A Re-analysis of the Wolfer Group Number Backbone, I

Leif Svalgaard

Stanford University

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And comparison with Chatzistergos et al. *A&A*, **602**, A69, 2017

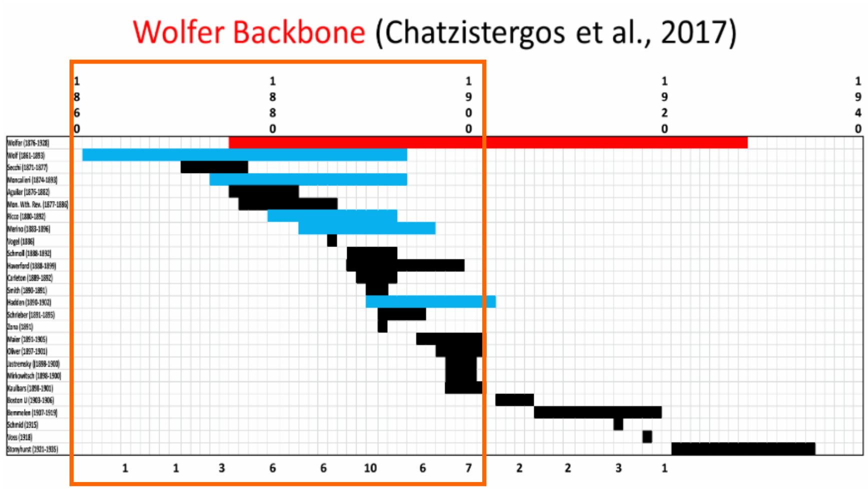
The ISSI Team Meeting 2018

- An ISSI Team meeting was held in Bern (CH) (Jan. 22–26, 2018): “Recalibration of the Sunspot Number Series”
- Led by Mathew Owens (UK) & Frédéric Clette (B)
- Although I was the instigator[1] of the whole recalibration effort back in 2010 (based on work stretching back to 2007[2]), my presence was not desired
- This talk is the presentation I would have given
- It validates the Svalgaard & Schatten (2016) reconstruction of the critical Wolfer GN Backbone

[1] Jan Stenflo (2014): “We are grateful to Leif Svalgaard for his magnificent and thorough exploration of previous counting methods and putting his finger on the problem areas, identifying what will be needed to eliminate these problems and letting us see the way to move forward

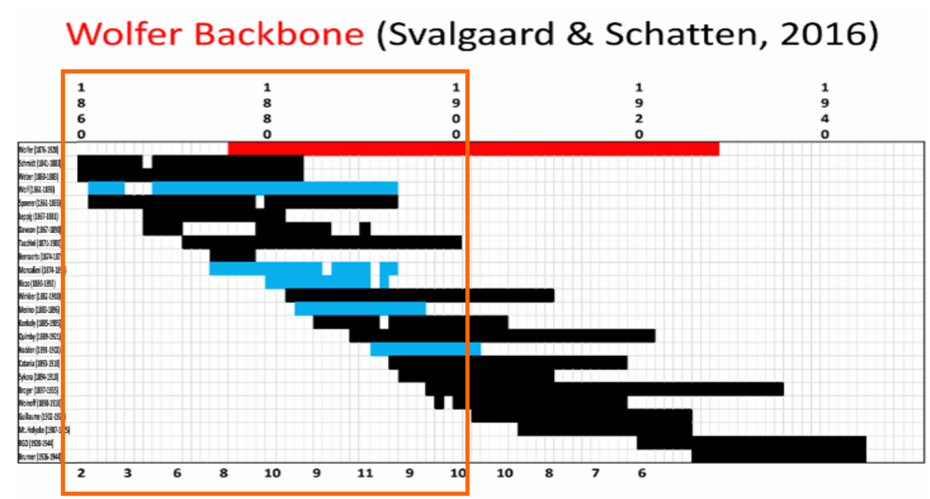
[2] See e.g. http://www.leif.org/research/Napa%20Solar%20Cycle%2024.pdf

Comparing Observer Selections for the Wolfer Backbones



Cliver & Chatzistergos 2018

Years in common with Svalgaard & Schatten (2016)



Cliver & Chatzistergos 2018

Years in common with Chatzistergos et al. (2017)

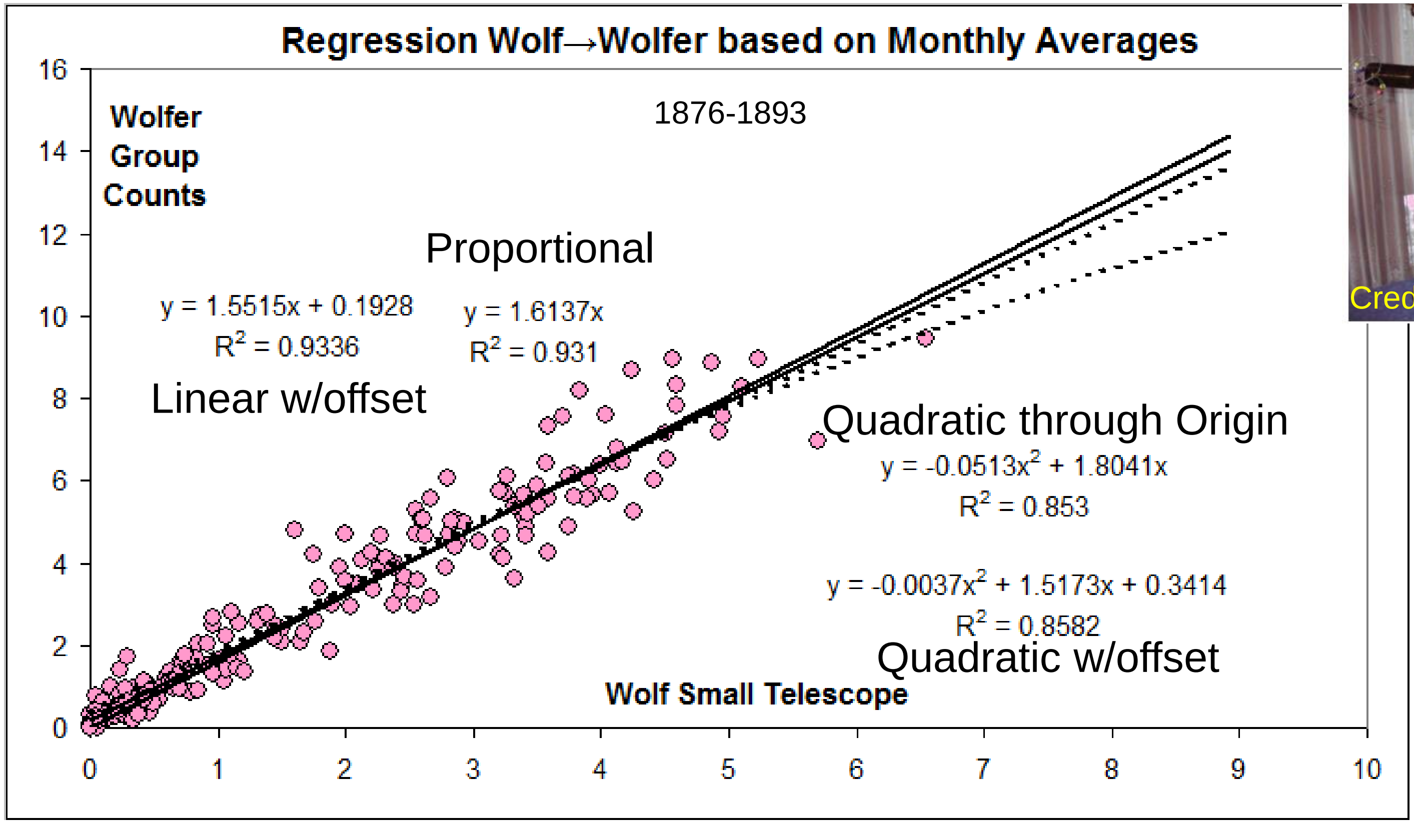
S&S 2016 argue that observers should be chosen on the basis of

(1) Long and regular observing series with good correlation (linear or otherwise) with the Primary observer without obvious drifts or discontinuities

(2) 'All' observers who satisfy (1) should be included. The Chatzistergos et al. 2017 backbone violates those criteria

As a major discrepancy with the old Hoyt & Schatten (1998) Group Sunspot Number occurs around 1880 we especially should pay attention to observations in a window centered on 1880 [Red box 1860-1900]. (See e.g. Cliver, *SWSC*, **7**, A12, 2017)

The [longest] and most Important Secondary Observer is Rudolf Wolf (small telescope)

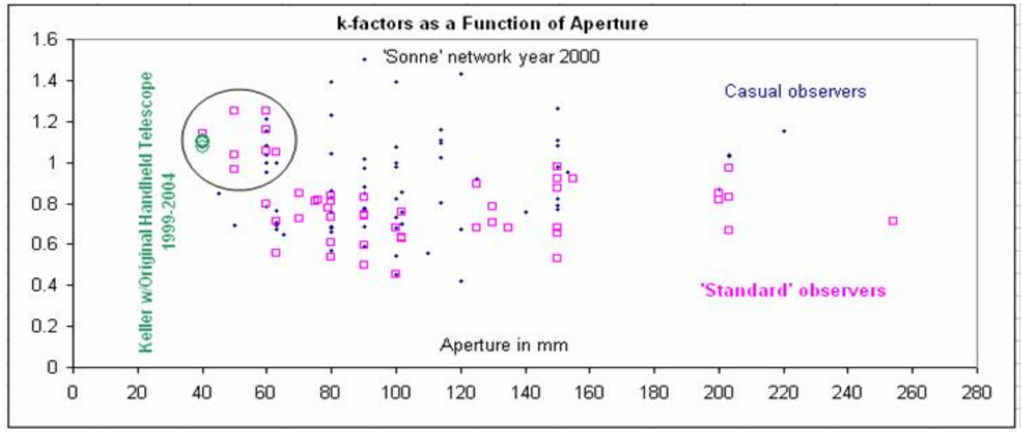


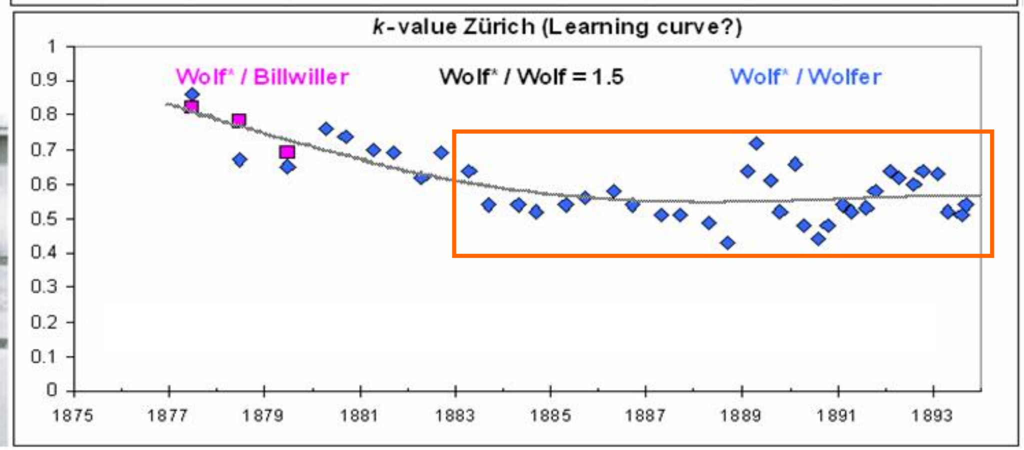
Wolf's small telescope: aperture 37mm magnification 20X

Used almost exclusively during 1861-1893

We calculate the monthly average group counts and plot Wolfer against Wolf. The resulting relation is quite linear with R^2=0.93. If we force the fit to be non-linear (up to quadratic, R^2=0.85) the fit is less good. We shall use the average of all four fits, not being selectively biased towards any of them.

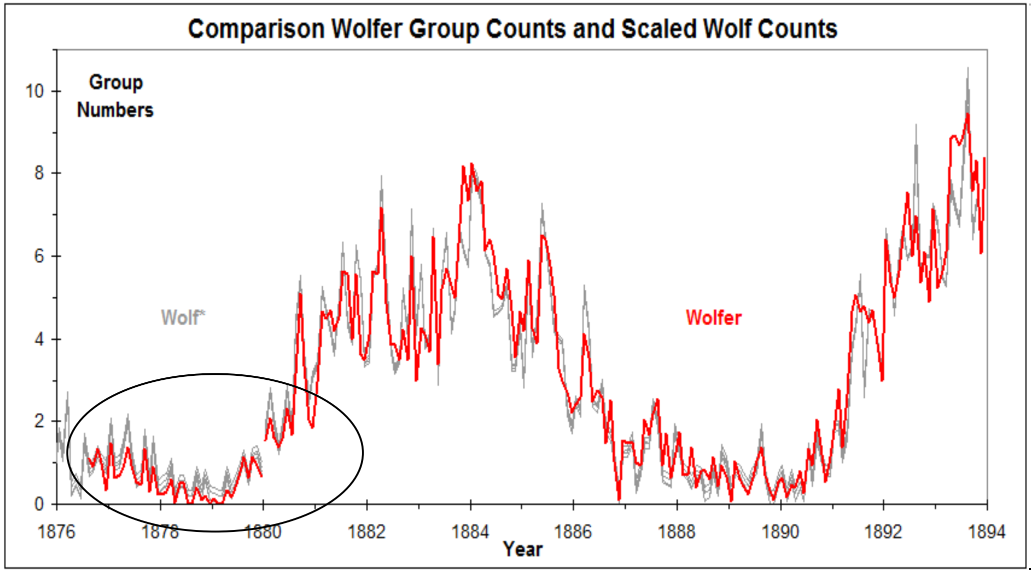
There is always a ‘Learning Curve’. It takes Several Years to Become ‘Good’ at it

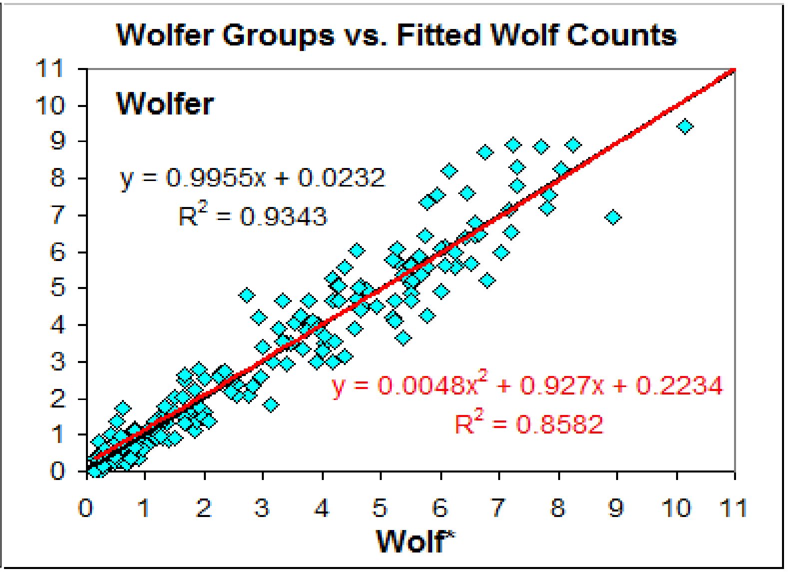




It took ~5 years for Wolfer’s k-value to stabilize [red box], illustrating the danger of relying only on a single secondary observer overlapping the primary during the early years (before 1883 for Wolf vs. Wolfer). Lesson: We need many (‘all’) observers.

How Well can we Represent Wolf on the Wolfer Scale?





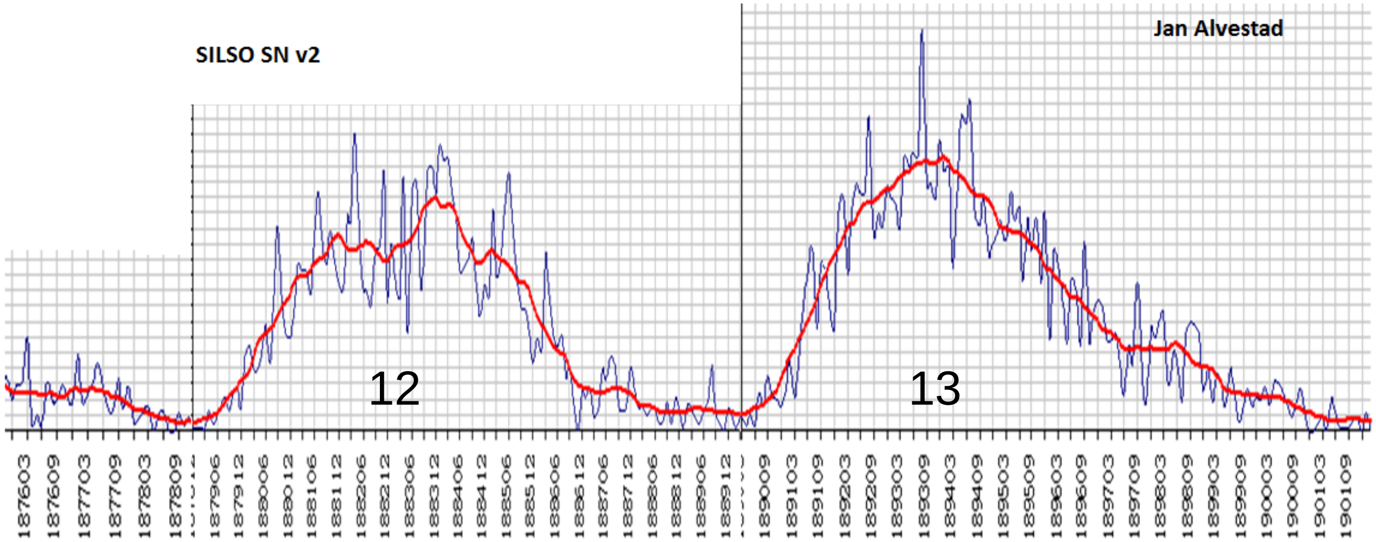
Monthly counts by Wolfer (red) and Wolf's counts scaled by all four of the regression equations (grey), individually plotted. Early learning curve for Wolfer (in oval) is evident.

Goodness of Fits of Monthly counts by Wolf to observed counts by Wolfer. Linear fit is better than the quadratic non-linear fit.

Answer: Very well, indeed. Only ~10% is 'unexplained' variance.

The goal is to reproduce Wolfer's count with warts and all, so the appropriate least-square procedure is to minimize the 'vertical' variance (since counts have no errors).

The Sunspot Numbers and the Group Numbers are in Good Agreement

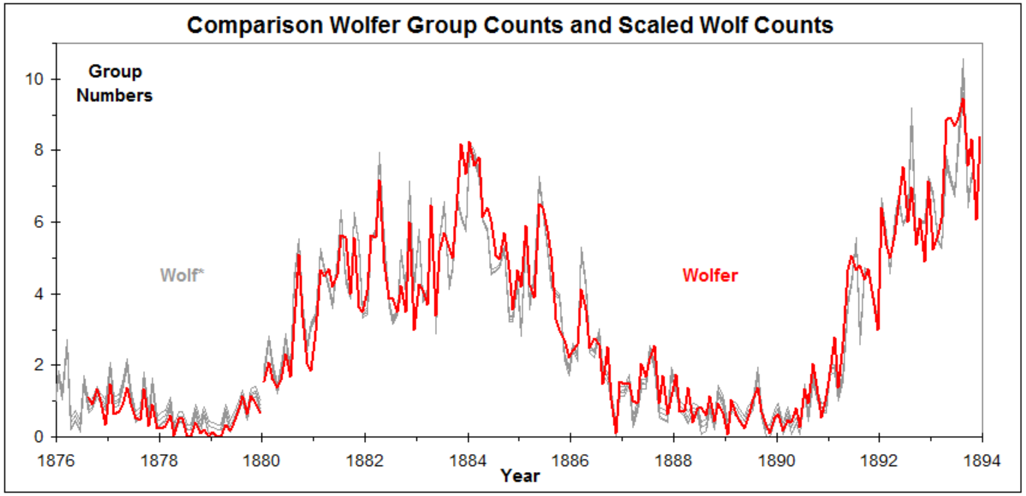


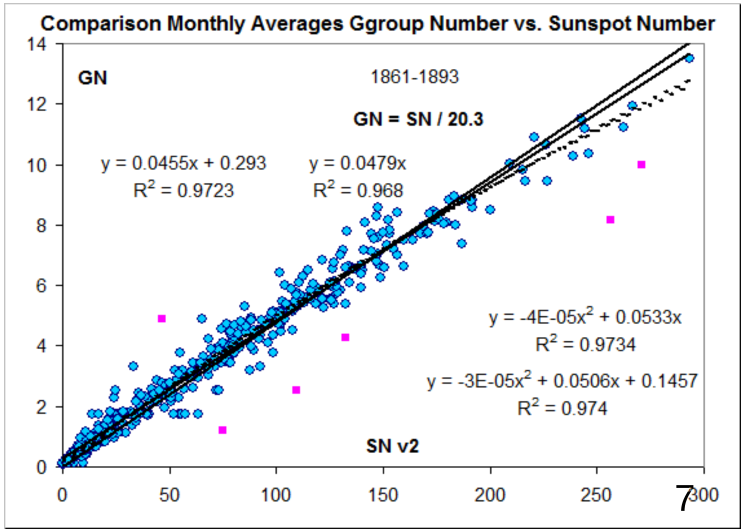
On average

SN = 20.3 * GN

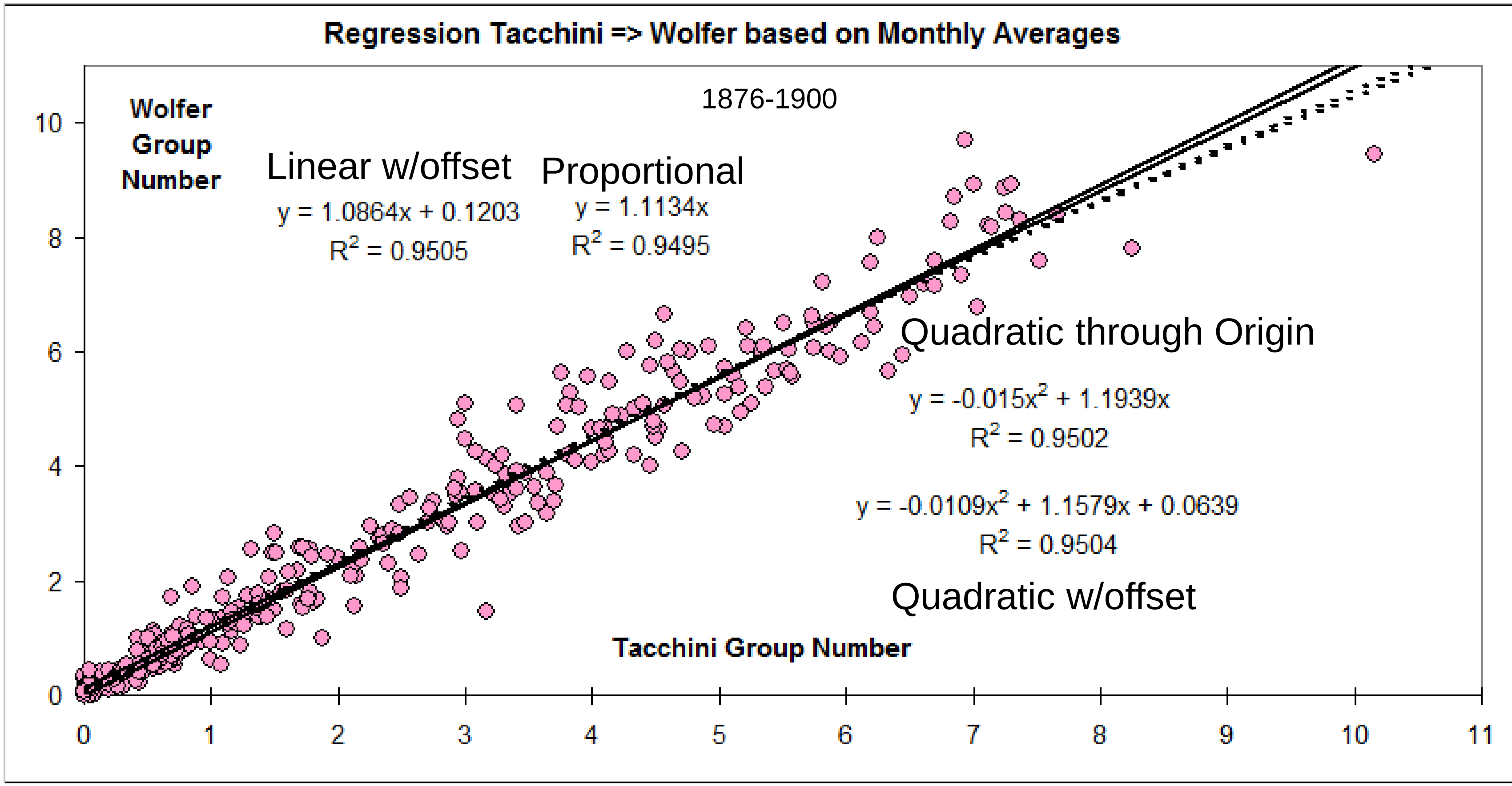
For monthly averages

No surprise as both are normalized to Wolf and Wolfer



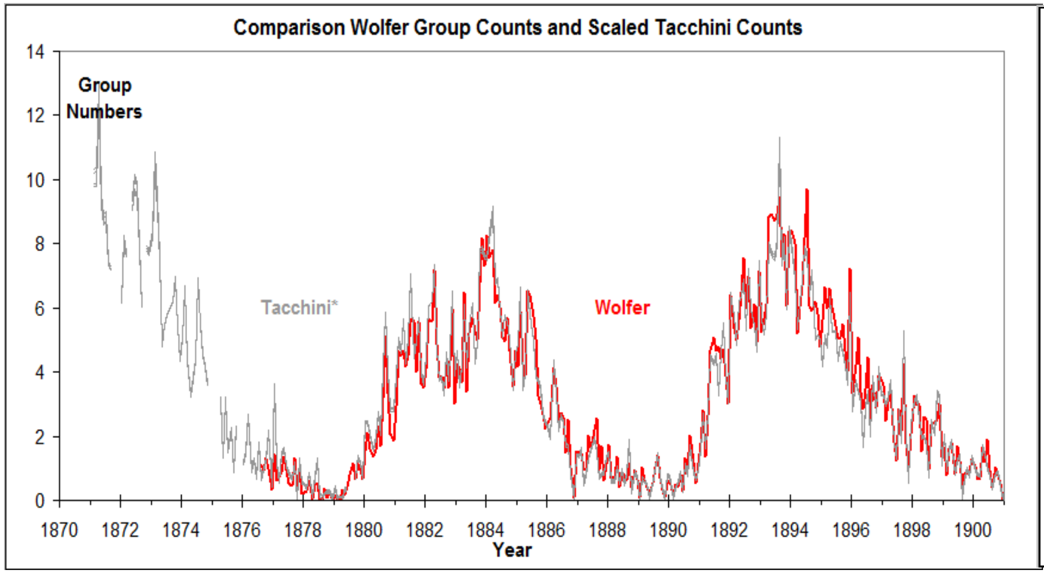


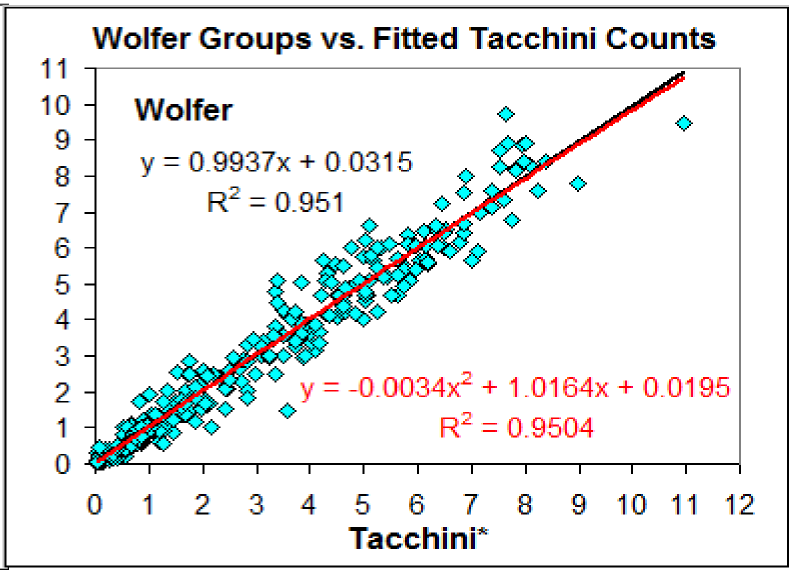
Another Long and Important Secondary Observer is Pietro Tacchini in Palermo



We calculate the monthly average group counts and plot Wolfer against Tacchini. The resulting relation is quite linear with R^2=0.95. If we force the fit to be non-linear (up to quadratic, R^2=0.95) the fit is also good. We shall use the average of all four fits, not being selectively biased towards any of them.

How Well can we Represent Tacchini on the Wolfer Scale?





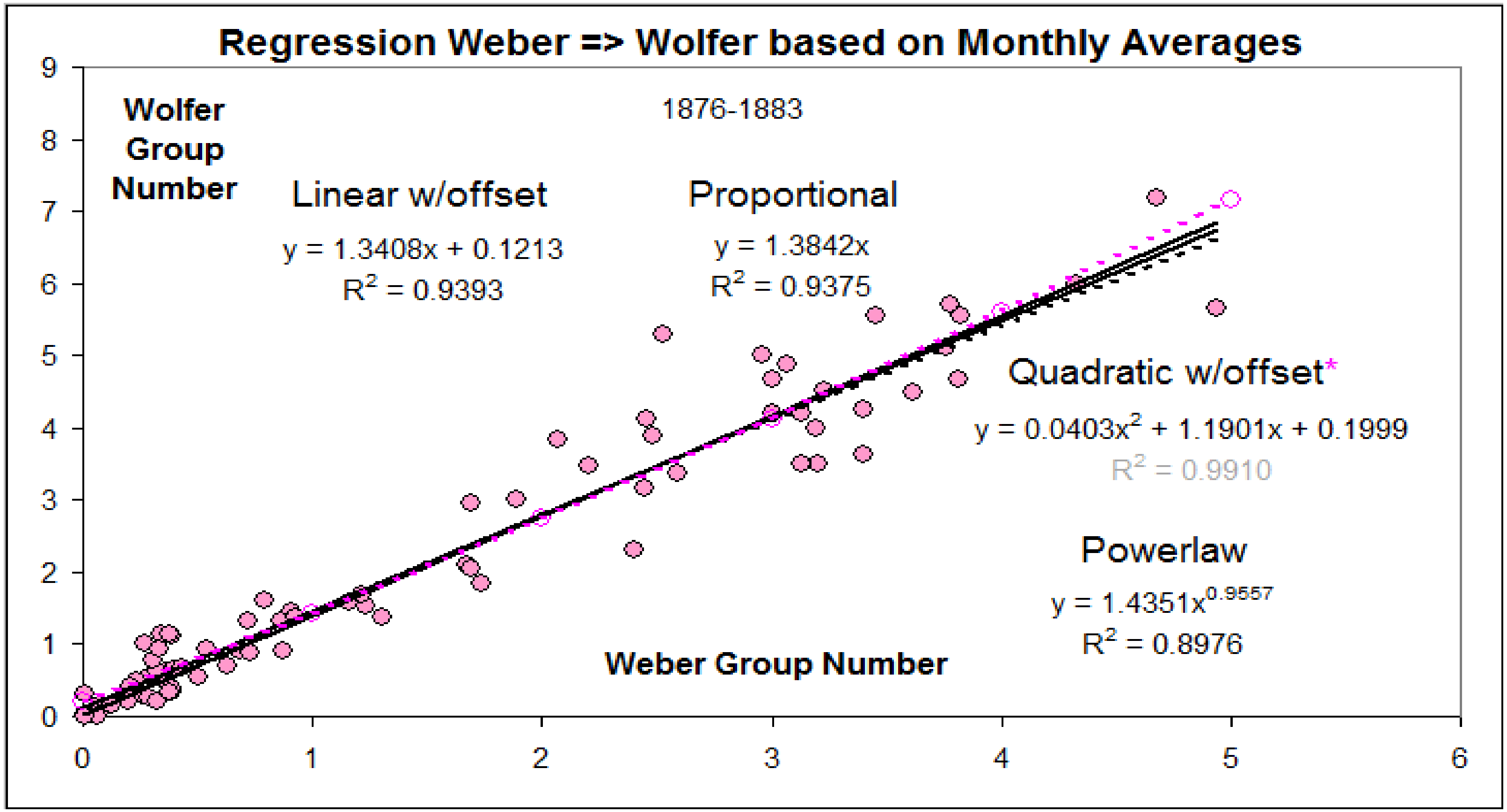
Monthly counts by Wolfer (red) and Tacchini's counts scaled by all four of the regression equations (grey), individually plotted.

Goodness of Fits of Monthly counts by Tacchini to observed counts by Wolfer.

Answer: Very well, indeed. Only ~5% is 'unexplained' variance.

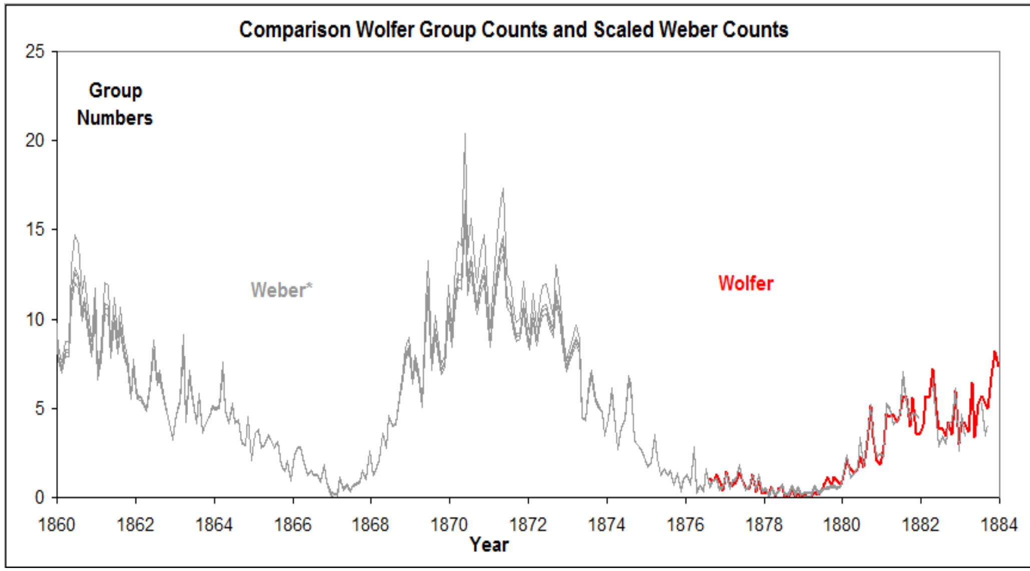
The goal is to reproduce Wolfer's count with warts and all, so the appropriate least-square procedure is to minimize the 'vertical' variance (since counts have no errors).

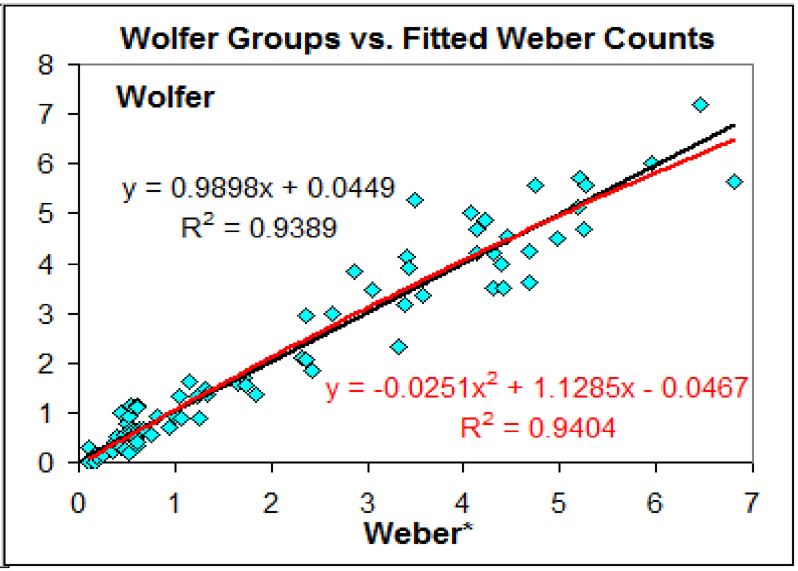
Weber in Peckeloh was a Regular Observer Since 1860



We calculate the monthly average group counts and plot Wolfer against Weber. The resulting relation is quite linear with R^2=0.94. If we force the fit to be non-linear the fit is less good. We shall use the average of all four fits, not being selectively biased towards any of them.

How Well can we Represent Weber on the Wolfer Scale?





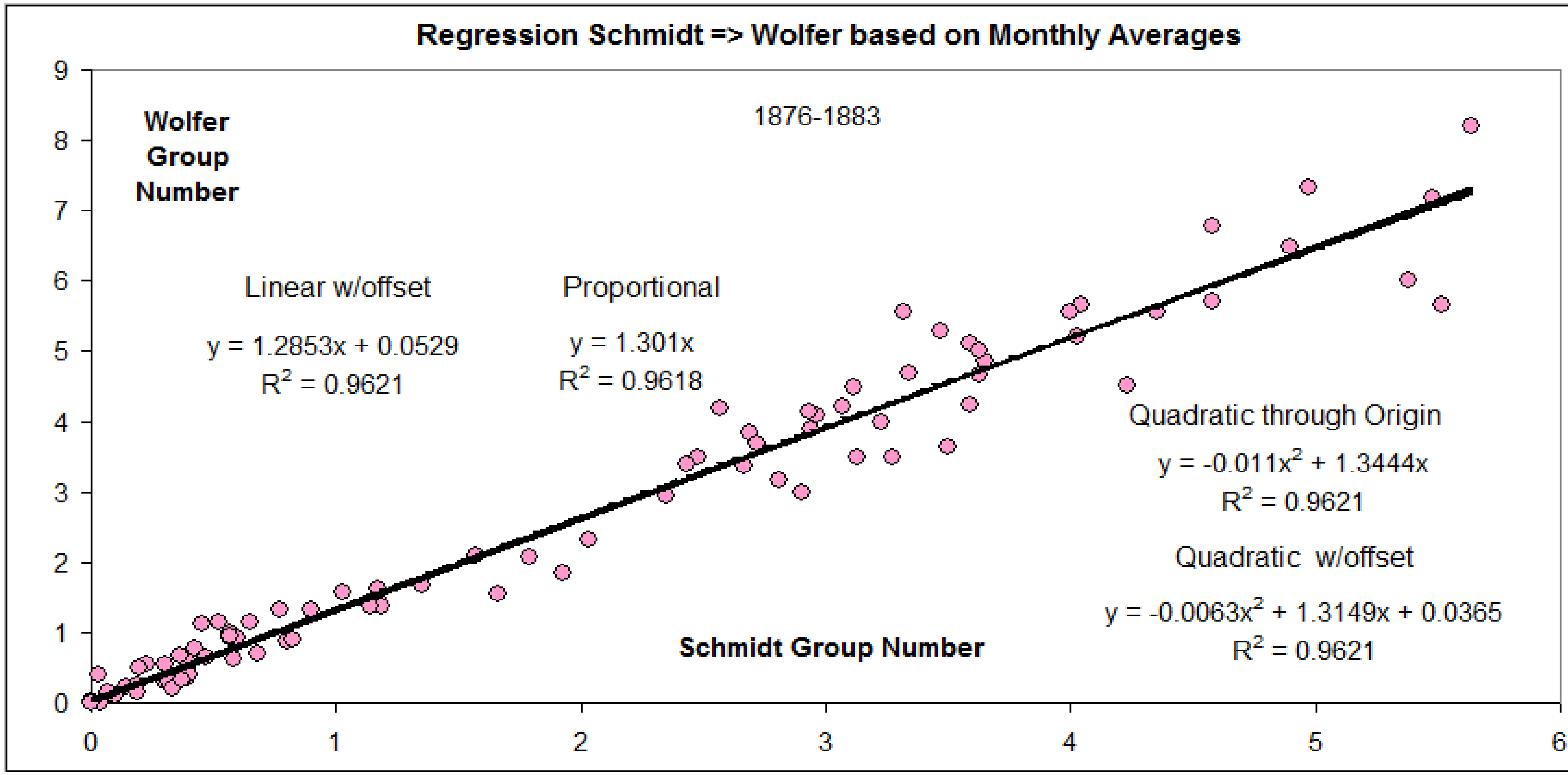
Monthly counts by Wolfer (red) and Weber's counts scaled by all four of the regression equations (grey), individually plotted.

Goodness of Fits of Monthly counts by Weber to observed counts by Wolfer.

Answer: Very well for the overlap. ~6% 'unexplained' variance.

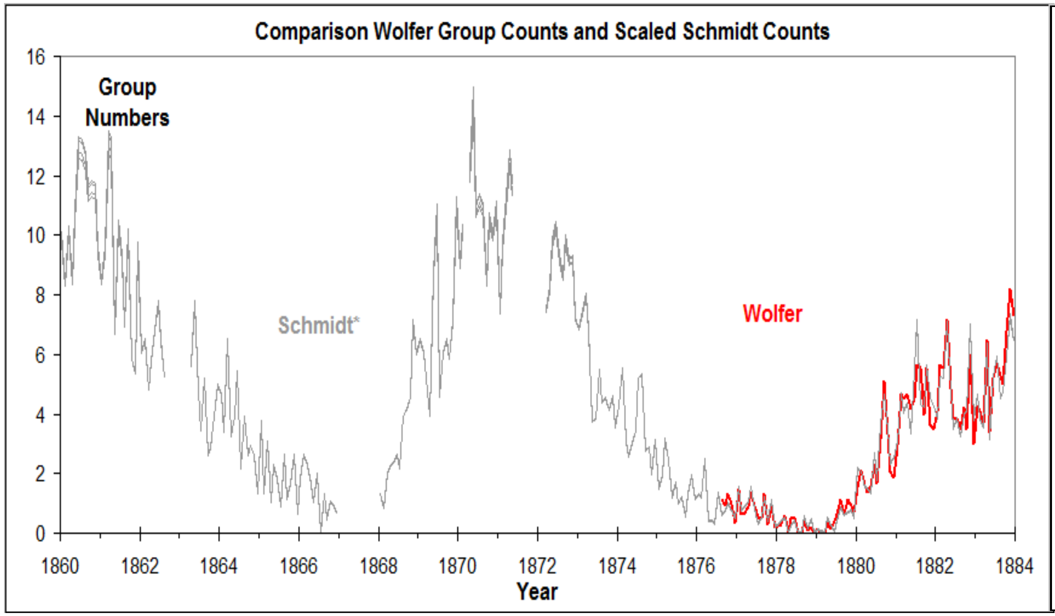
But: a potential (and large) problem is the [necessary] extrapolation from a low-activity fit to Wolfer to the high-activity reconstruction for the previous two cycles.

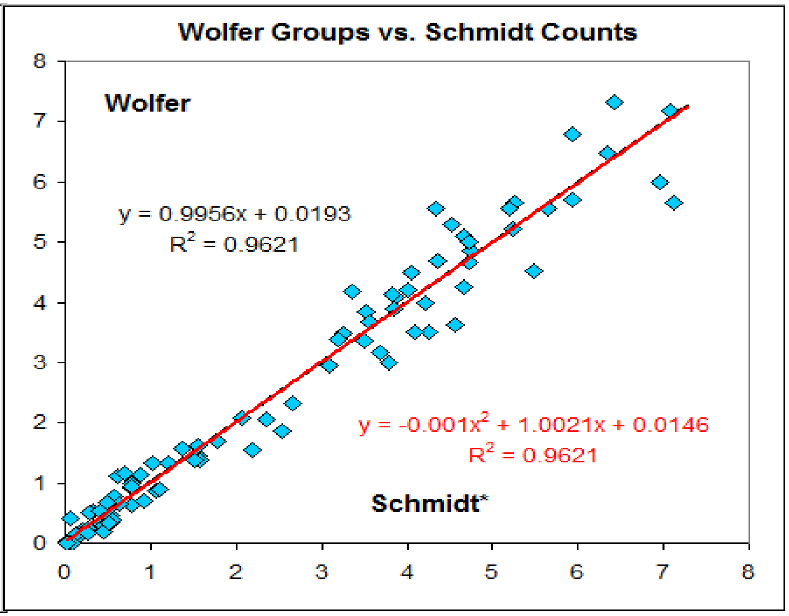
Schmidt in Athens Gave us an Amazing 42-year Series 1841-1883



We calculate the monthly average group counts and plot Wolfer against Schmidt. The resulting relation is quite linear with R^2=0.96. If we force the fit to be non-linear the fit is equally good. We shall use the average of all four fits, not being selectively biased towards any of them (especially when they agree anyway).

How Well can we Represent Schmidt on the Wolfer Scale?



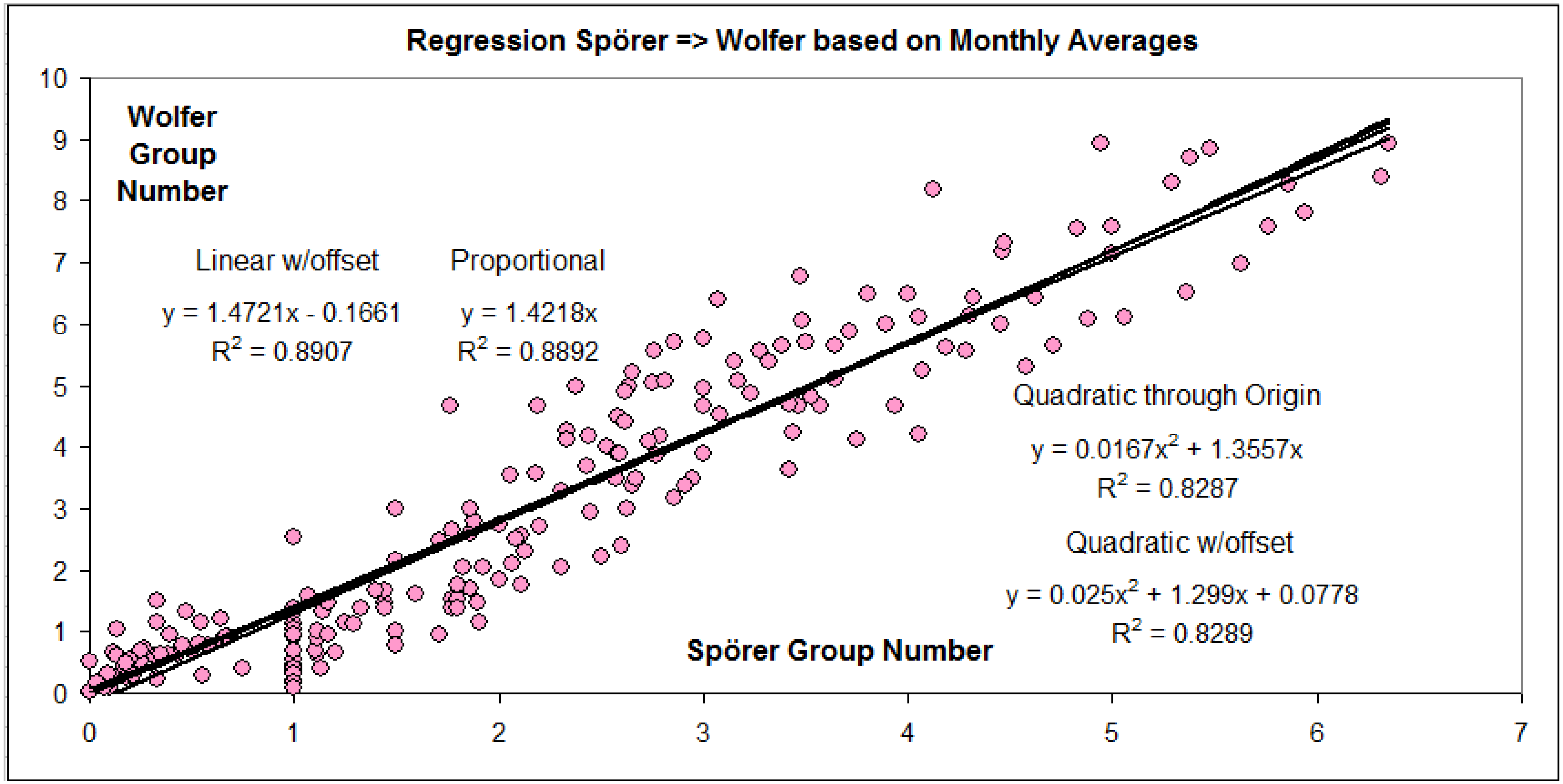


Monthly counts by Wolfer (red) and Schmidt's counts scaled by all four of the regression equations (grey), individually plotted.	Goodness of Fits of Monthly counts by Schmidt to observed counts by Wolfer.

Answer: Very well, indeed. Only ~4% 'unexplained' variance.

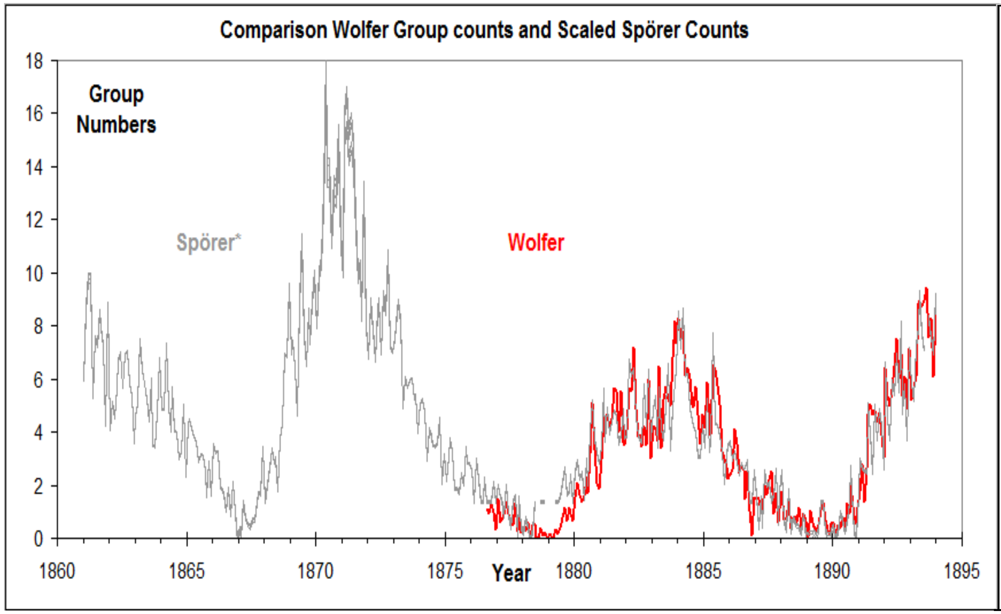
But: a potential (and large) problem is the [necessary] extrapolation from a low-activity fit to Wolfer to the high-activity reconstruction for the previous two cycles.

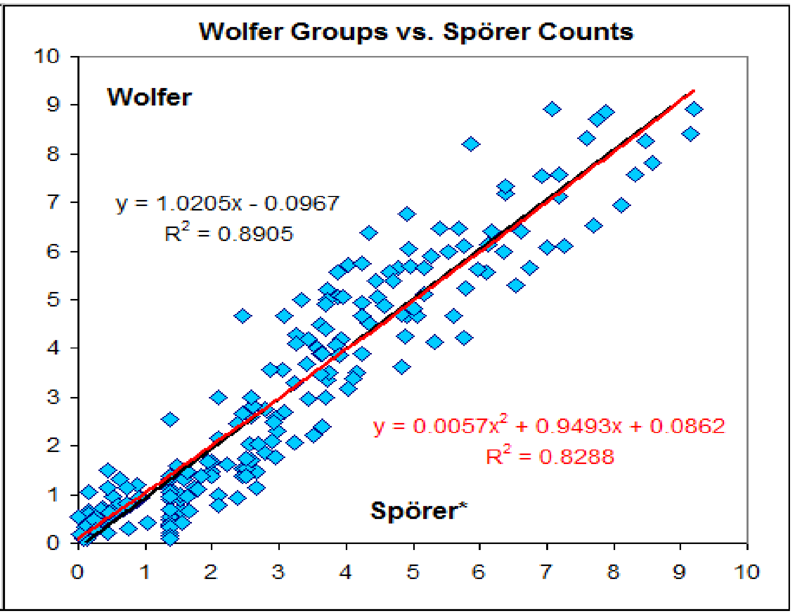
Spörer was Another Distinguished Observer with a Long Record



We calculate the monthly average group counts and plot Wolfer against Spörer. The resulting relation is almost linear with R^2=0.89. If we force the fit to be non-linear the fit is less good. We shall use the average of all four fits, not being selectively biased towards any of them. Spörer's series does not look as homogeneous as desired

How Well can we Represent Spörer on the Wolfer Scale?



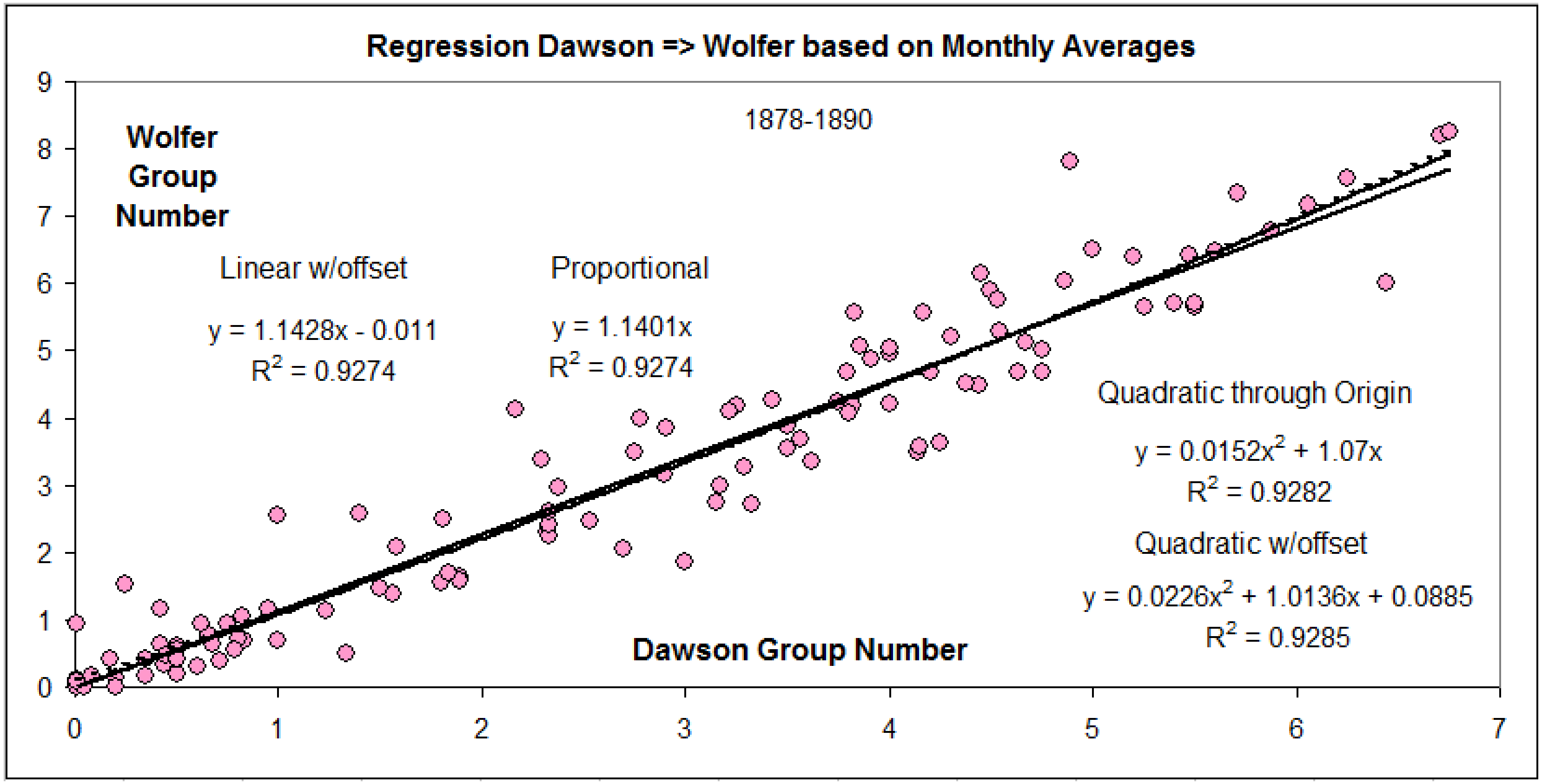


Monthly counts by Wolfer (red) and Spörer's counts scaled by all four of the regression equations (grey), individually plotted.	Goodness of Fits of Monthly counts by Spörer to observed counts by Wolfer.

Answer: Reasonably well. ~14% 'unexplained' variance.

But: The Spörer series looks to be less homogenous than we would like, especially for low activity where the observing may have been less enthusiastic.

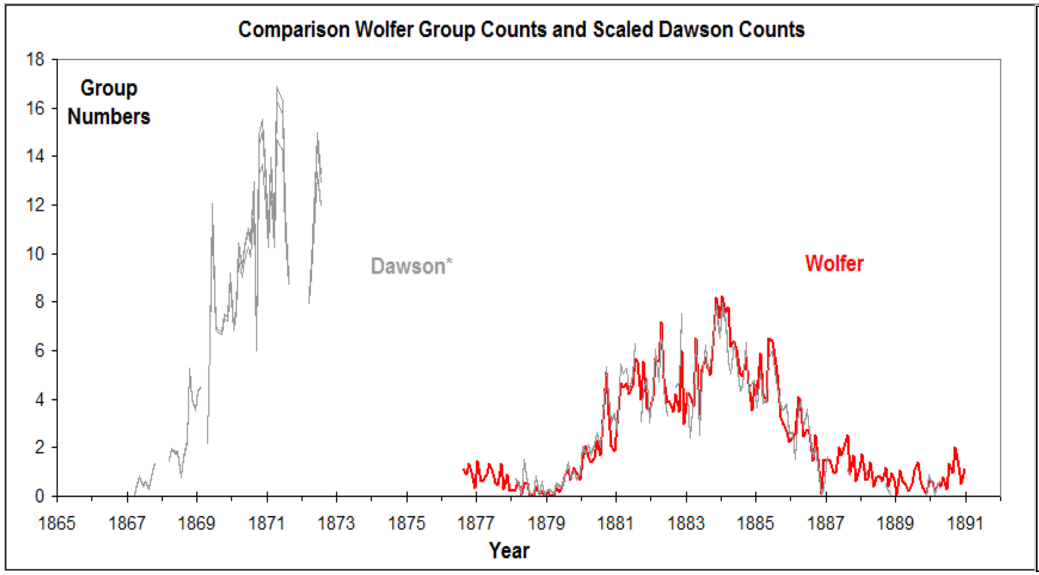
W. M. Dawson Provides a Long, Albeit Somewhat Spotty[1] Record

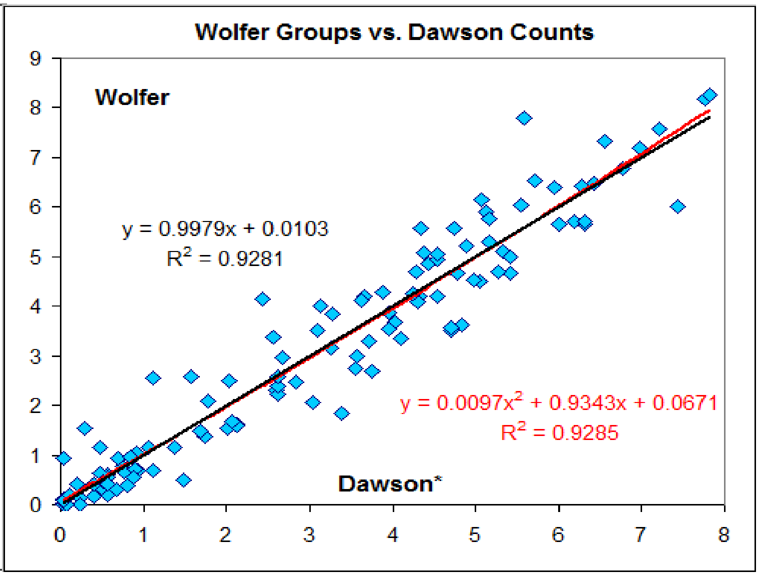


We calculate the monthly average group counts and plot Wolfer against Dawson. The resulting relation is nicely linear with R^2=0.93. If we force the fit to be non-linear the fit is as good. We shall use the average of all four fits, not being selectively biased towards any of them. A few months with only one observation have been omitted.

[1] No pun intended

How Well can we Represent Dawson on the Wolfer Scale?



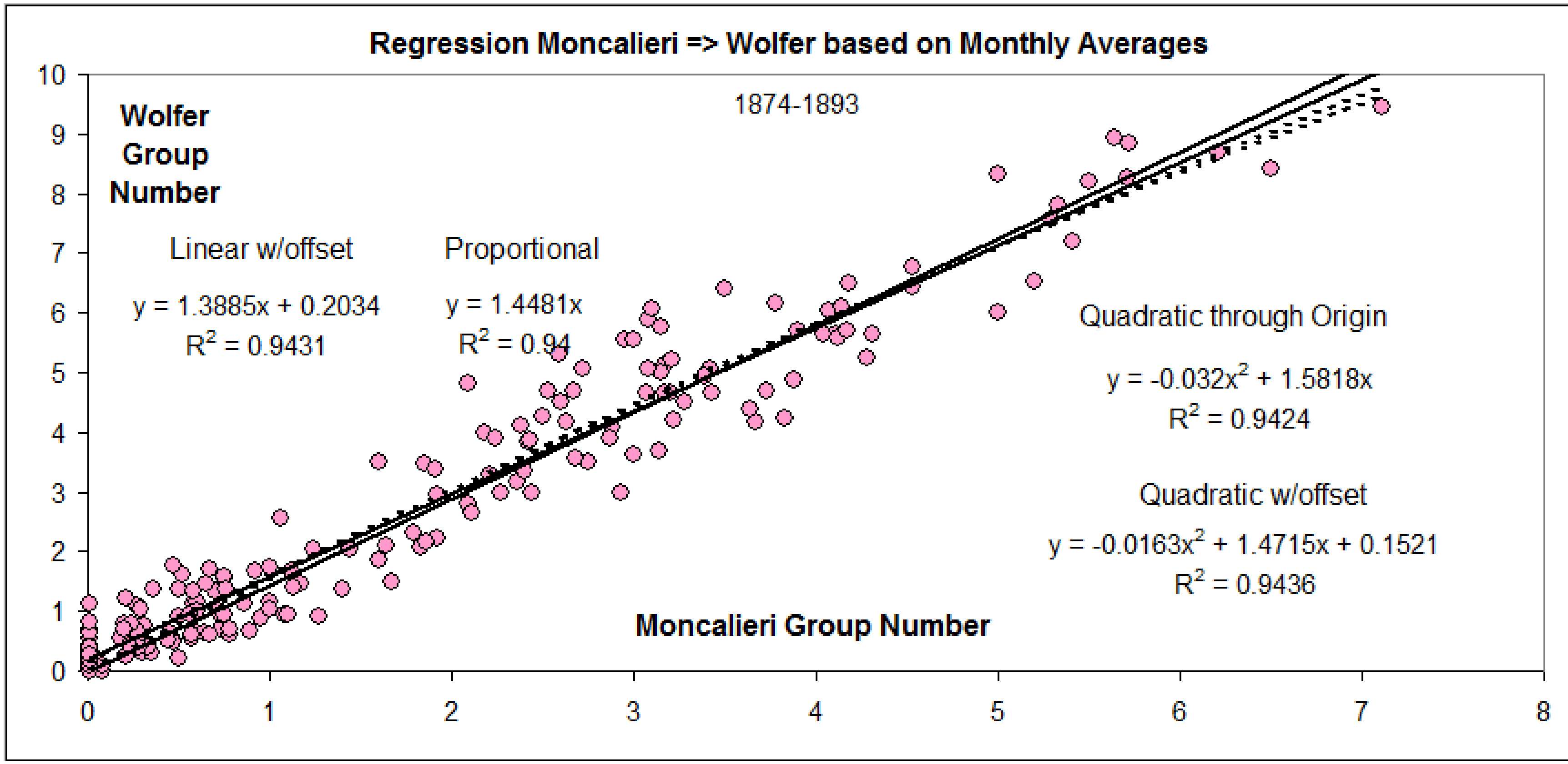


Monthly counts by Wolfer (red) and Dawson's counts scaled by all four of the regression equations (grey), individually plotted.	Goodness of Fits of Monthly counts by Dawson to observed counts by Wolfer.

Answer: Very well, indeed. Only ~7% 'unexplained' variance.

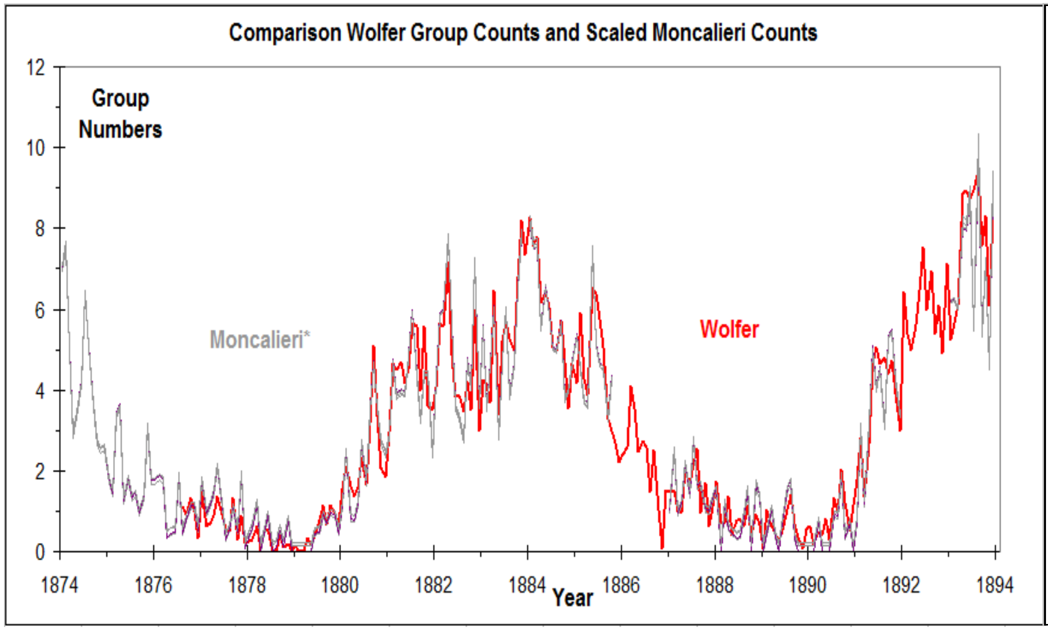
But: a potential (and large) problem is the [necessary] extrapolation from a low-activity fit to Wolfer to the high-activity reconstruction for the previous cycle.

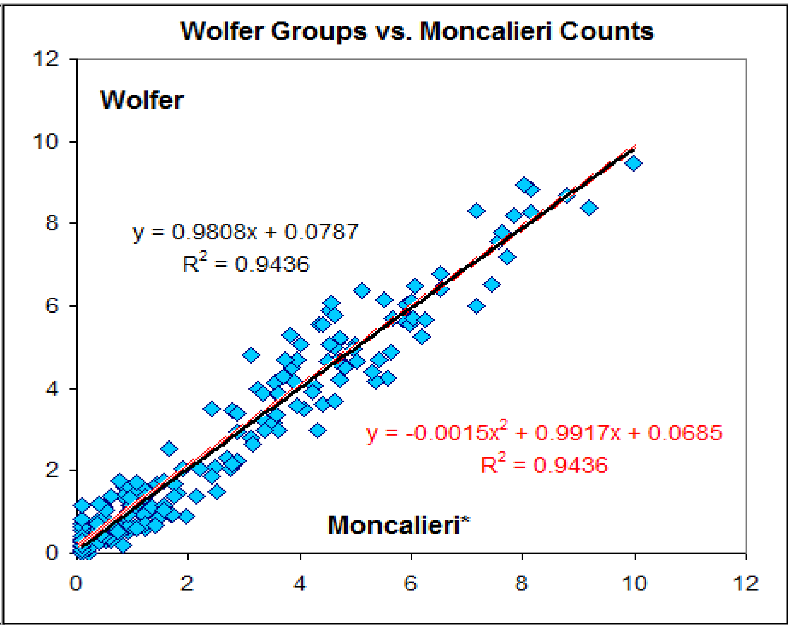
Padre Francesco Denza Observed at Moncalieri 1874-1893



We calculate the monthly average group counts and plot Wolfer against Moncalieri. The resulting relation is quite linear with R^2=0.94. If we force the fit to be non-linear the fit is equally good. We shall use the average of all four fits, not being selectively biased towards any of them.

How Well can we Represent Moncalieri on the Wolfer Scale?



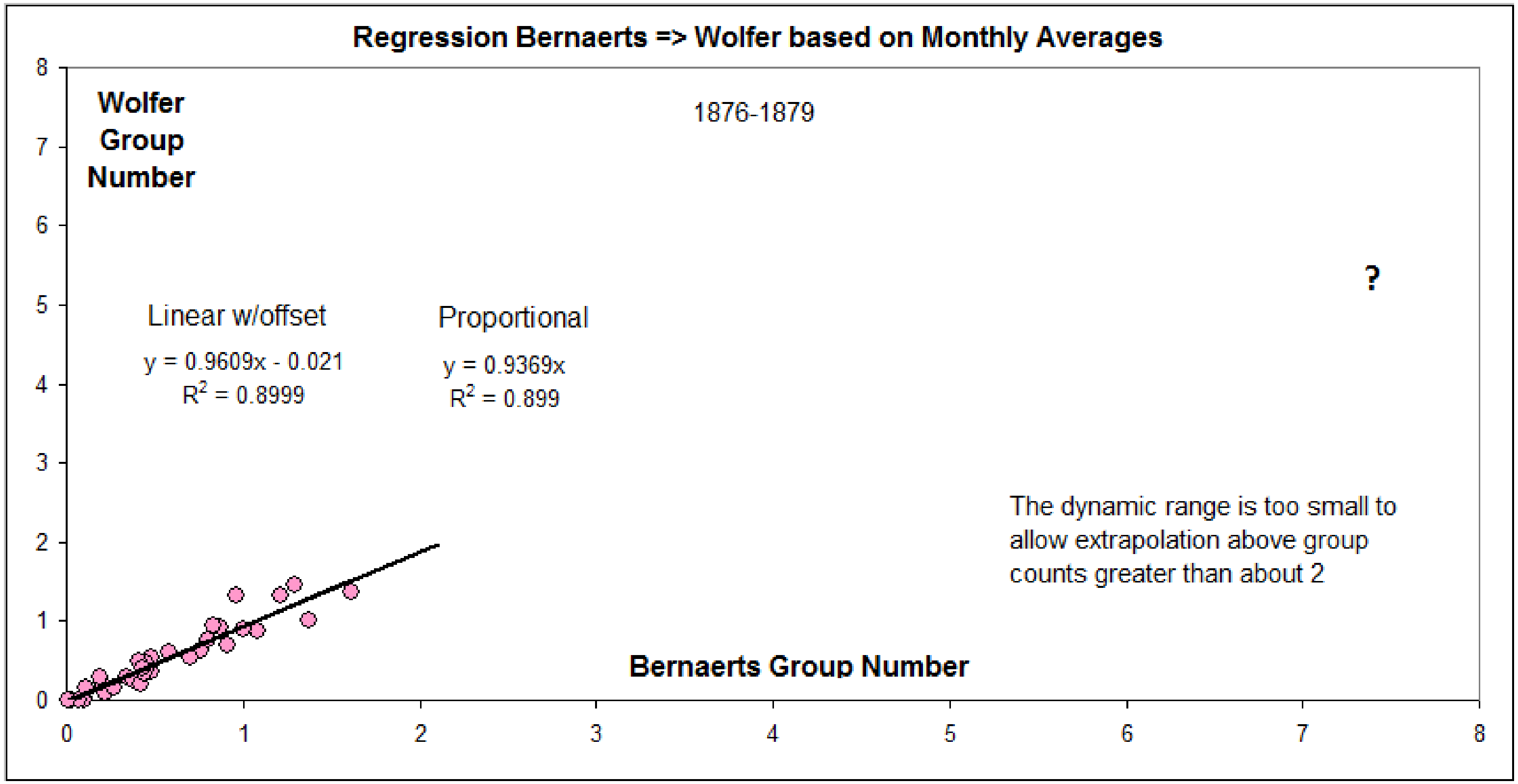


Monthly counts by Wolfer (red) and Moncalieri's counts scaled by all four of the regression equations (grey), individually plotted.	Goodness of Fits of Monthly counts by Moncalieri to observed counts by Wolfer.

Answer: Very well, indeed. Only ~6% 'unexplained' variance.

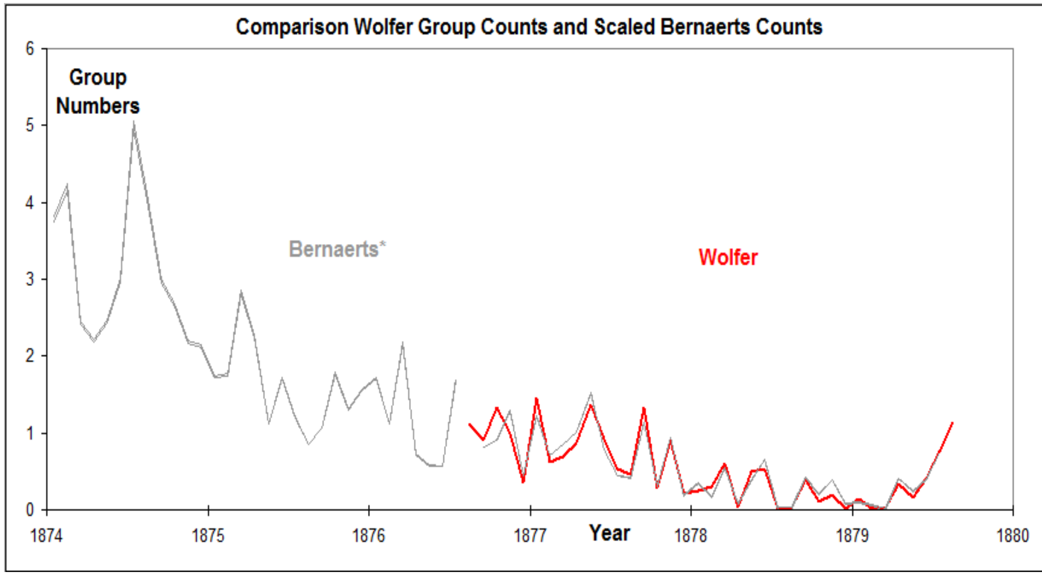
We have allowed ourselves the luxury of removing two glaring outliers for two months with very few observations.

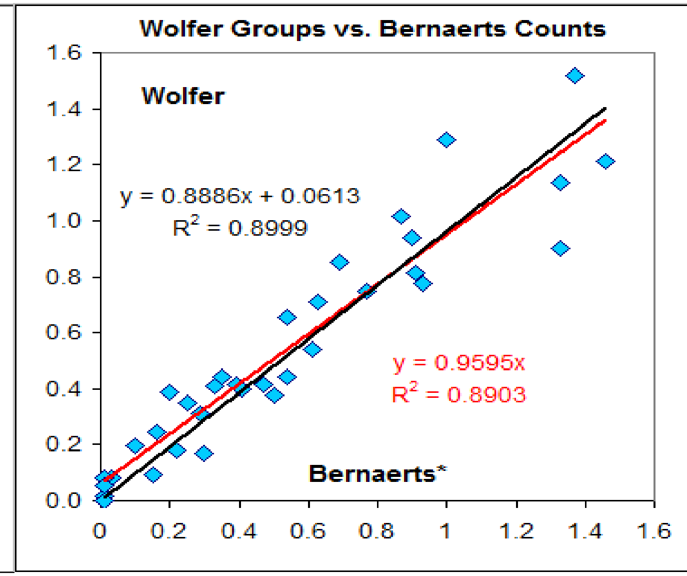
G. L. Bernaerts Observed in England during 1870-1879



We calculate the monthly average group counts and plot Wolfer against Bernaerts. The resulting relation is reasonably linear with R^2=0.90. The range of values is too small to allow secure polynomial fits for group counts much outside the window of overlap, so extrapolation to the high activity in 1870-1871 is not advisable.

How Well can we Represent Bernaerts on the Wolfer Scale?



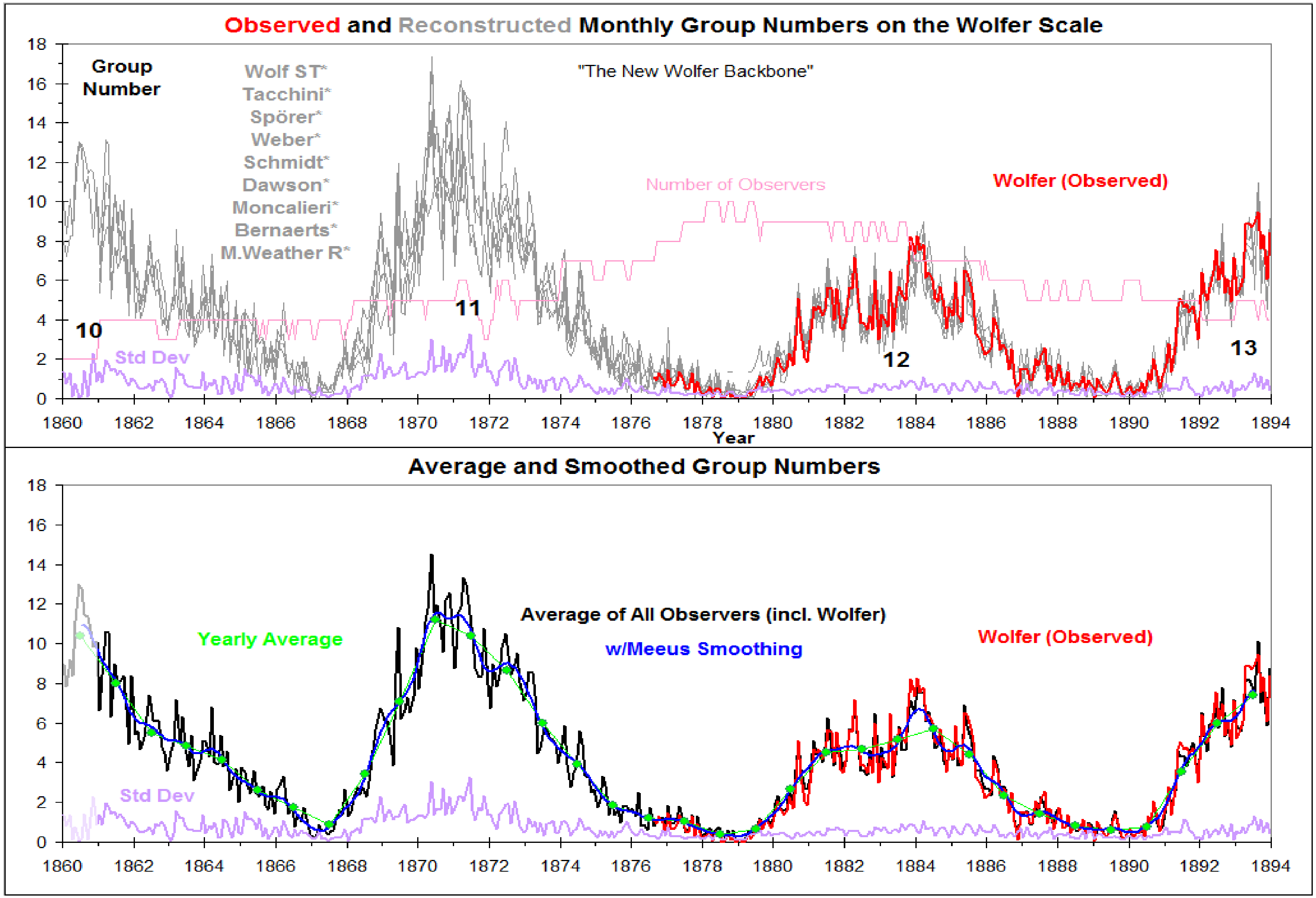


Monthly counts by Wolfer (red) and Bernaerts' counts scaled by all of the regression equations (grey), individually plotted.	Goodness of Fits of Monthly counts by Bernaerts to observed counts by Wolfer.

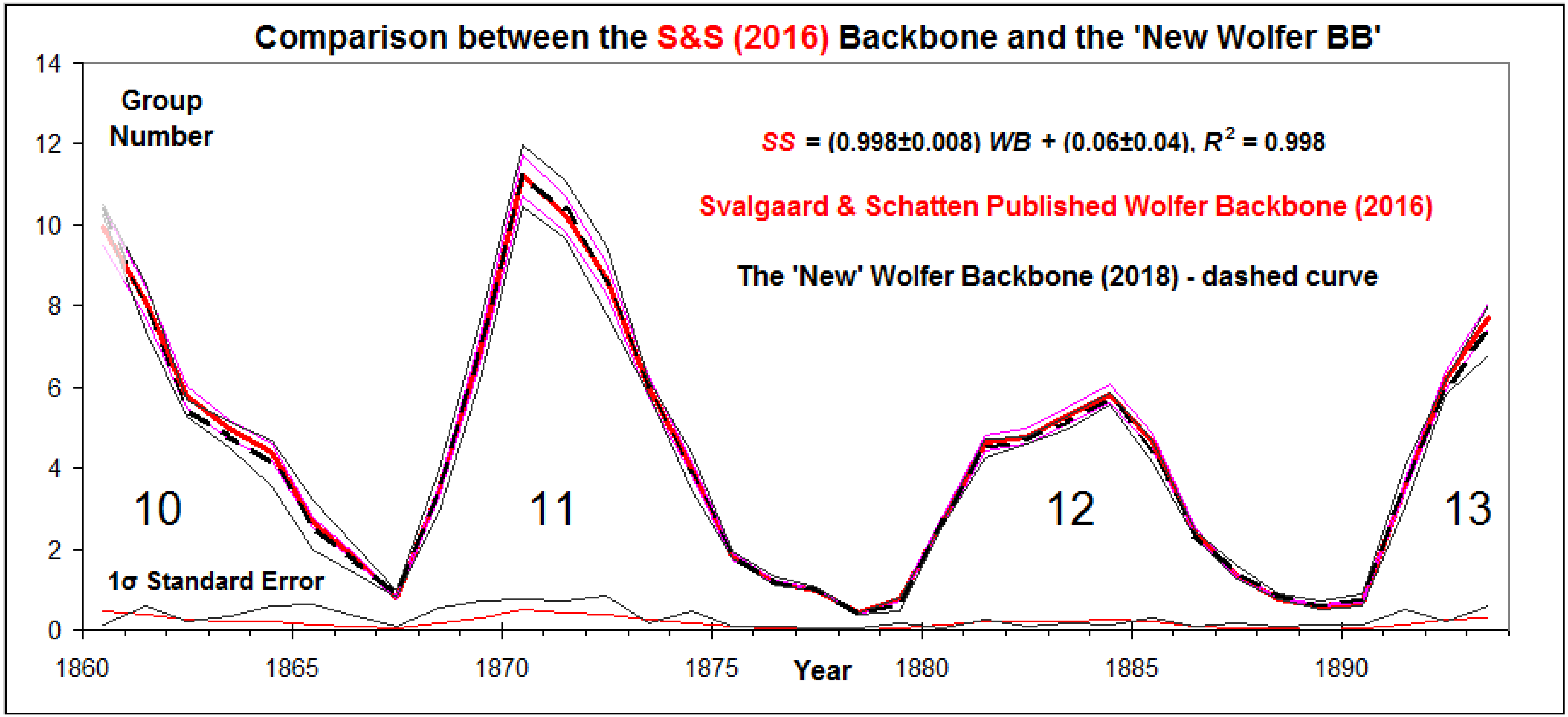
Answer: Very well, at least for this low activity period. With ~10% 'unexplained' variance.

But: Extrapolation to 1870-1871's level of activity yields values half of all the other observers

Putting It All Together: A New Wolfer Backbone



Perfect Agreement with Svalgaard & Schatten (2016) Wolfer Backbone



The two backbones agree perfectly within their error bars (thin curves). This is not a surprise as they are based on the same input data and fundamentally sound (albeit different) analysis techniques. It would have been a surprise if they had not agreed.