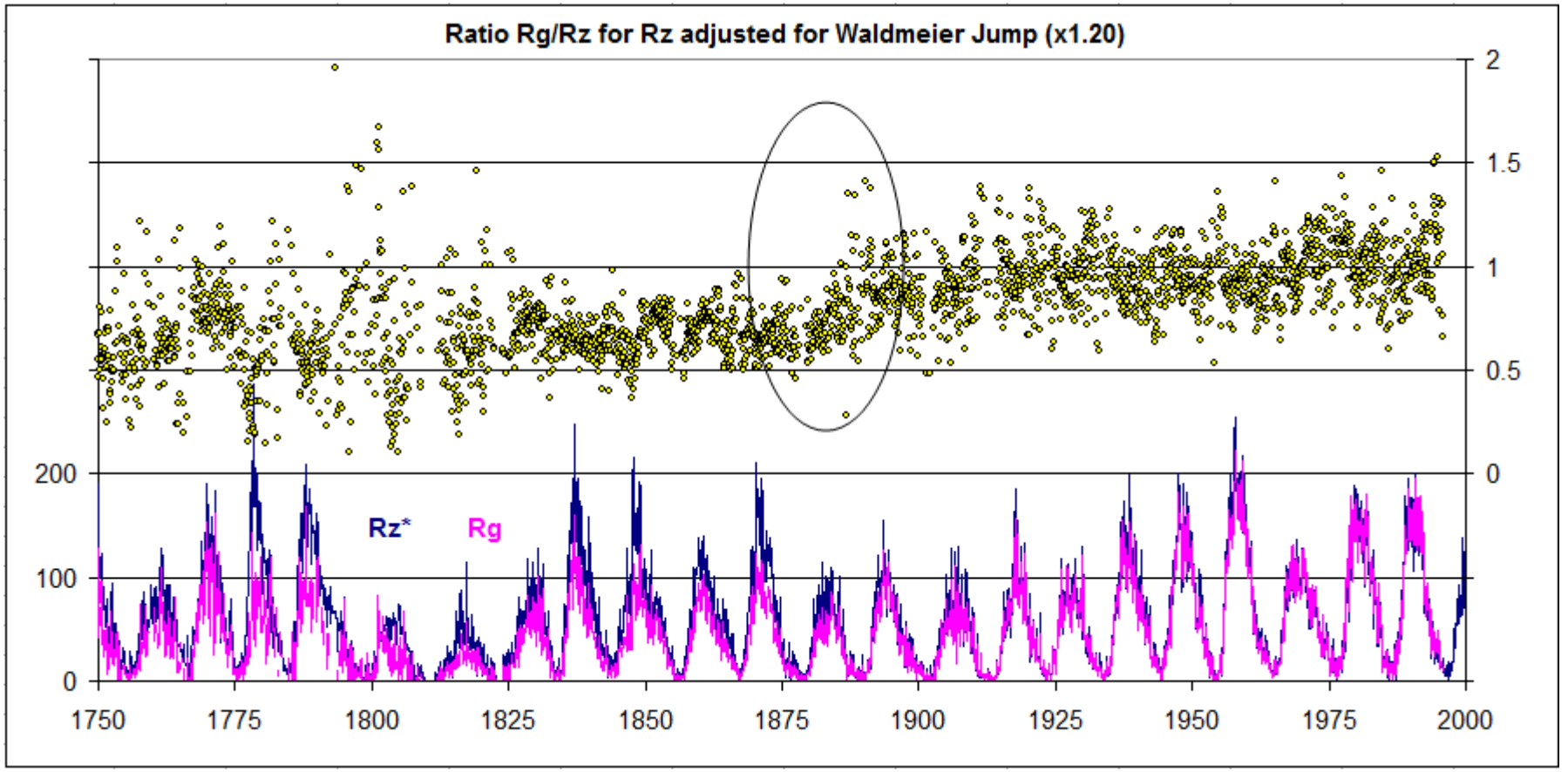




Weights [from 1 to 5] were assigned according to the size of a spot. Here is an example where the three spots present were counted as 9, inflating the sunspot number by 18% [(3*10+9)/(3*10+3)=1.18]

Waldmeier claimed that the weighting scheme dates from 1882. However, Wolfer (1907) explicitly states that he counts spots without regard to size

Removing the discontinuity in ~1946, by multiplying Rz before 1946 by 1.20, yields



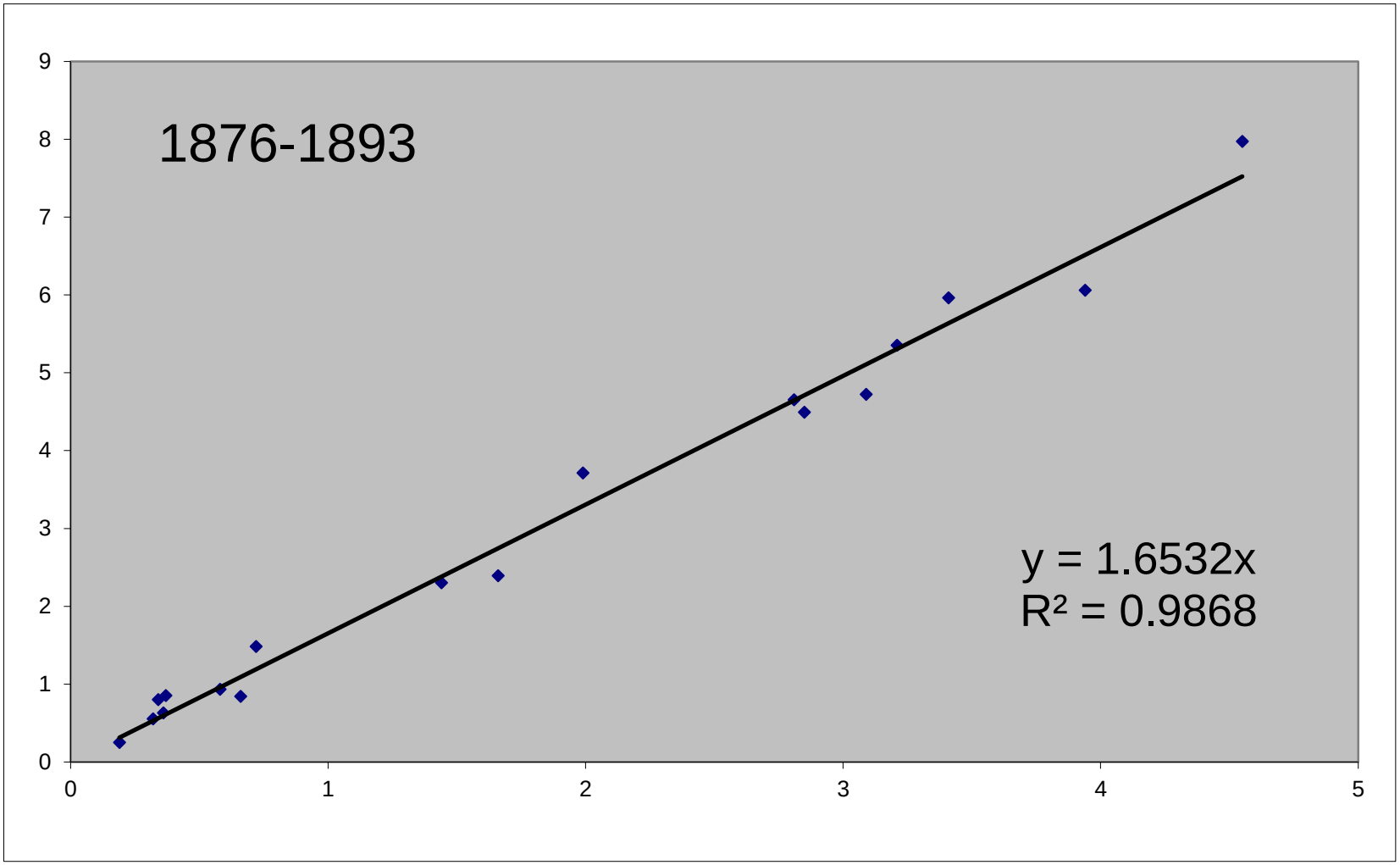
Leaving one significant discrepancy ~1885

Independent
Group Sunspot Number Determination

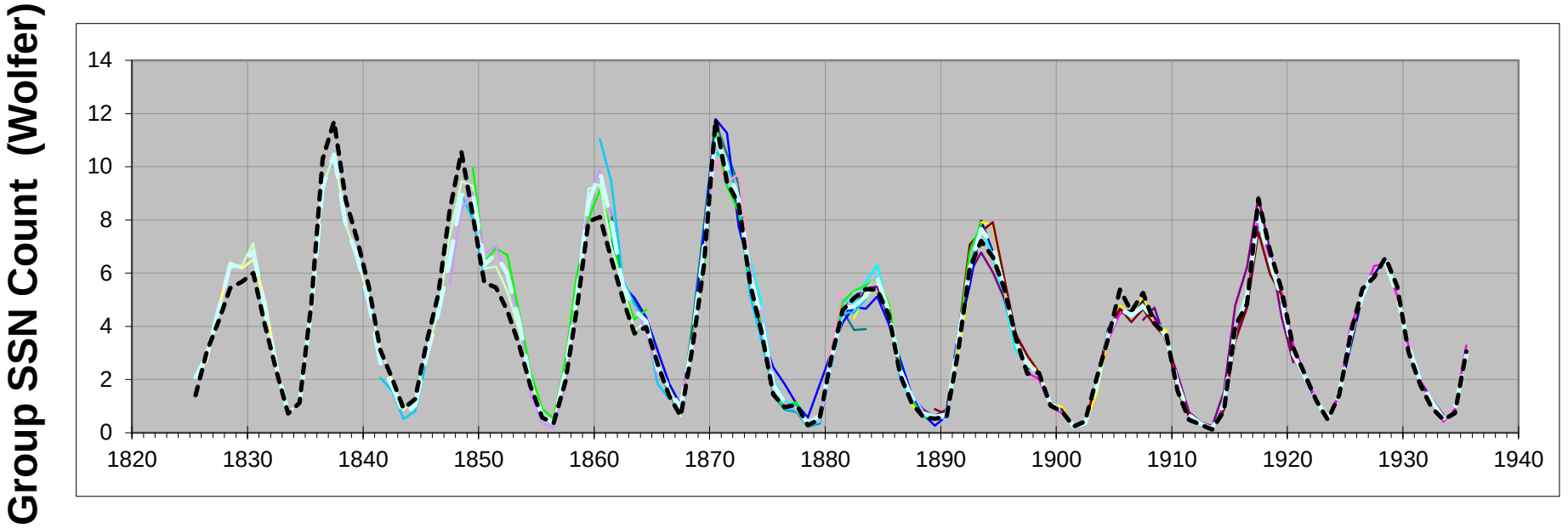
- Includes all major observers from 1825-1900

- Based on group counts (scaled to Wolfer who observed from 1876-1928)

Alfred Wolfer (1854-1931)



Wolfer reported 65% more groups than Wolf



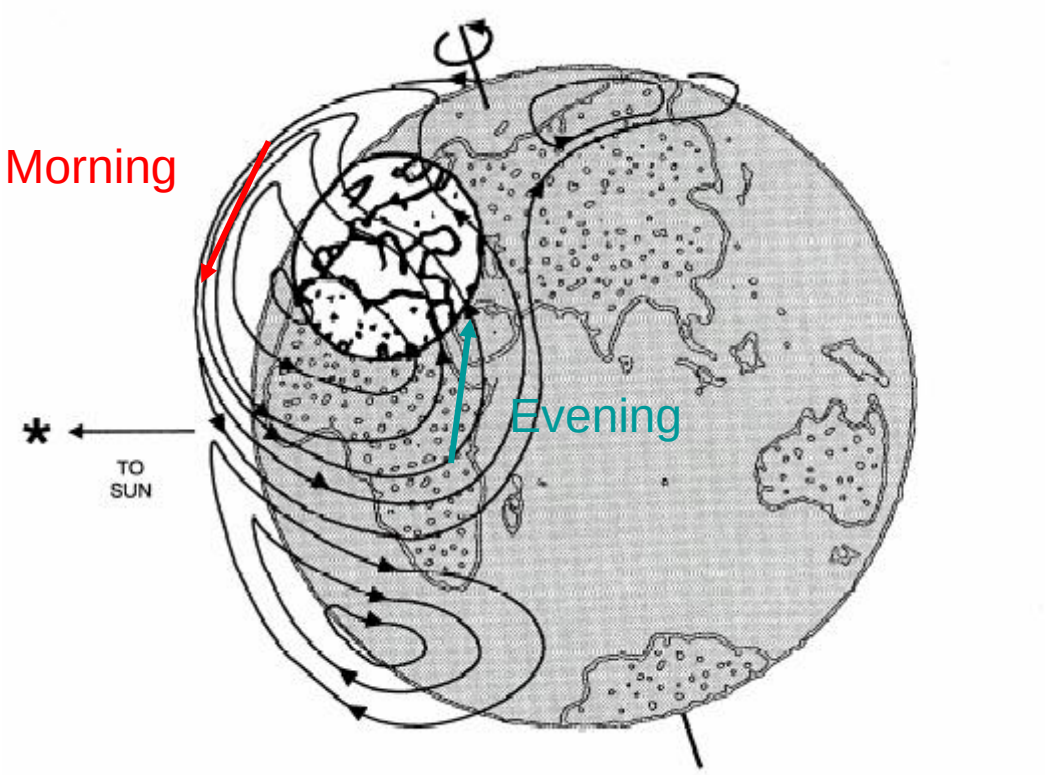
15 Observers: Wolfer, Broger, Madrid, Leppig, Moncalie, Pastorff, Quimby, Schmidt, Schwabe, Shea, Spoerer, Tacchini, Weber, Winckler, Wolf

------ = Ri/12

No significant systematic difference between Ri & Rg

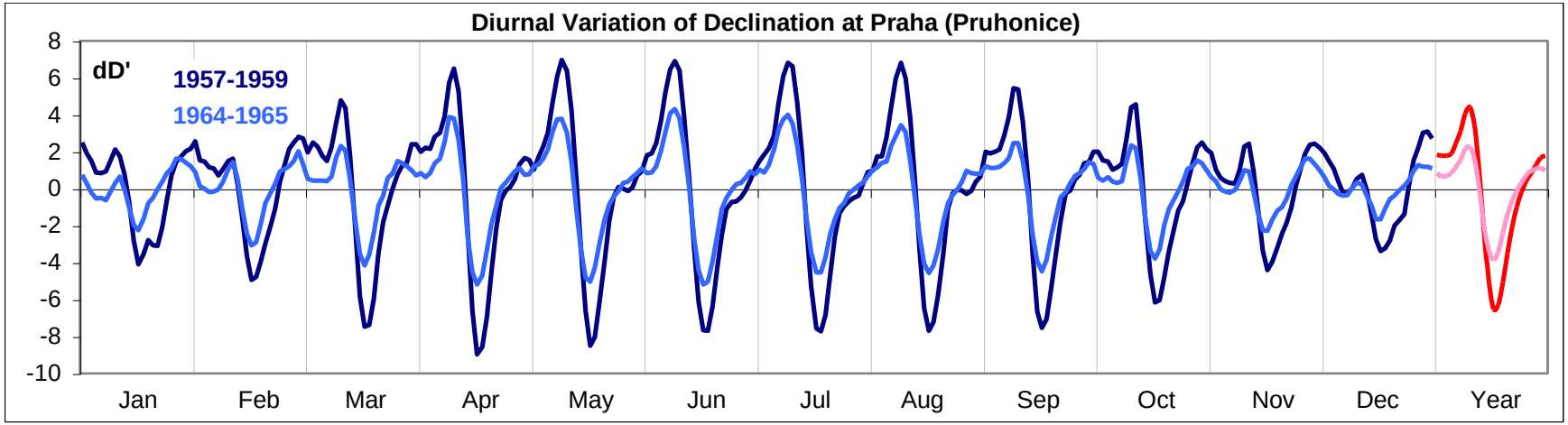
Confirmed by a technique based on geomagnetic data:

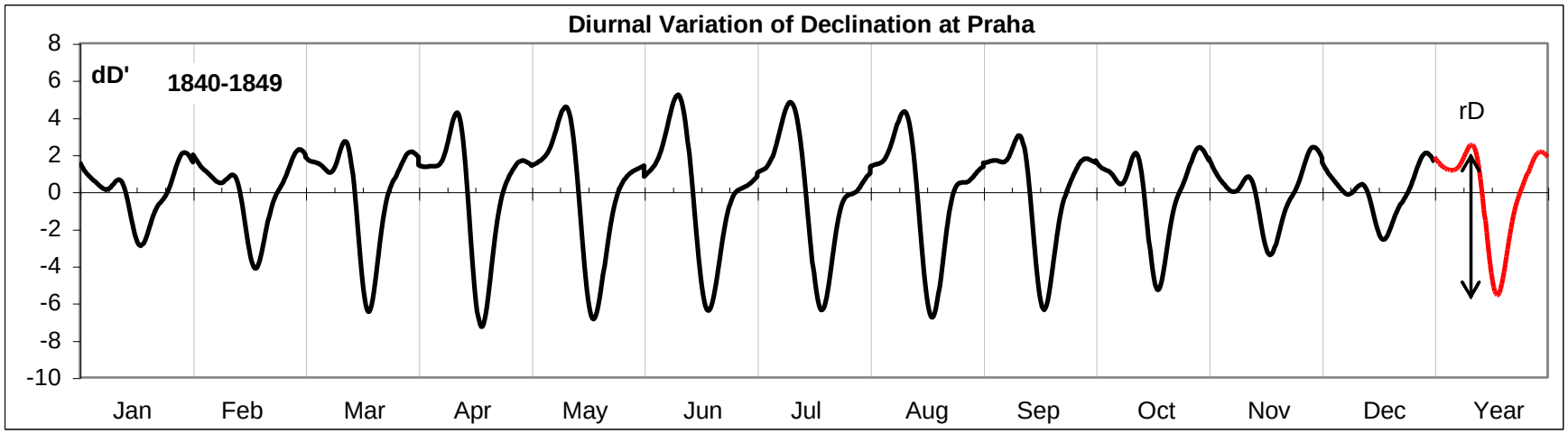
It has been known since 1852 that the daily range of geomagnetic activity varies with the SSN (Wolf & Gautier)



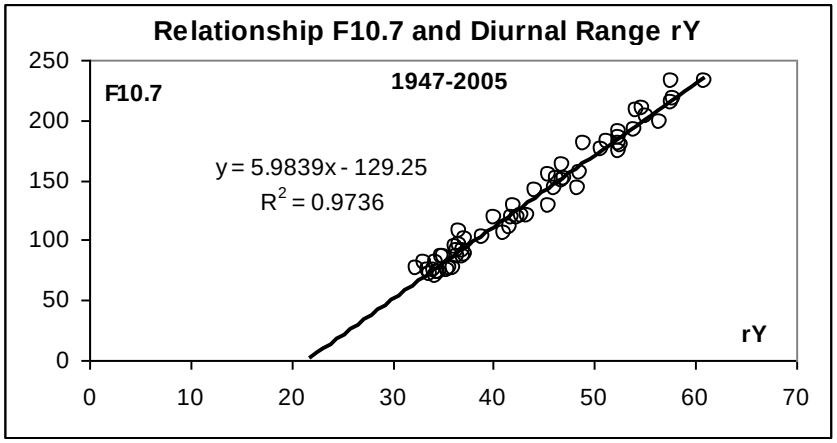
A current system in the ionosphere [E-layer] is created and maintained by solar FUV radiation

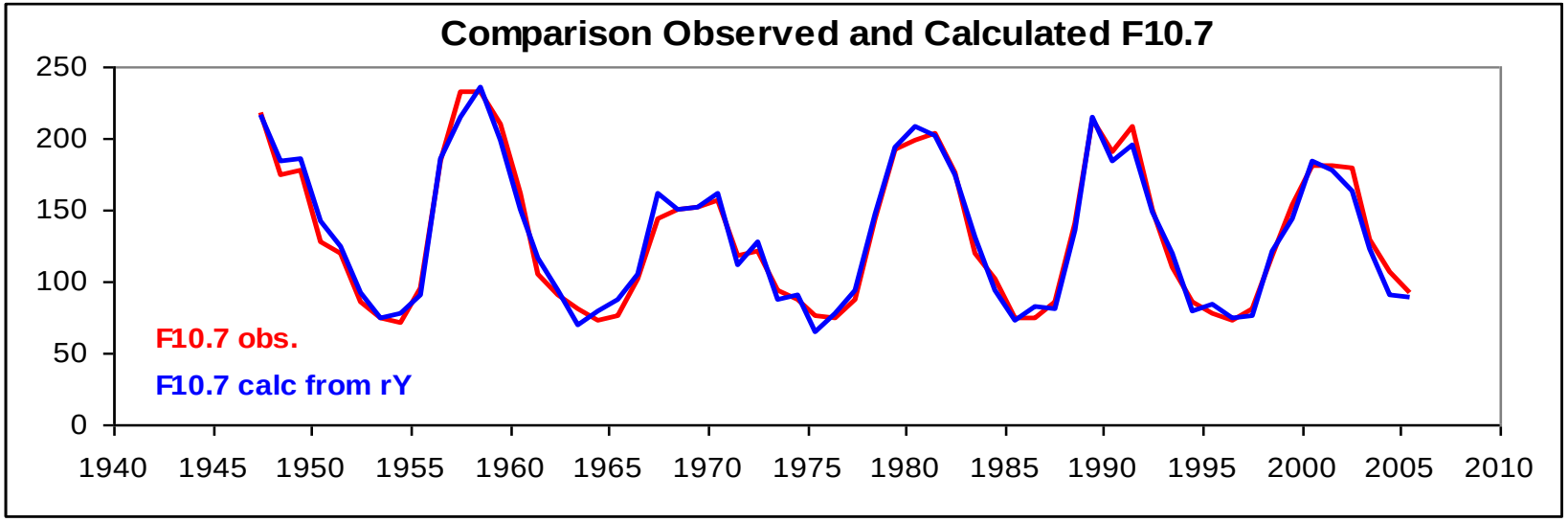
The Diurnal Variation of the Declination for Low, Medium, and High Solar Activity



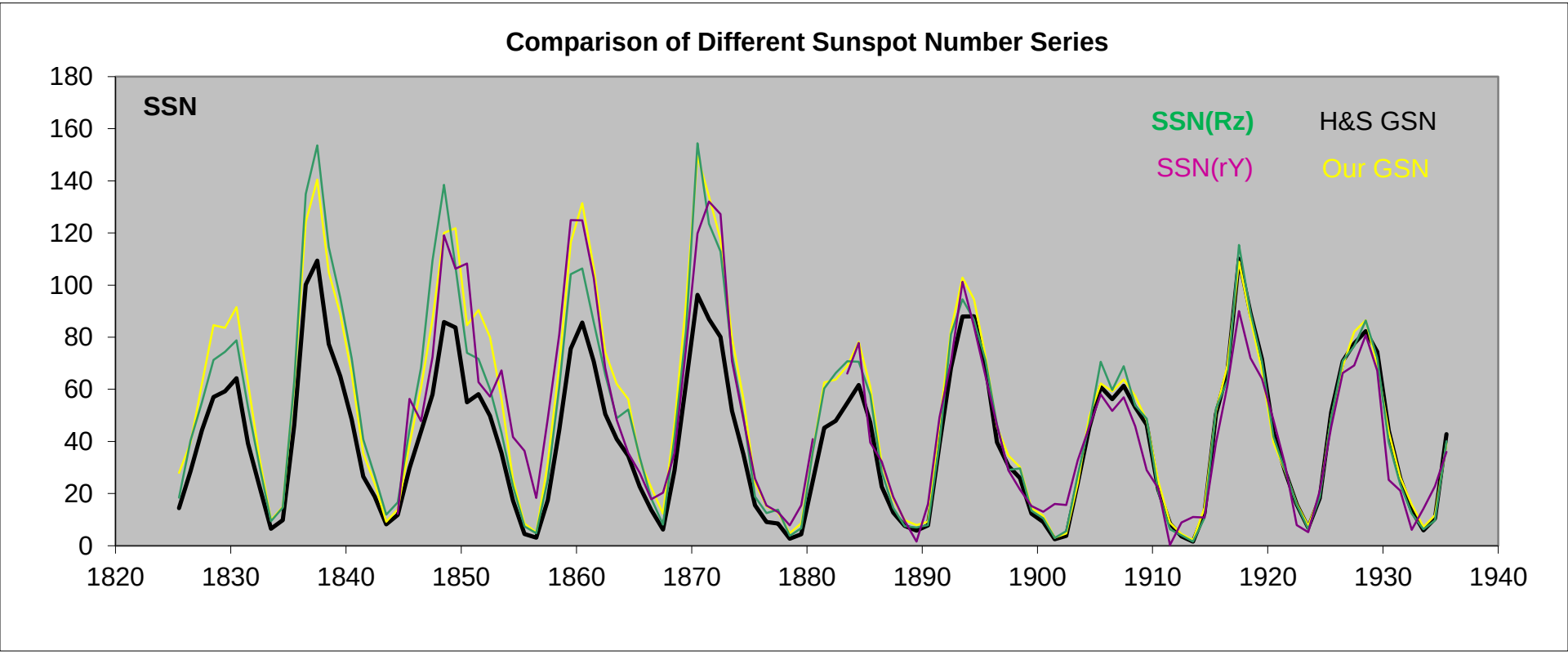


The Diurnal Range *rY* is a very good proxy for the Solar Flux at 10.7 cm

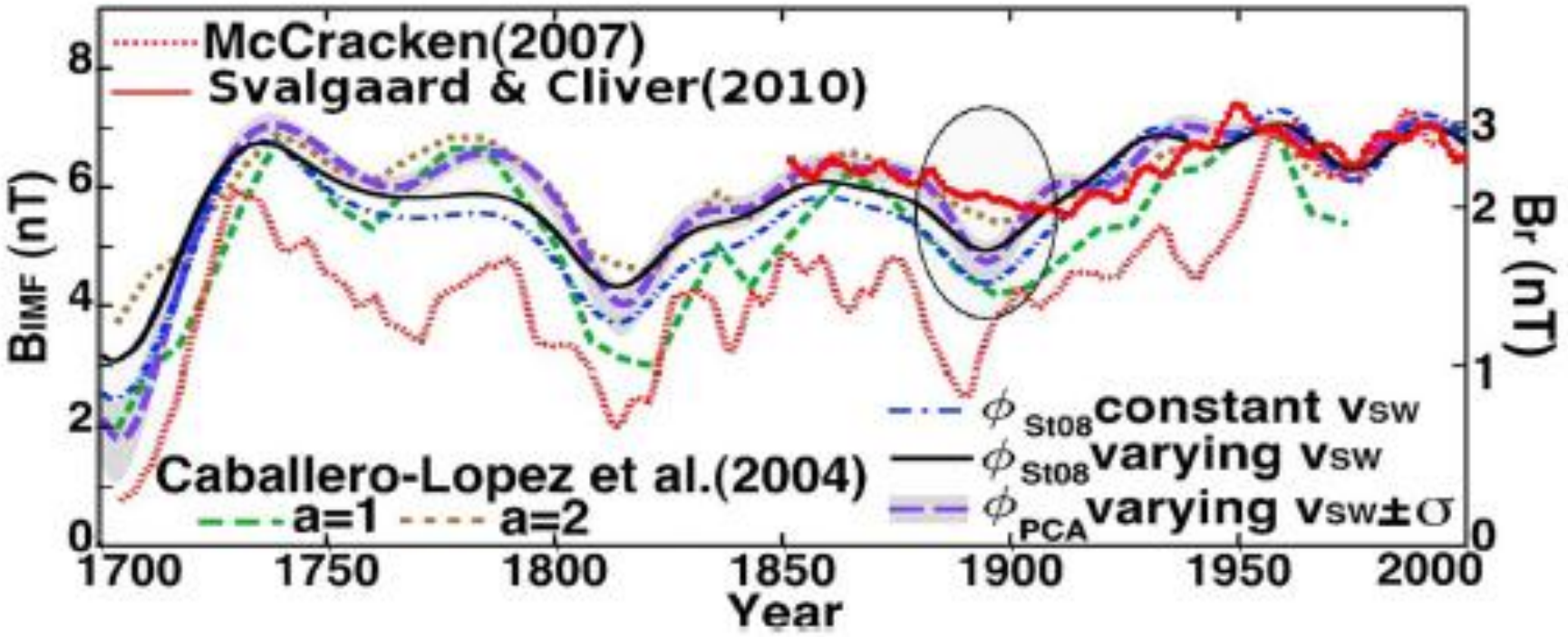




F10.7, in turn, is highly correlated with the SSN

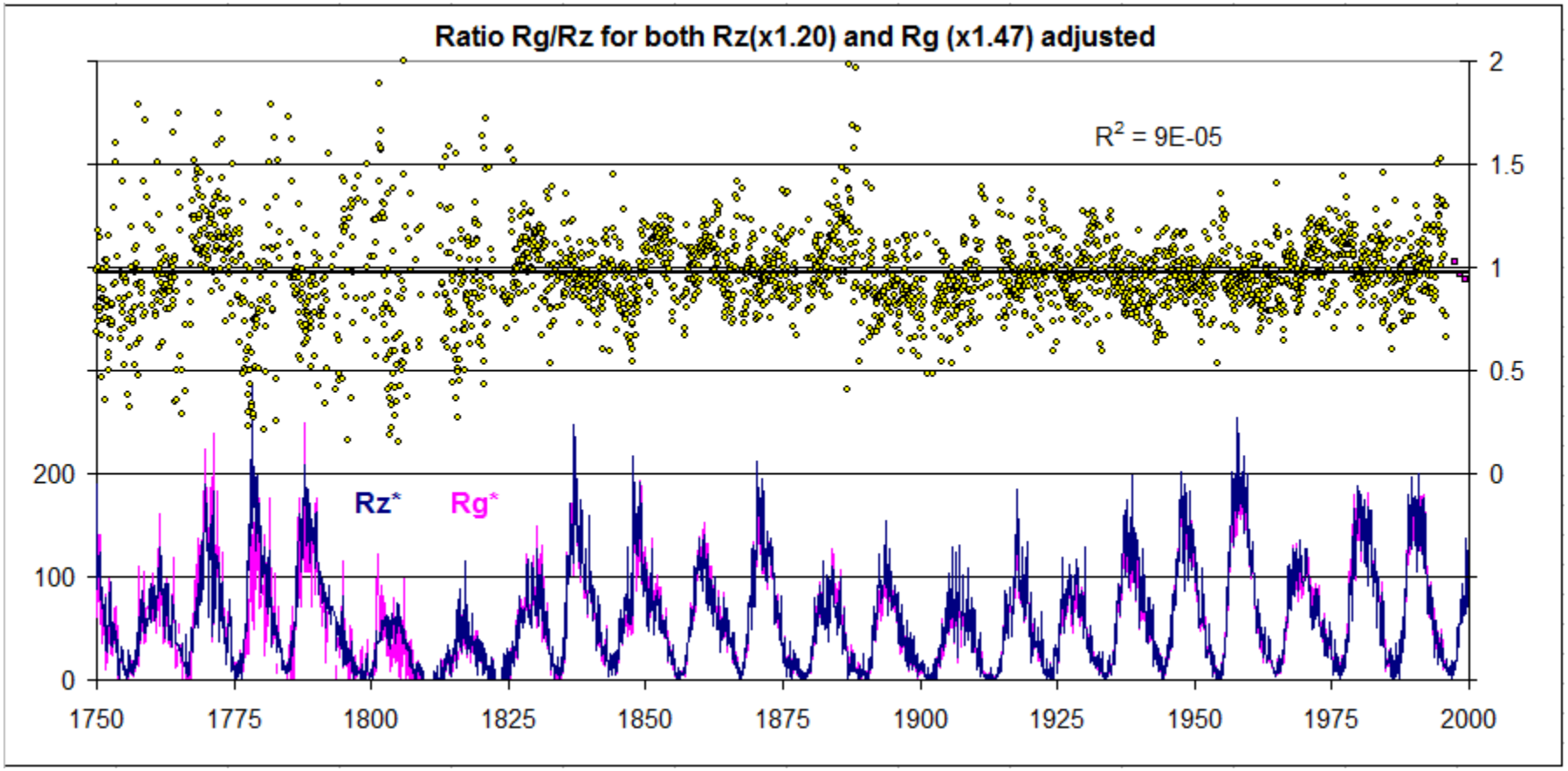

Comparison of Different Sunspot Number Series
SSN
SSN(Rz)
H&S GSN
SSN(rY)
Our GSN
180
160
140
120
100
80
60
40
20
0
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940

The most recent long-term solar reconstructions based on ^{10}Be data from ice cores is generally consistent with our result



Steinhilber et al. (2010)

Removing the discontinuity in ~1885 by multiplying Rg by 1.47, yields



Only two adjustments remove most of the disagreement after 1825

and the evidence for a recent grand maximum (1945-1995)

Conclusions

- Two corrections reconcile the International and Group numbers back to 1825

- Original Group SSN is flawed before 1885

- No evidence for Grand Maximum from ~1945-1995

Where do we go from here?

- Need to reconcile the two Wolf & Group SSN series from1610-1825

-Do not want to create a third choice for the SSN series (International, Group, Reconciled)

- Goal is to establish a standard time series (1610-present)

-To do this we have initiated a series of workshops on SSN calibration involving all segments of the solar community

1st SSN Workshop: 1885 - present

Credit line: *Dave Dooling, NSO/AURA/NSF*

NSO Sunspot, 19-22 September 2011

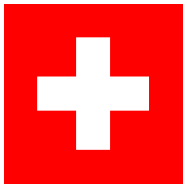
2nd SSN Workshop: 1825 -1885

ROB Brussels, 21-25 May 2012

3rd SSN Workshop: 1750-1825

Tucson, 22-25 January 2013

4th SSN Workshop: 1610-1750



Switzerland, September 2013

Please join us in this effort