Building a Sunspot Group Number Backbone Series

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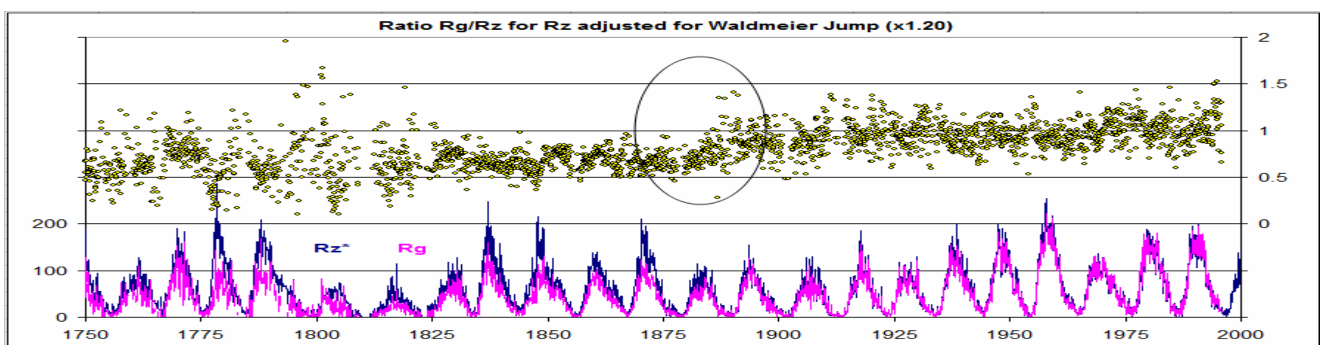
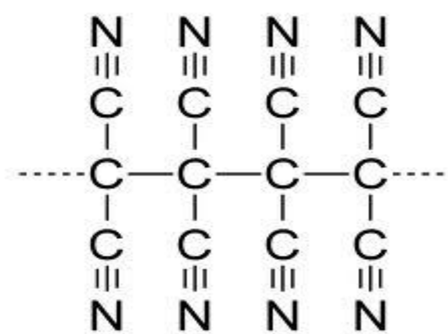


Why a Backbone? And What is it?

Building a long time series from observations made over time by several observers can be done in two ways:

- Daisy-chaining: successively joining observers to the ‘end’ of the series, based on overlap with the series as it extends so far [accumulates errors]
- Back-boning: find a primary observer for a certain [long] interval and normalize all other observers individually to the primary based on overlap with only the primary [no accumulation of errors]



Carbon Backbone

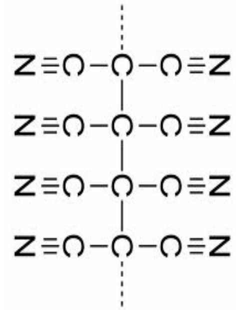
When several backbones have been constructed we can join [daisy-chain] the backbones. Each backbone can be improved individually without impacting other backbones

The Backbones

- SIDC Backbone [????-2013]
- Waldmeier Backbone [????-????]
- Wolfer Backbone [1841-1945]
- Schwabe Backbone [1794-1883]
- Staudach Backbone [????-????]
- Earlier Backbone(s) [1610-????]

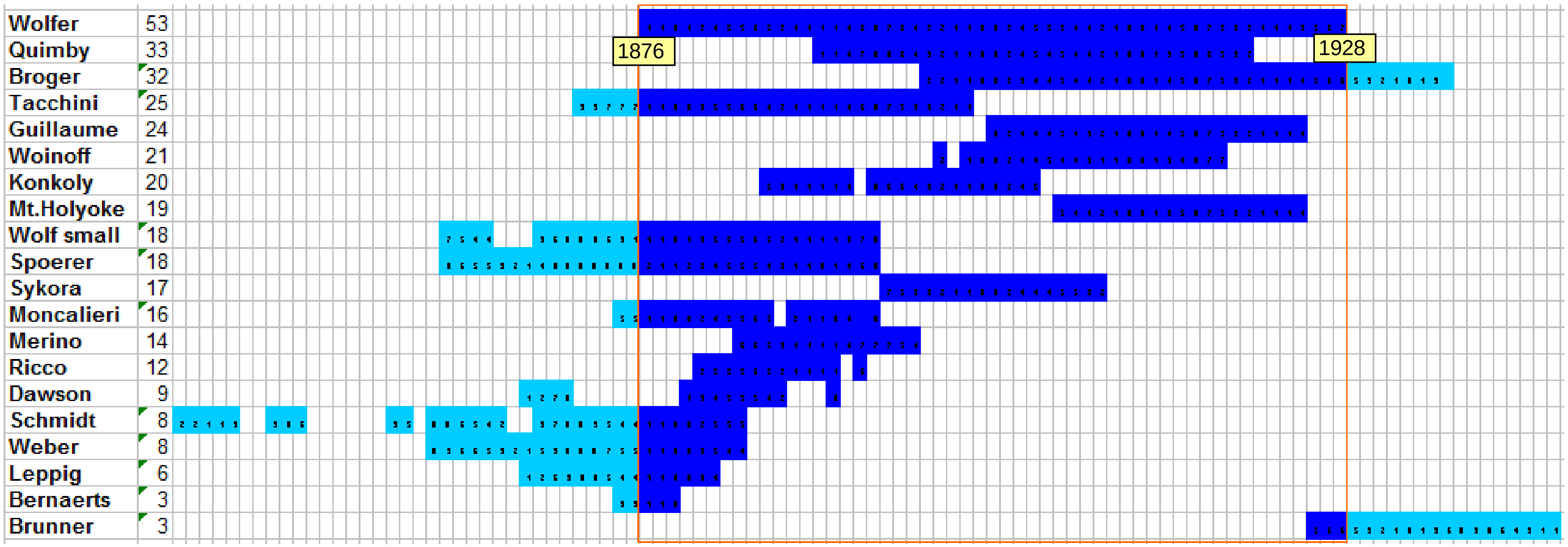
Sources of Data

- The primary source is the very valuable tabulations by Hoyt and Schatten of the ‘raw’ count of groups by several hundred observers
- In some cases [especially Wolf and Schwabe] data has been re-entered and re-checked from Wolf’s published lists, as some discrepancies have been found with the H&S list



The Wolfer Backbone

Alfred Wolfer observed 1876-1928 with the 'standard' 80 mm telescope



Rudolf Wolf from 1860 on mainly used smaller 37 mm telescope(s) so those observations are used for the Wolfer Backbone

Normalization Procedure, I

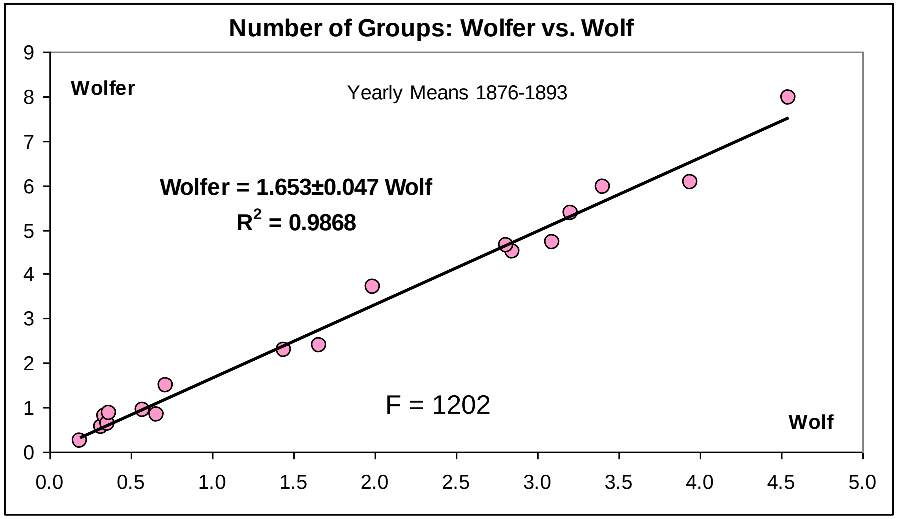
What we do not do:

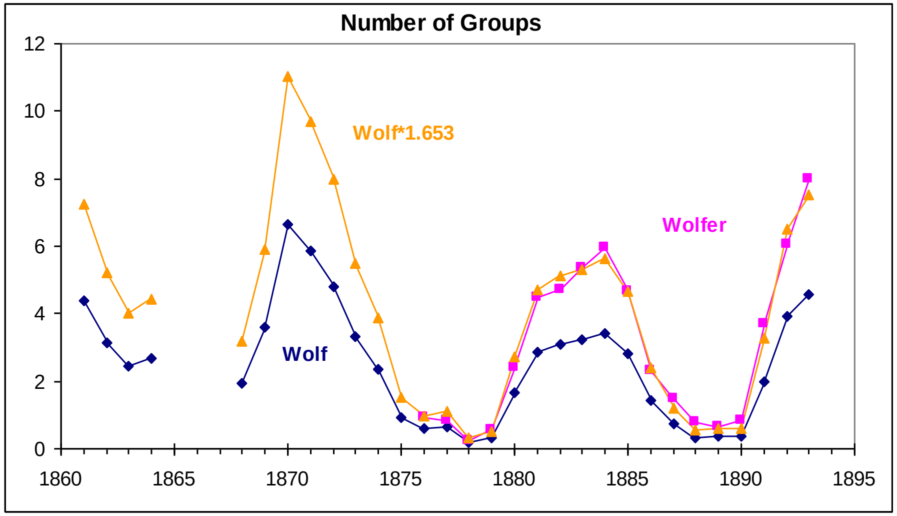
- Compare only days when both observers actually observed. This is problematic when observations are sparse as during the early years.
- Compare only days when both observers actually recorded at least one group. This is clearly wrong as it will bias towards higher activity.

What we do:

- We compute, for each observer, the monthly mean of actual observations [including days when it was indeed observed that there were no groups].
- We compute, for each observer and for each year, the yearly mean of the average counts for months with at least one observation.

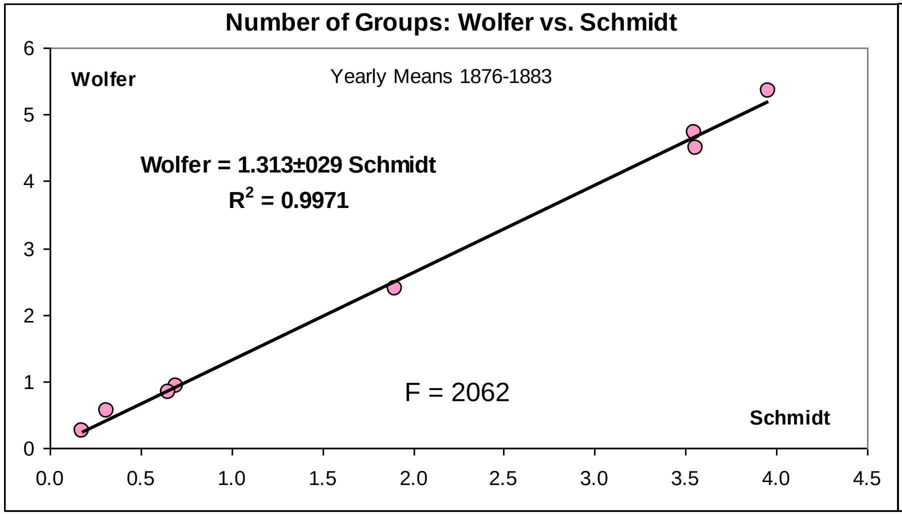
Normalization Procedure, II

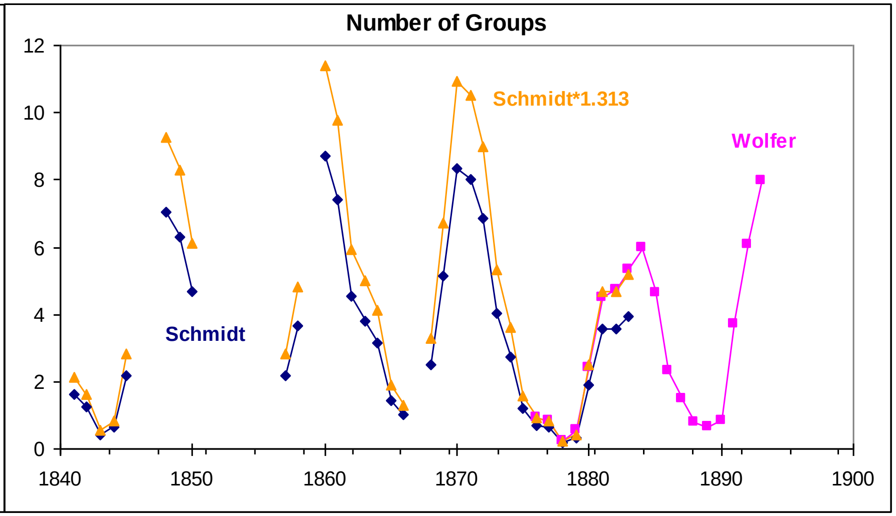


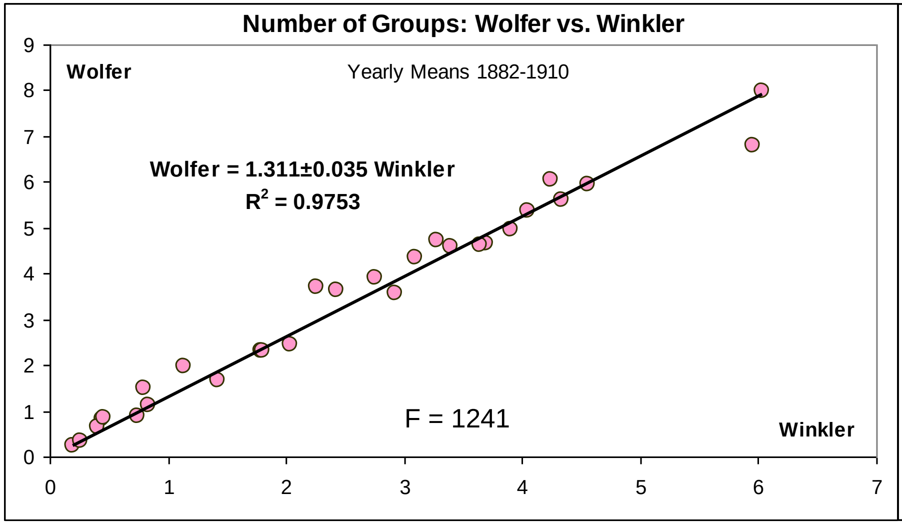


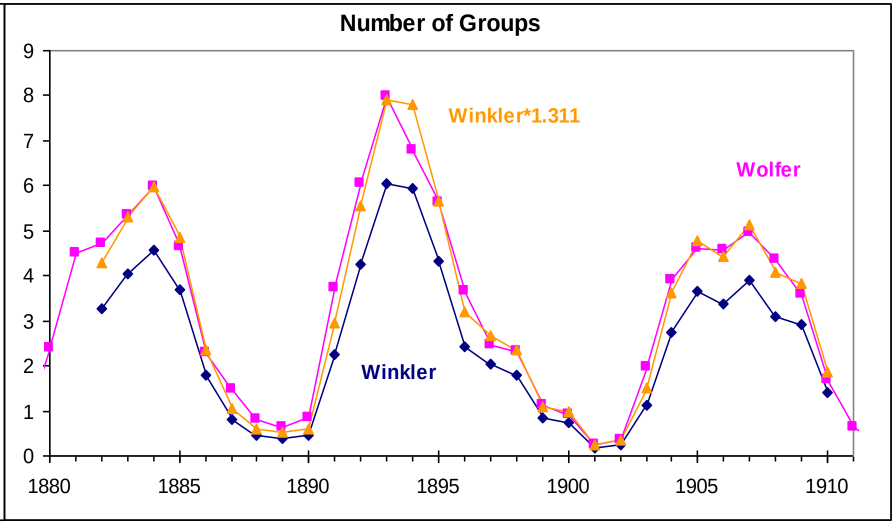
For each Backbone we regress each observers group counts for each year against those of the primary observer, and plot the result [left panel]. Experience shows that the regression line almost always very nearly goes through the origin, so we *force* it to do that and calculate the slope and various statistics, such as 1-σ uncertainty and the F-value. The slope gives us what factor to multiply the observer's count by to match the primary's. The right panel shows a result for the Wolfer Backbone: blue is Wolf's count [with his small telescope], pink is Wolfer's count [with the larger telescope], and the orange curve is the blue curve multiplied by the slope. It is clear that the harmonization works well [at least for Wolf vs. Wolfer].

Schmidt, Winkler

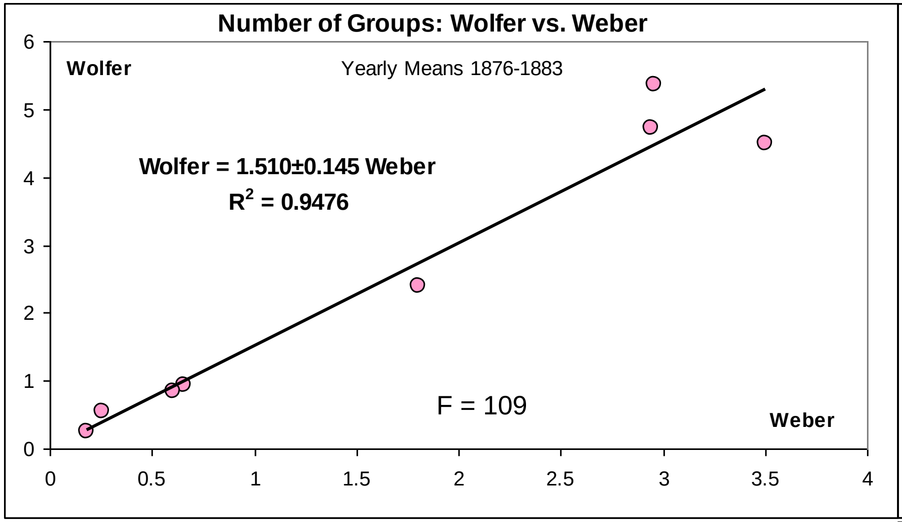


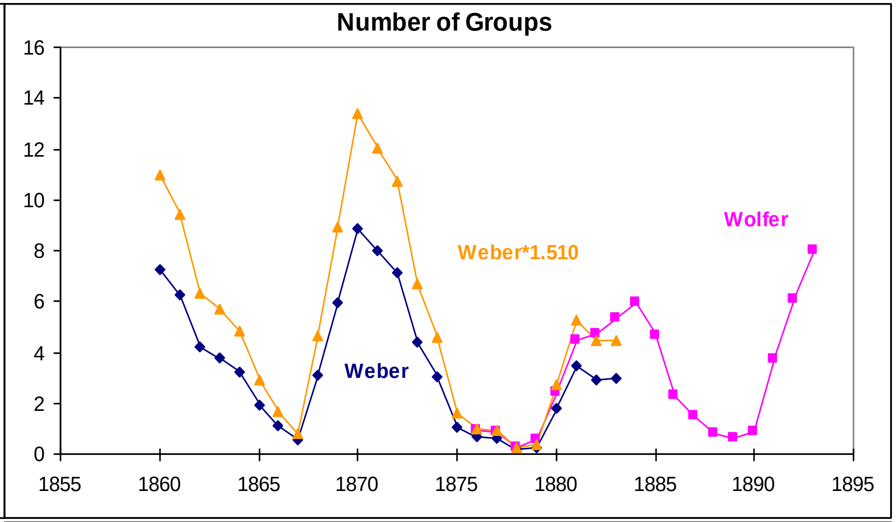


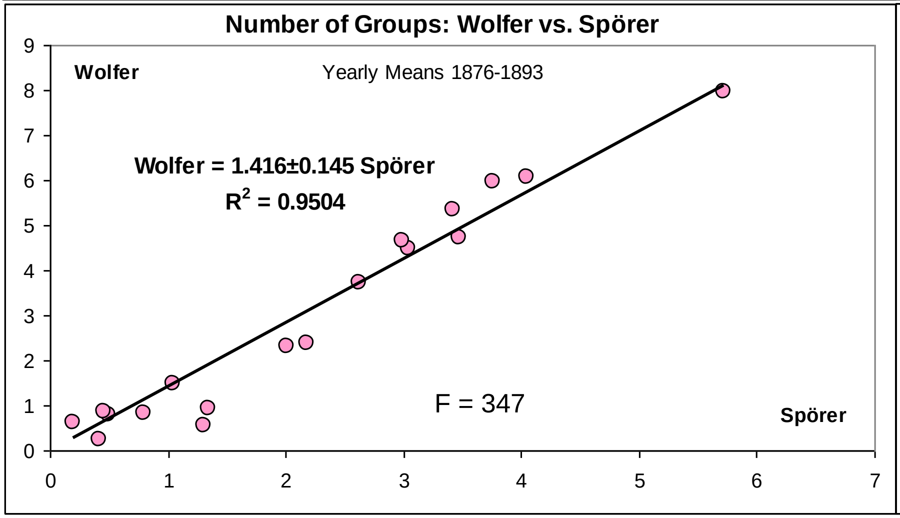


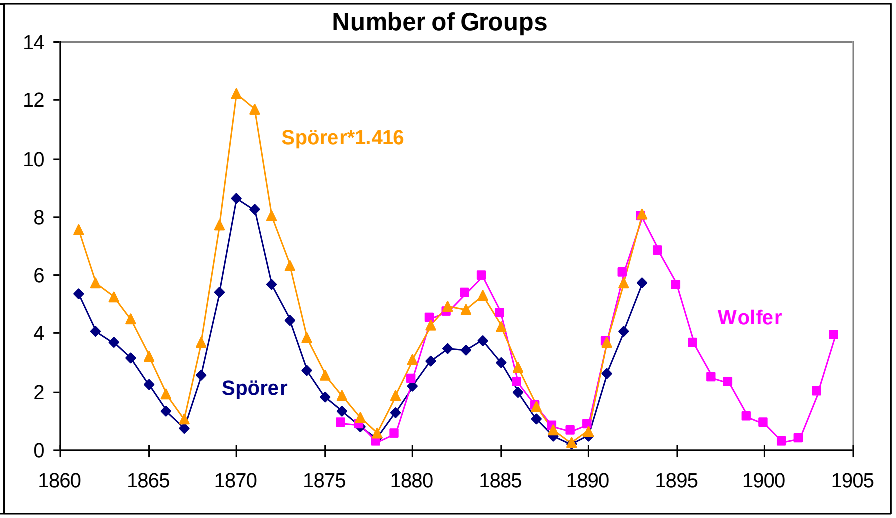


Weber, Spörer

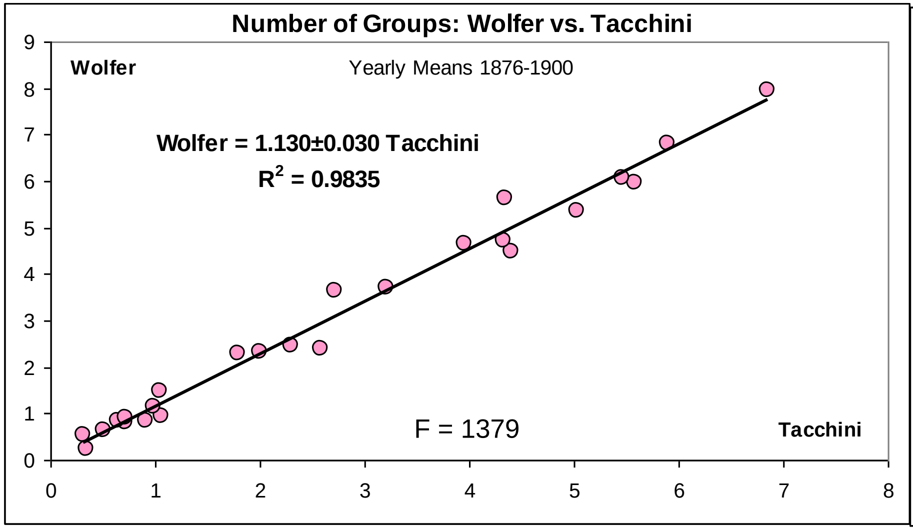


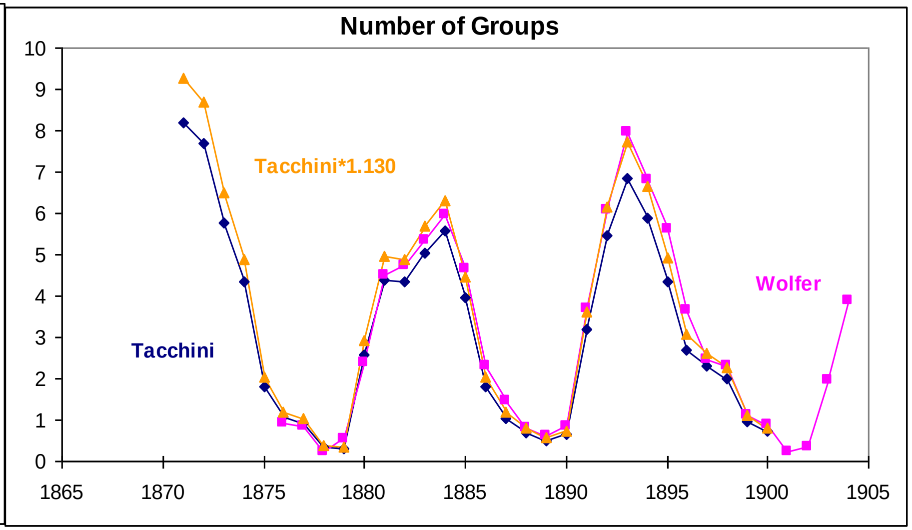


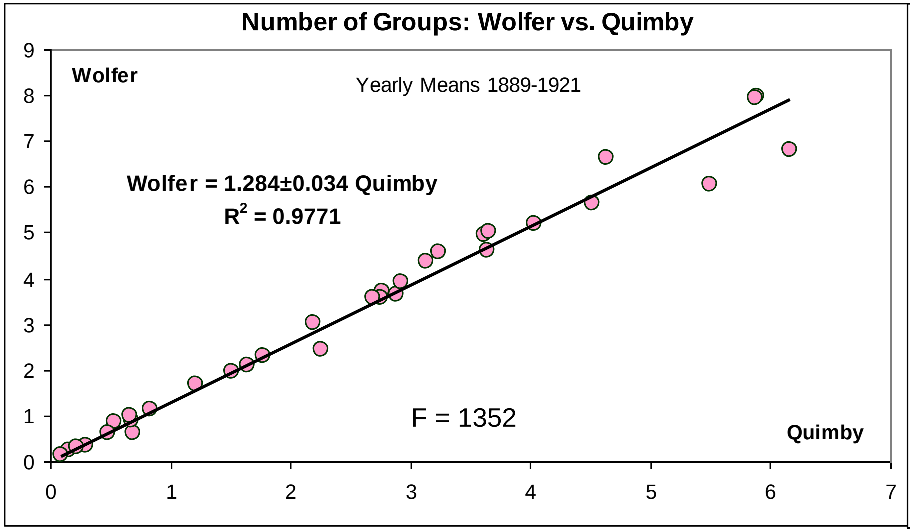


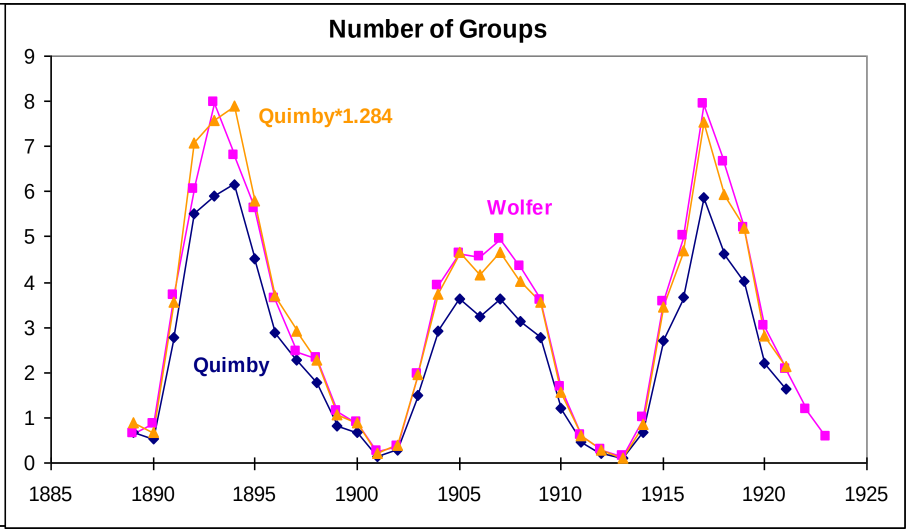


Tacchini, Quimby

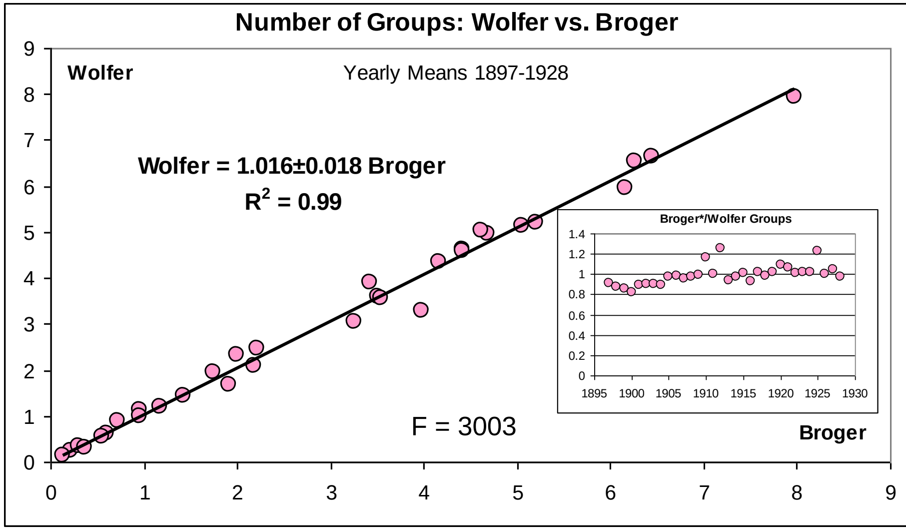


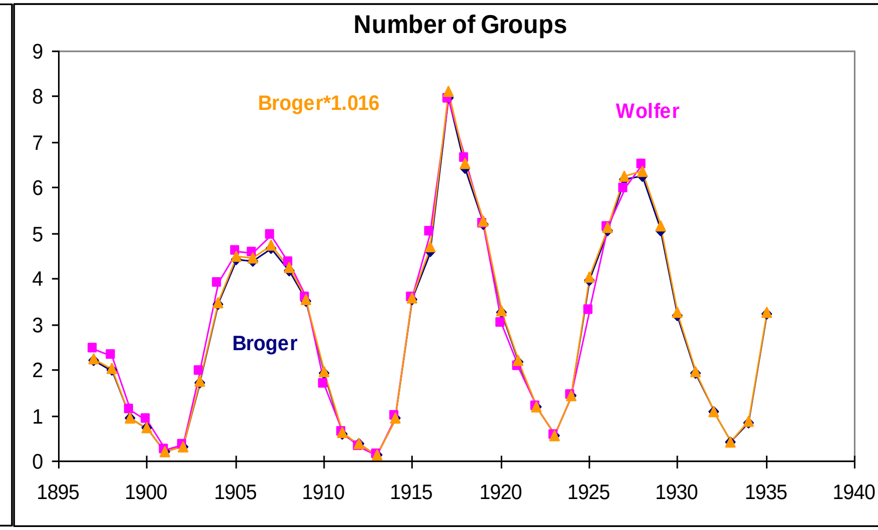


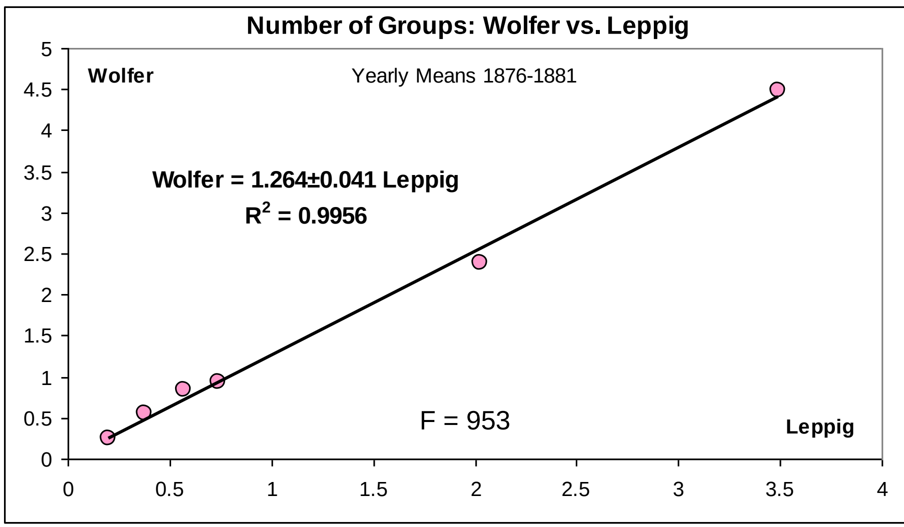


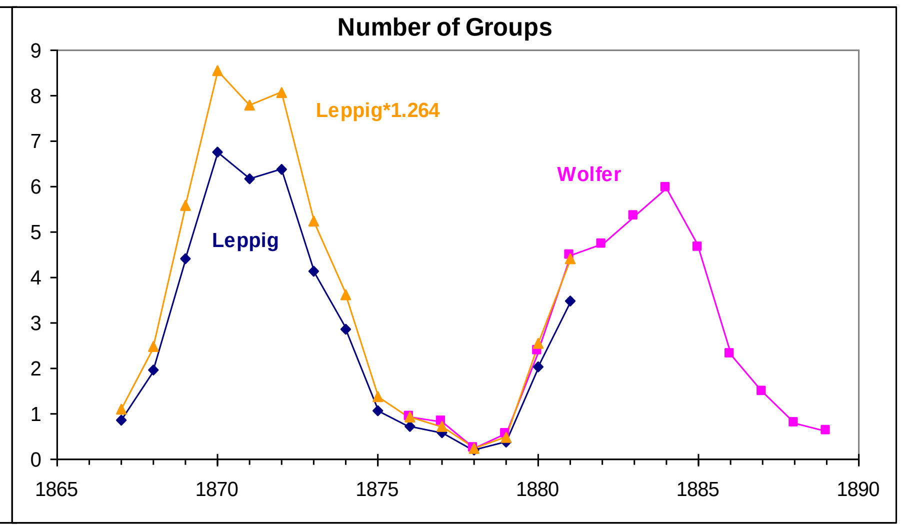


Broger, Leppig

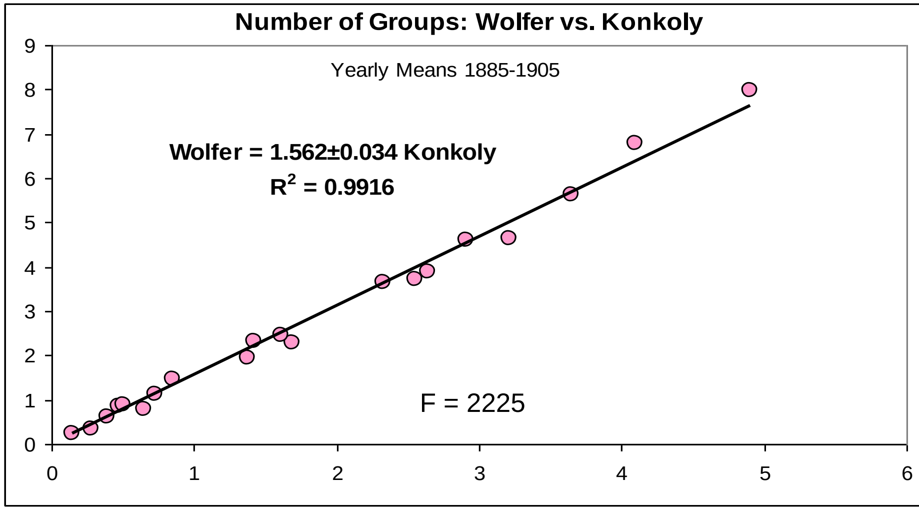


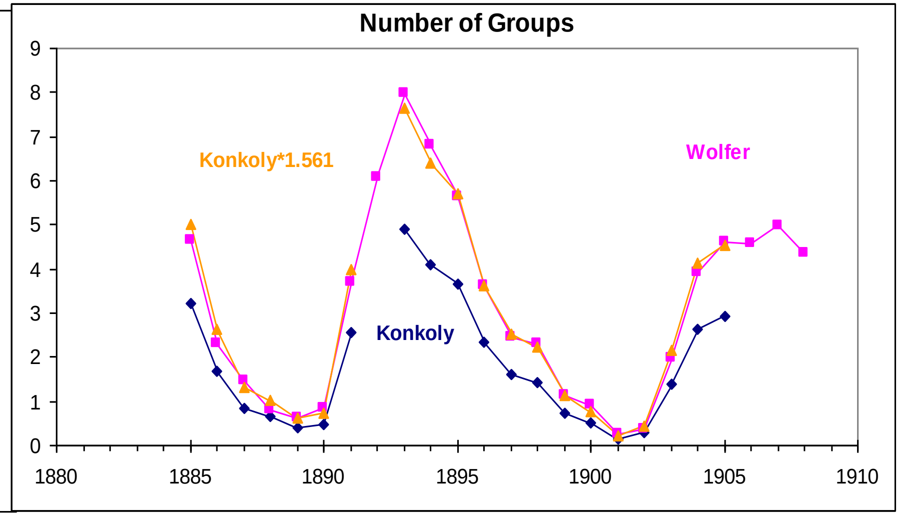


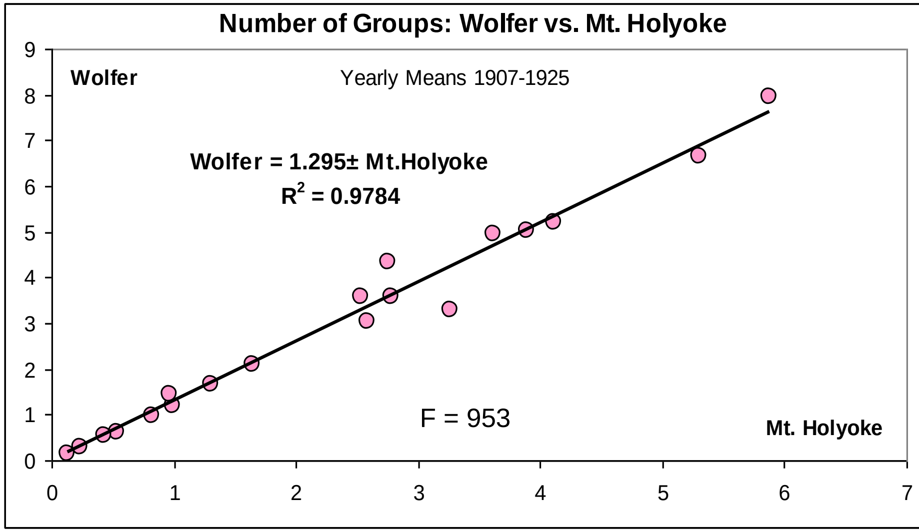


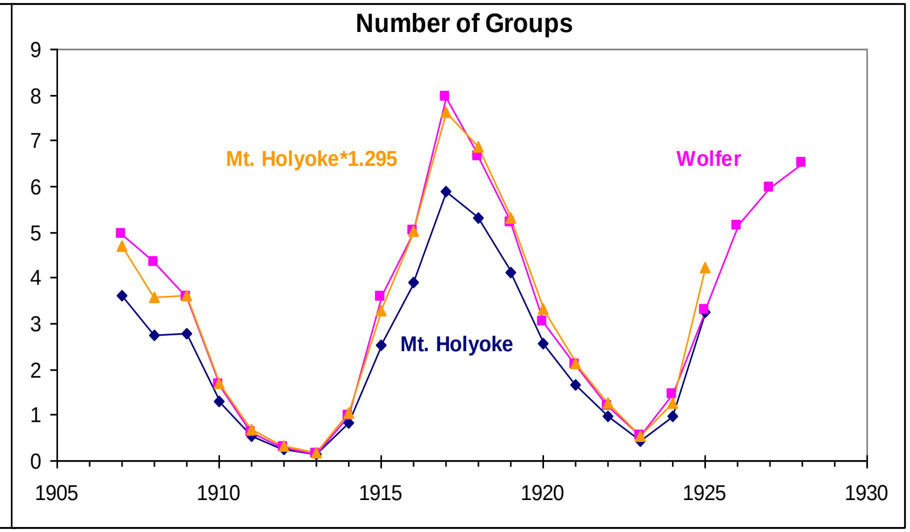


Konkoly, Mt. Holyoke



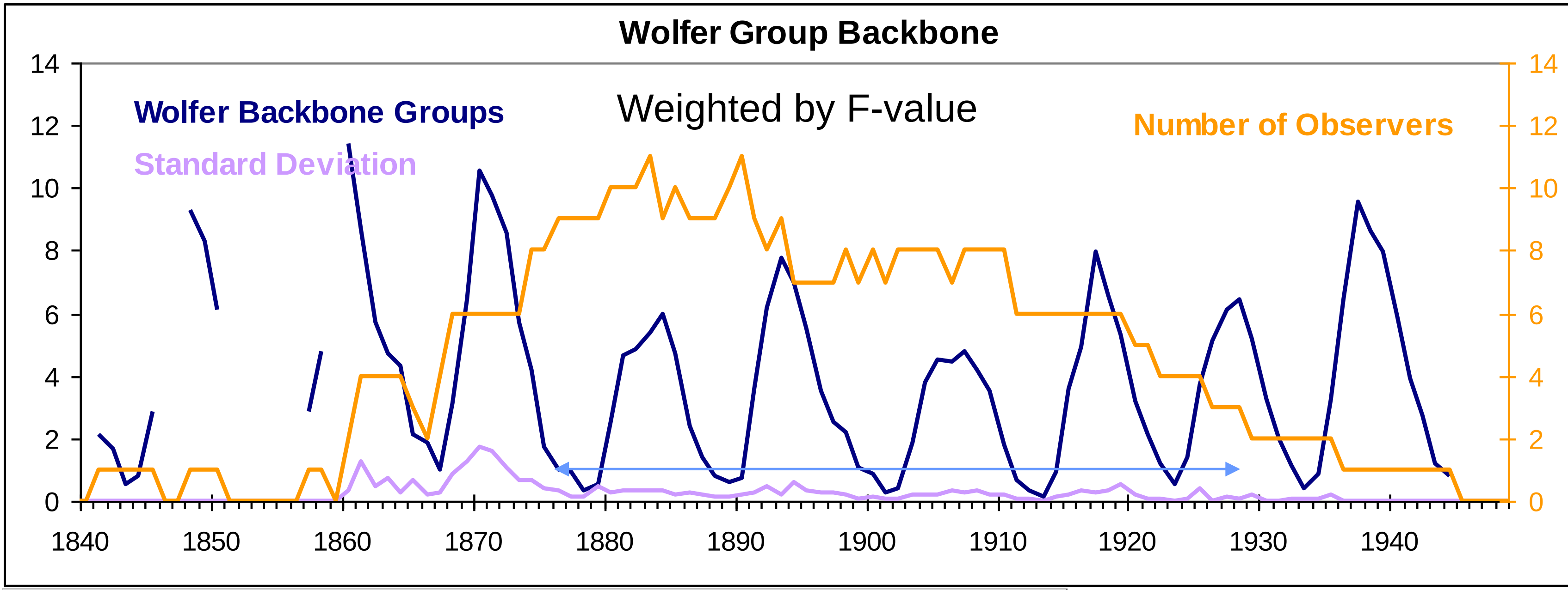


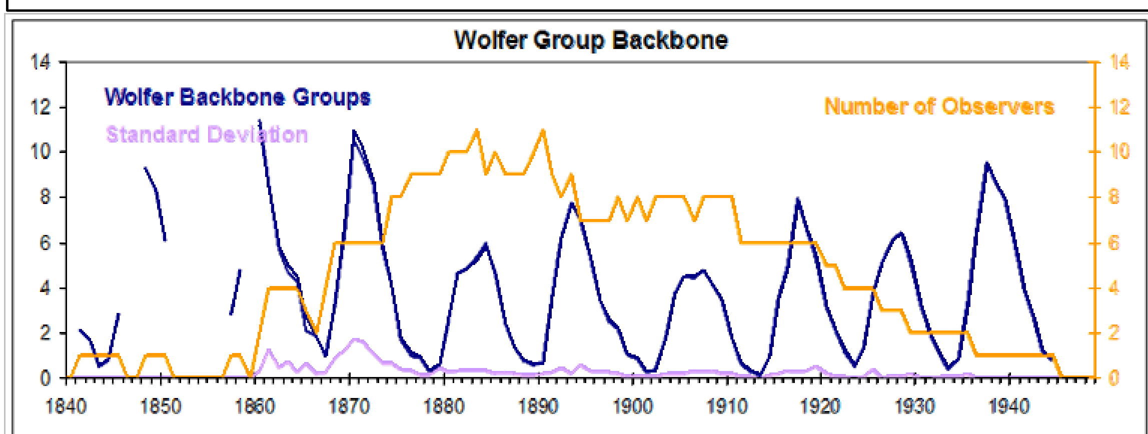




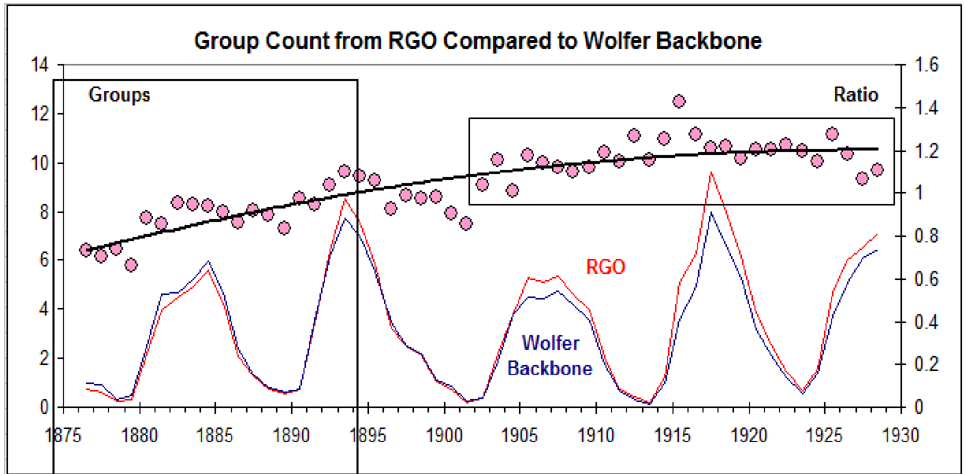
Etc… Dawson, Guillaume, Bernaerts, Woinoff, Merino, Ricco, Moncalieri, Sykora, Brunner,…

The Wolfer Group Backbone

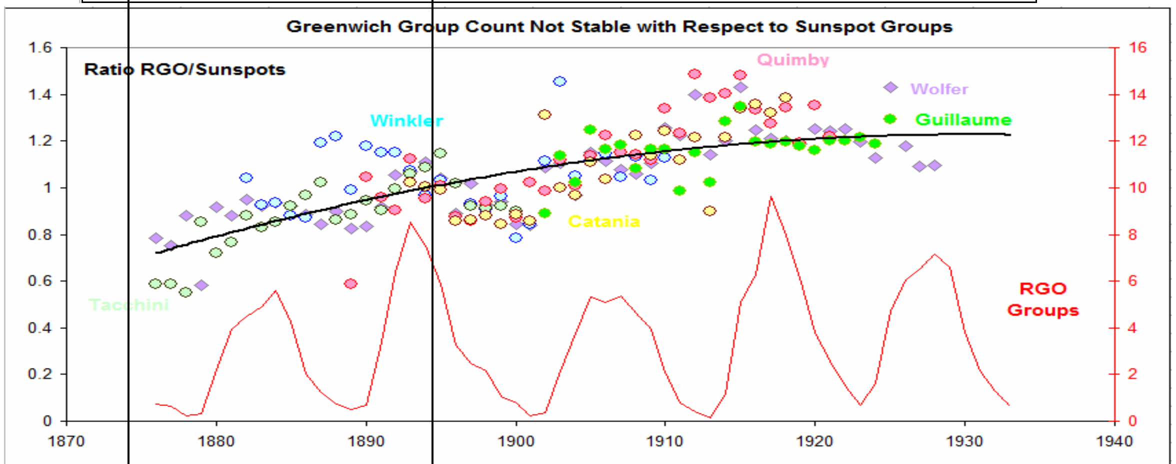




If we average without weighting by the F-value we get very nearly the same result as the overlay at the left shows

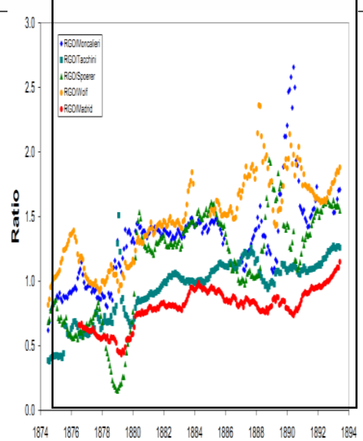


Hoyt & Schatten used the Group Count from RGO [Royal Greenwich Observatory] as their Normalization Backbone. Why don't we?



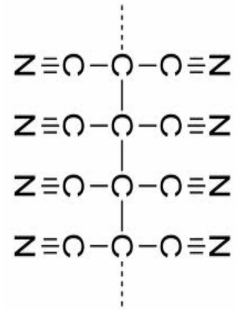
Because there are strong indications that the RGO data is drifting before ~1900

Could this be caused by Wolfer's count drifting? His *k*-factor for R_Z *was*, in fact, declining slightly the first several years as assistant (seeing fewer spots early on – wrong direction). The group count is less sensitive than the Spot count and there are also the other observers…



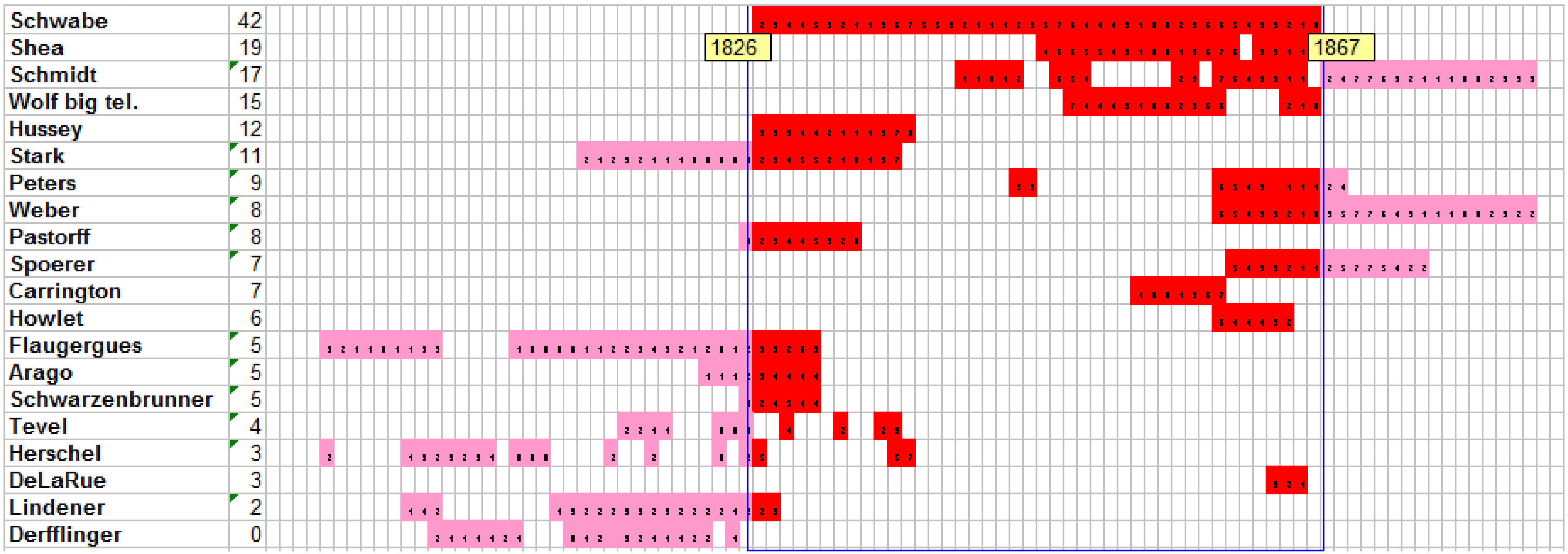
José Vaquero found a similar result which he reported at the 2nd Workshop in Brussels.

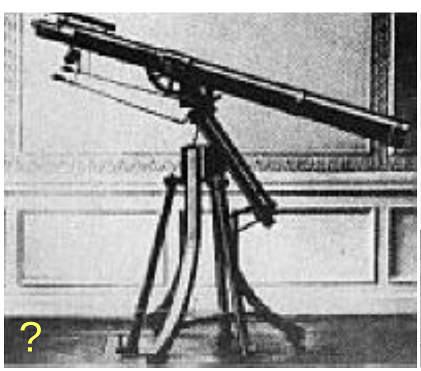
Sarychev & Roshchina report in Solar Sys. Res. 2009, *43*: "There is evidence that the Greenwich values obtained before 1880 and the Hoyt–Schatten series of Rg before 1908 are incorrect".



The Schwabe Backbone

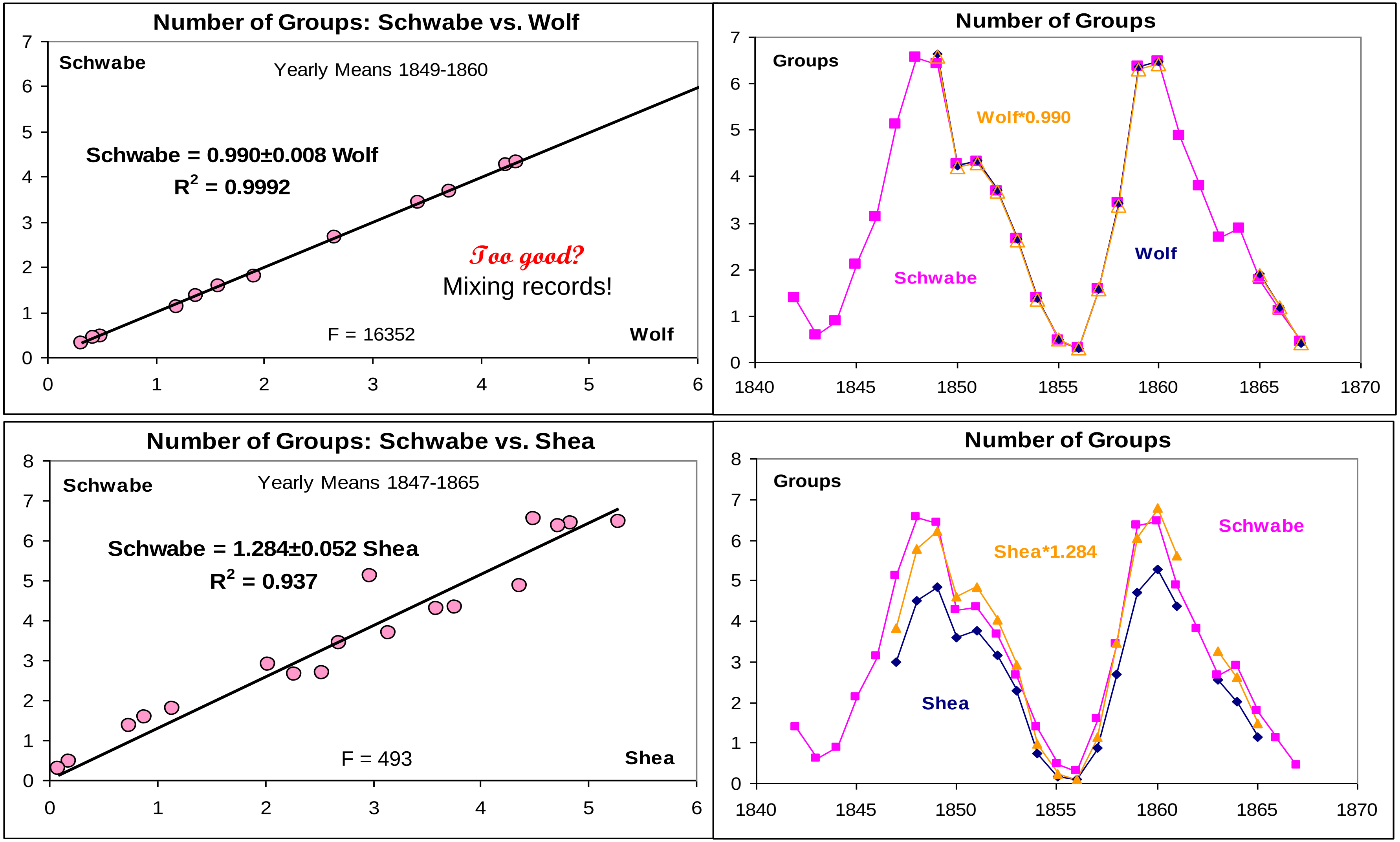
Schwabe received a 50 mm telescope from Fraunhofer in 1826 Jan 22. This telescope was used for the vast majority of full-disk drawings made 1826–1867.





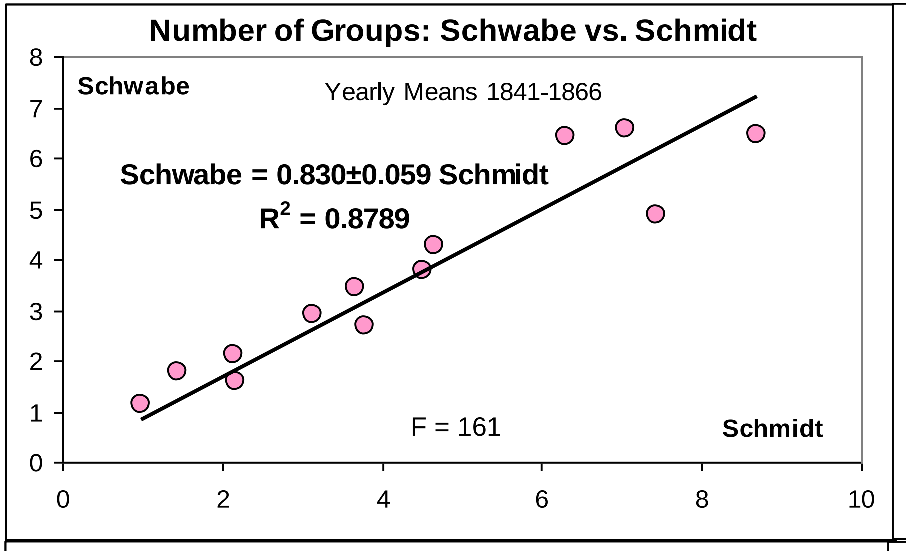
For this backbone we use Wolf's observations with the large 80mm standard telescope

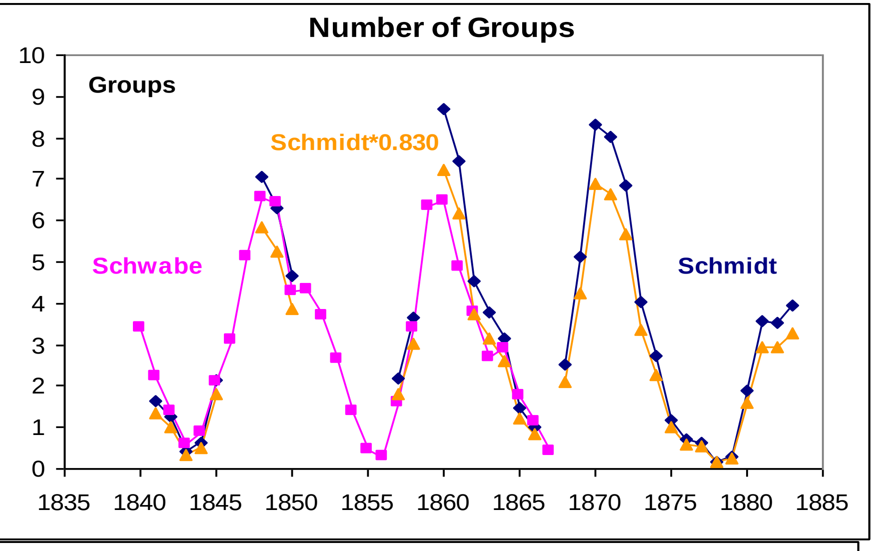
Wolf, Shea

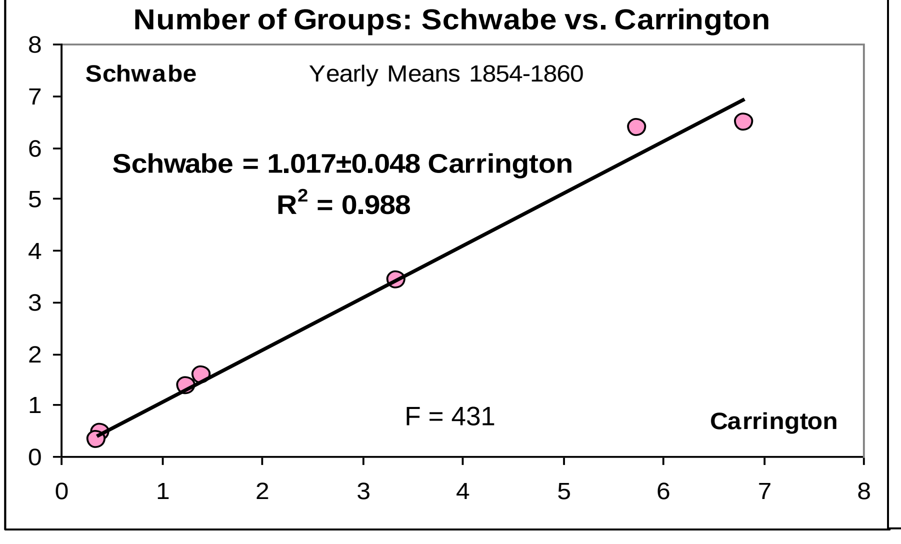


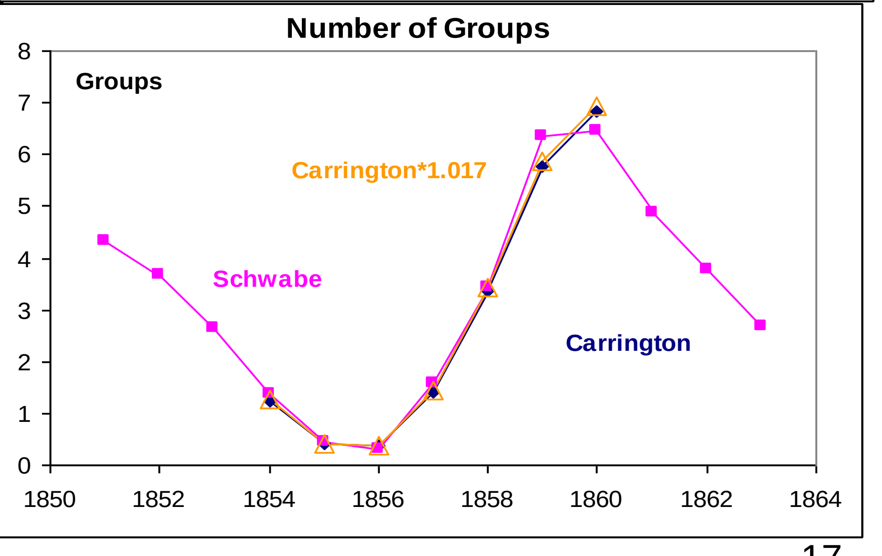
Number of Groups: Schwabe vs. Wolf
Schwabe
Yearly Means 1849-1860
Schwabe = 0.990±0.008 Wolf
R2 = 0.9992
Too good?
Mixing records!
F = 16352
Wolf
Number of Groups
Groups
Wolf*0.990
Schwabe
Wolf
Number of Groups: Schwabe vs. Shea
Schwabe
Yearly Means 1847-1865
Schwabe = 1.284±0.052 Shea
R2 = 0.937
F = 493
Shea
Number of Groups
Groups
Schwabe
Shea*1.284
Shea

Schmidt, Carrington

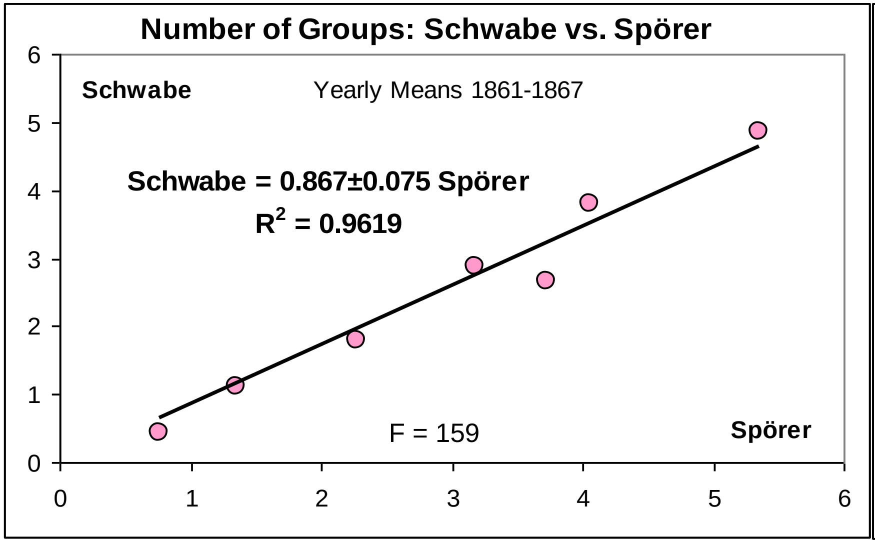


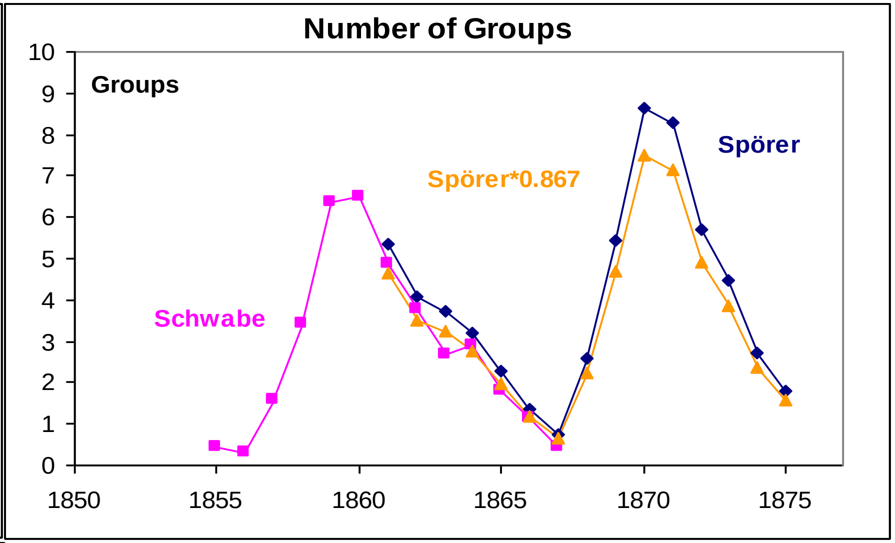


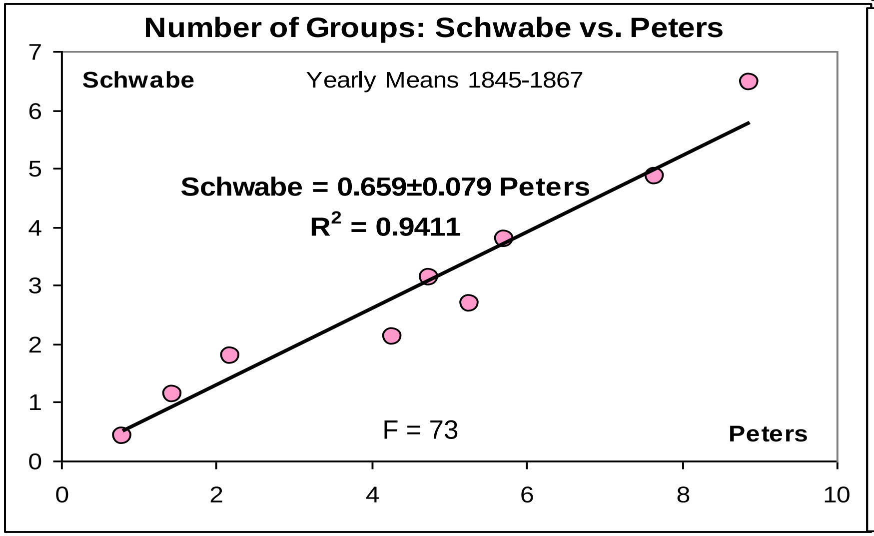


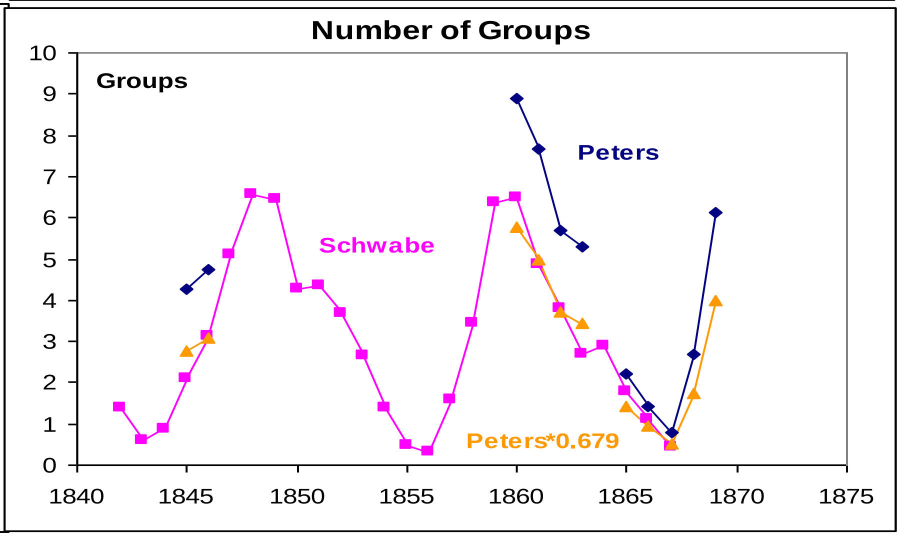


Spörer, Peters

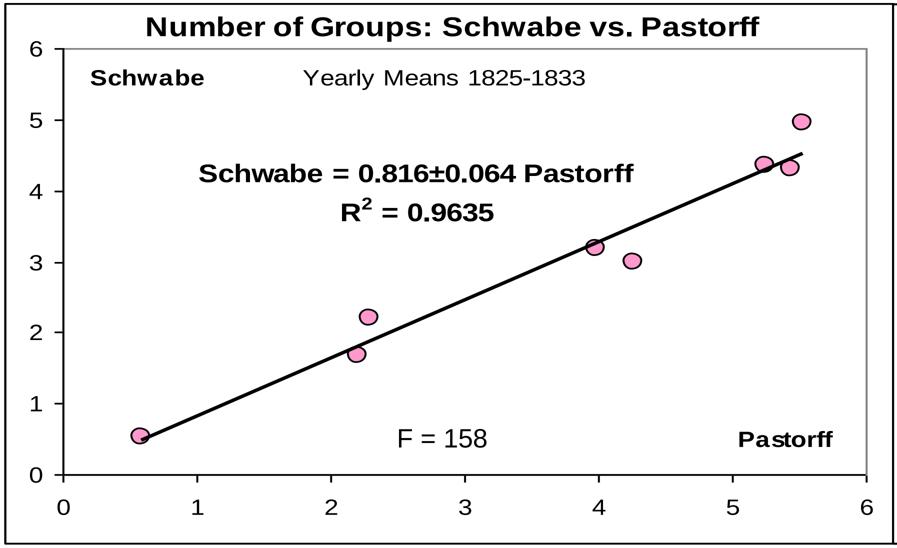


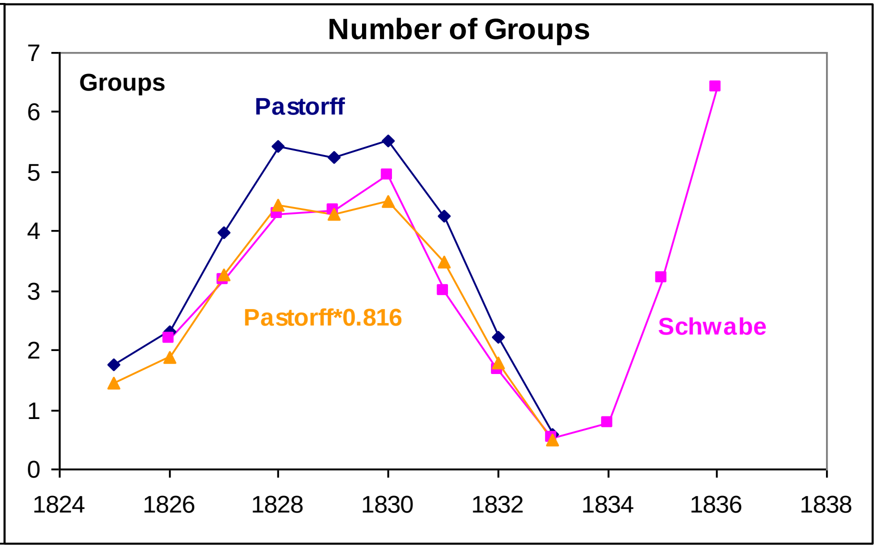


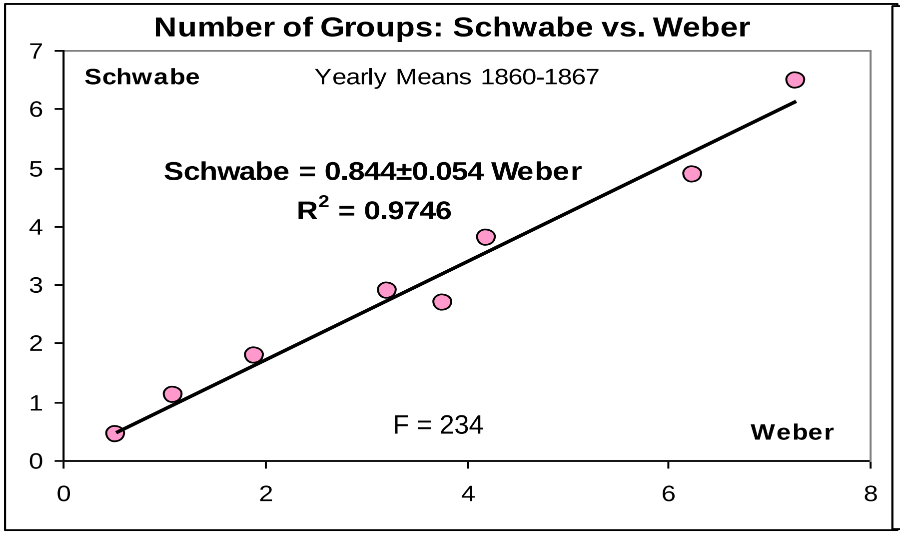


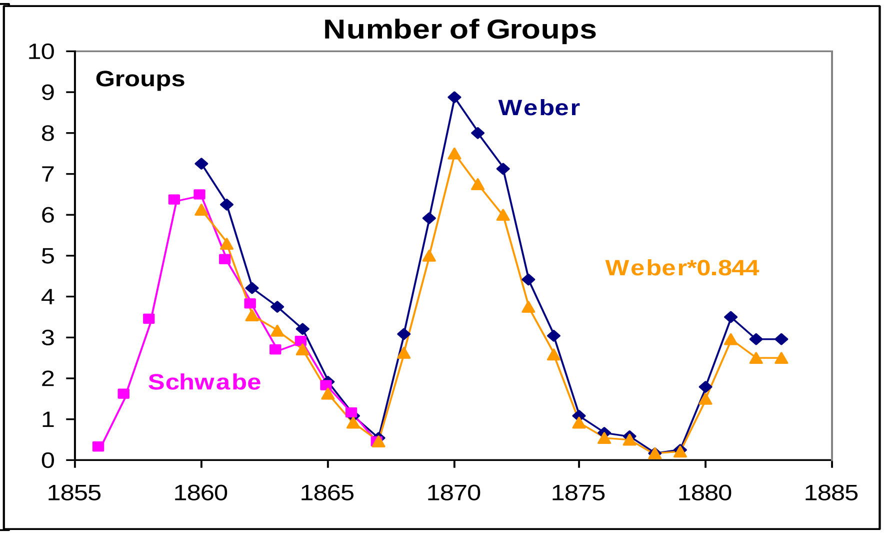


Pastorff, Weber

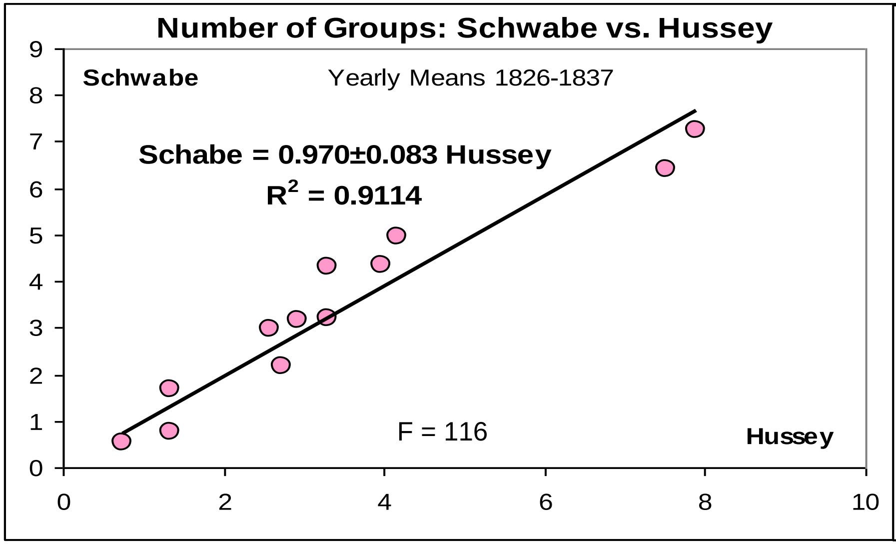


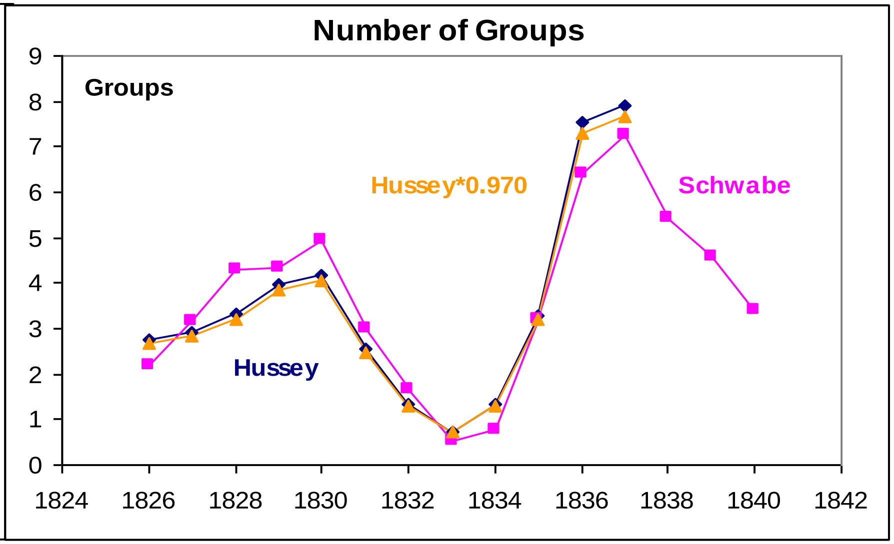


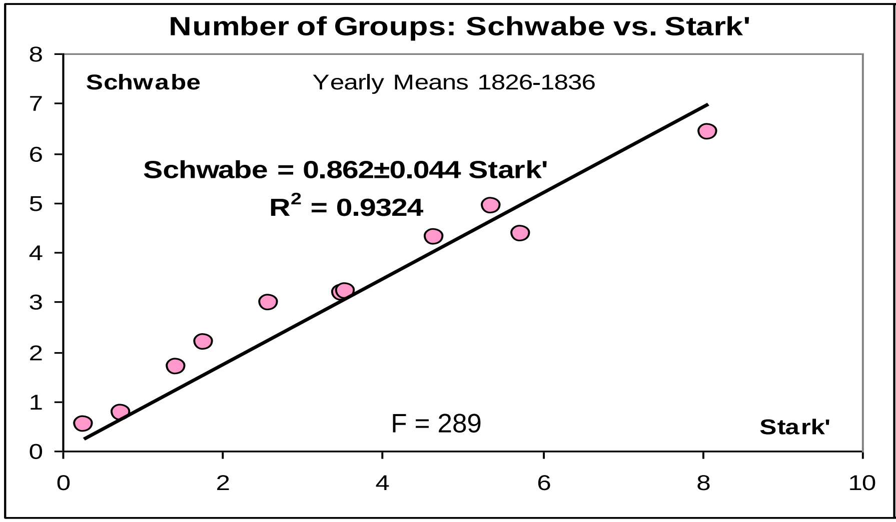


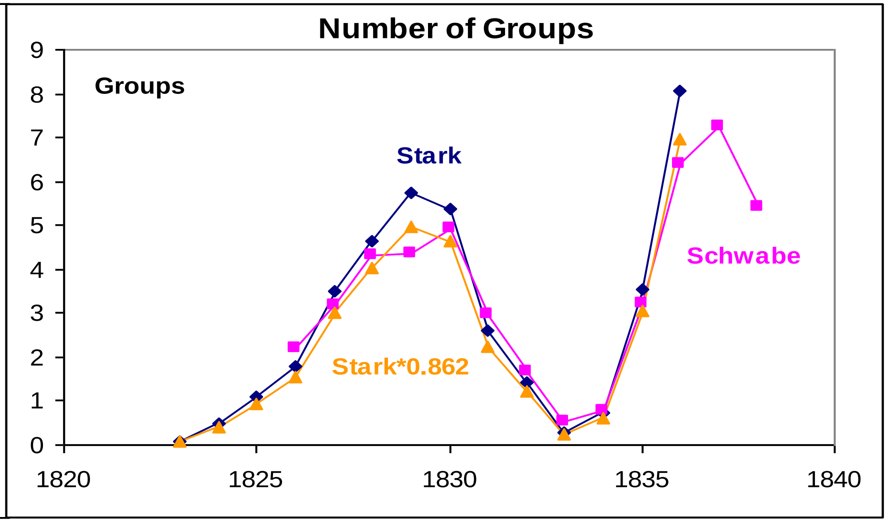


Hussey, Stark'

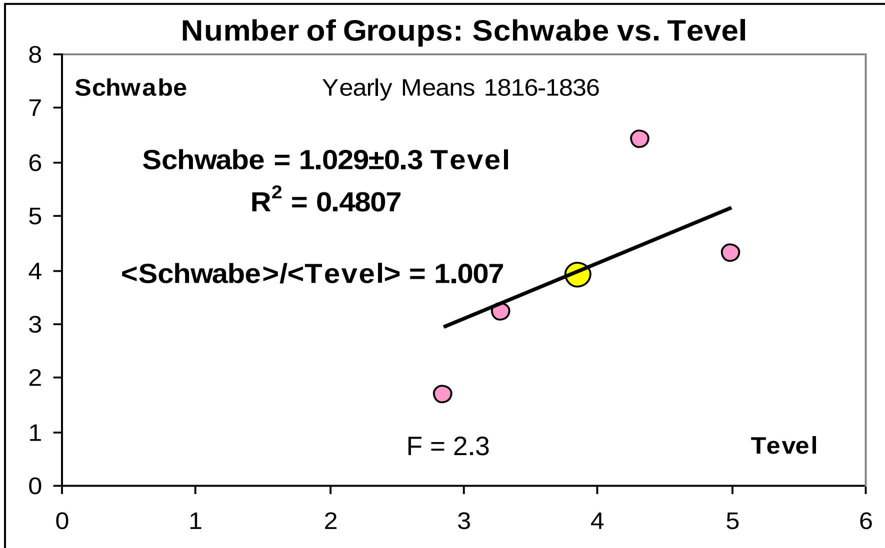


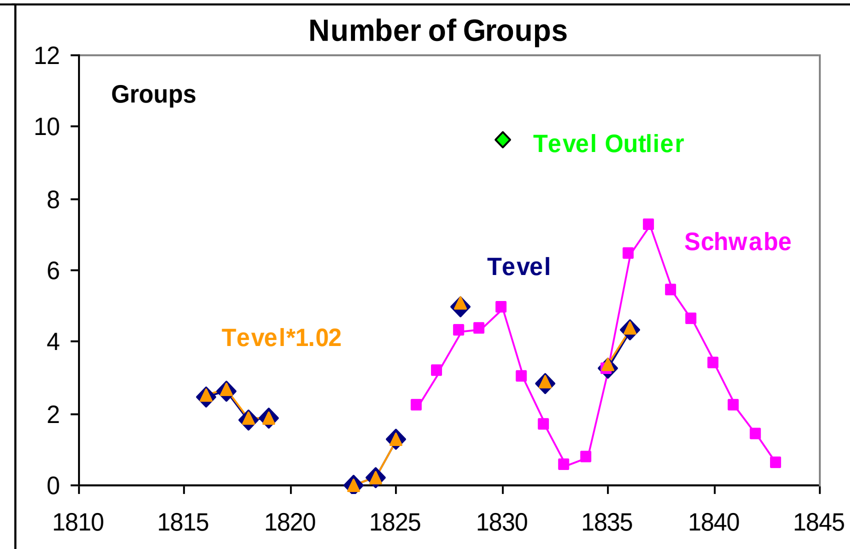


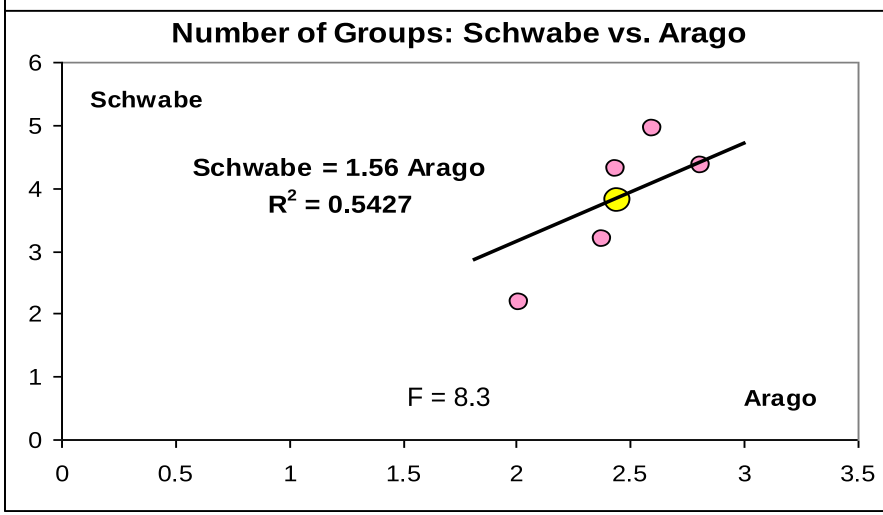


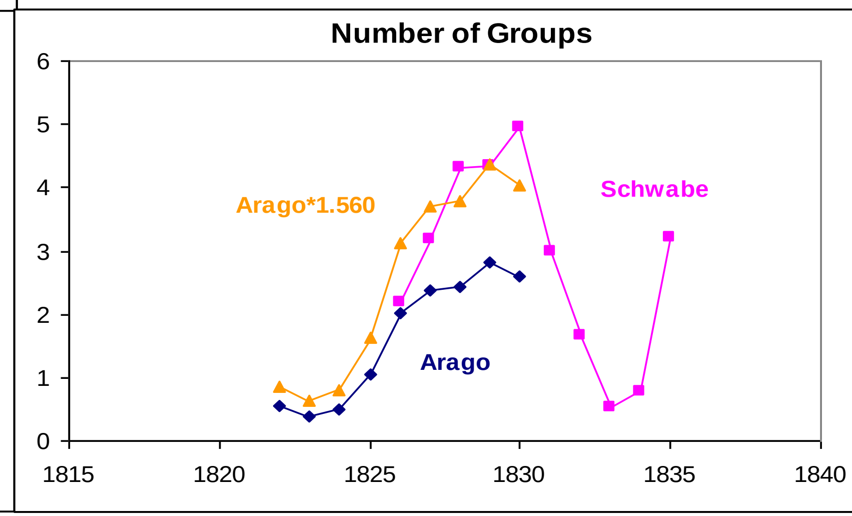


Tevel, Arago

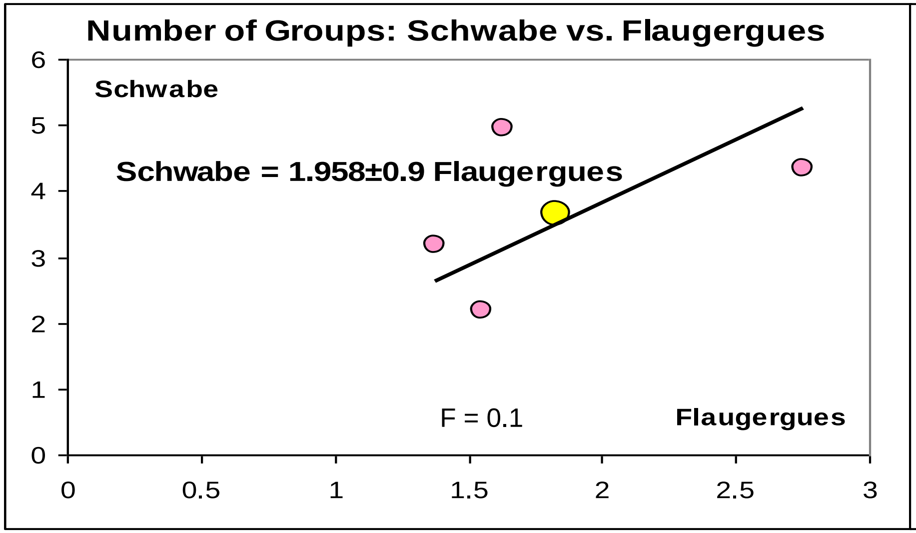

Number of Groups: Schwabe vs. Tevel
Schwabe
Yearly Means 1816-1836
Schwabe = 1.029±0.3 Tevel
R2 = 0.4807
<Schwabe>/<Tevel> = 1.007
F = 2.3
Tevel

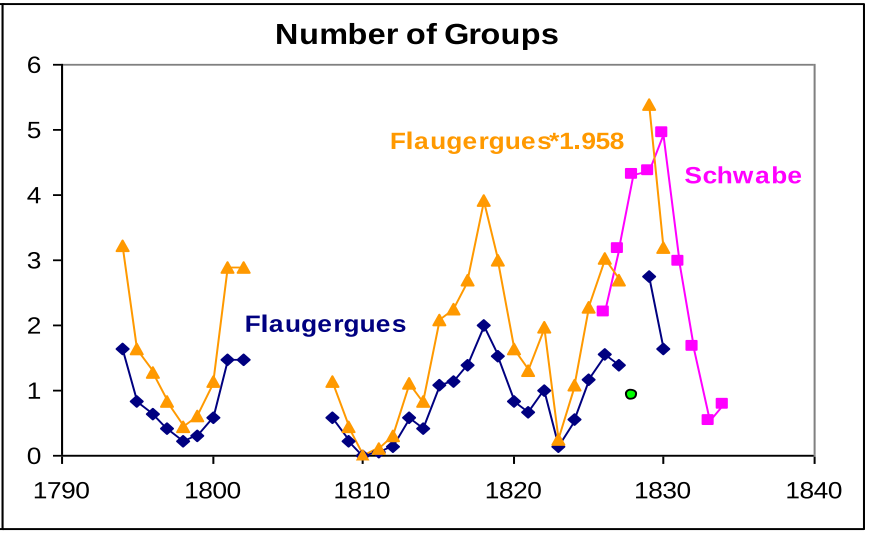

Number of Groups
Groups
Tevel Outlier
Schwabe
Tevel
Tevel*1.02

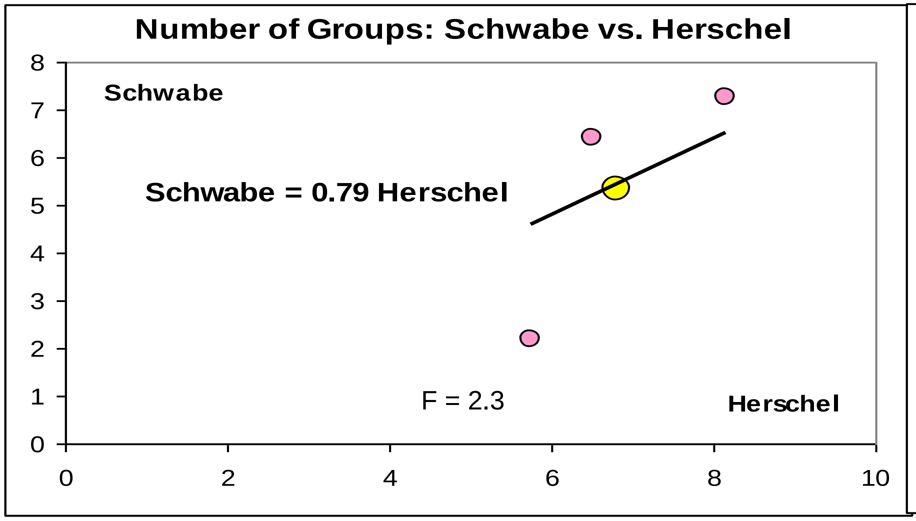

Number of Groups: Schwabe vs. Arago
Schwabe
Schwabe = 1.56 Arago
R2 = 0.5427
F = 8.3
Arago

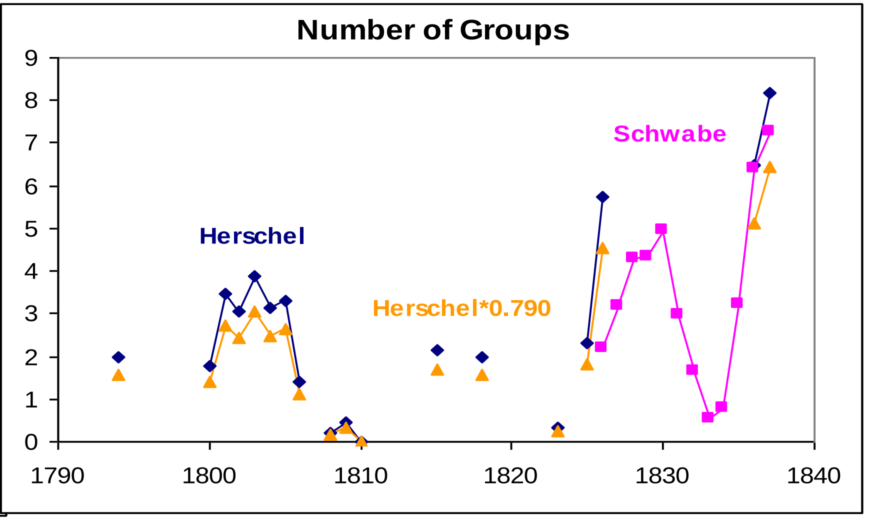

Number of Groups
Arago*1.560
Schwabe
Arago

Flaugergues, Herschel



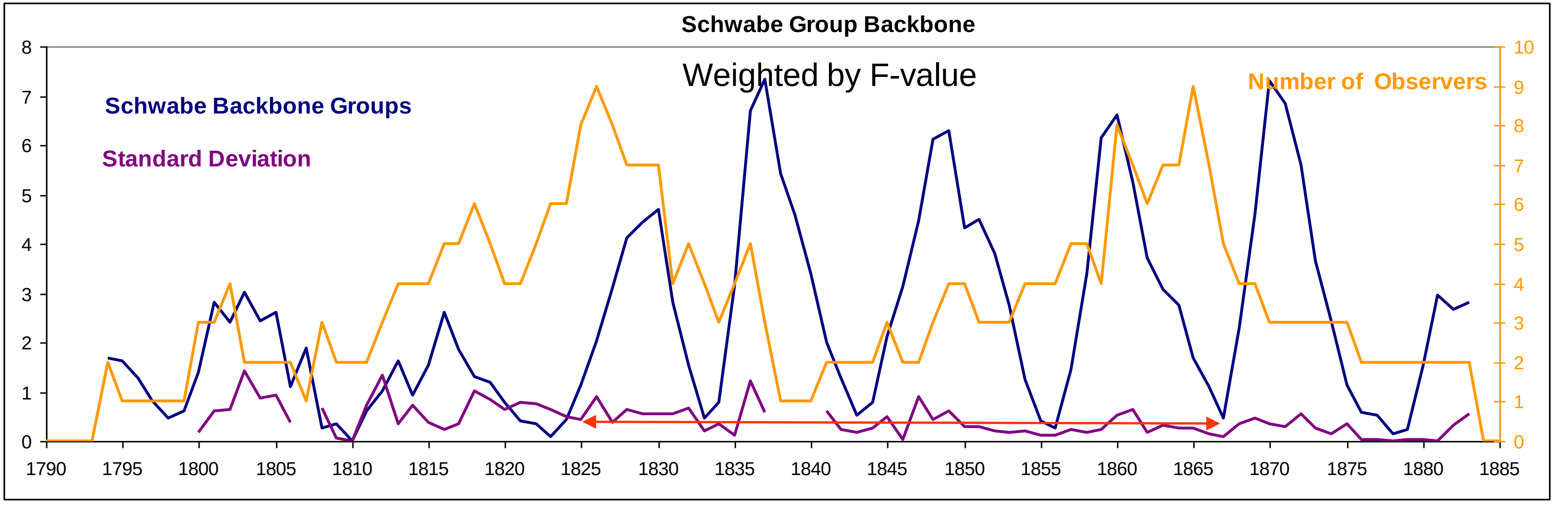


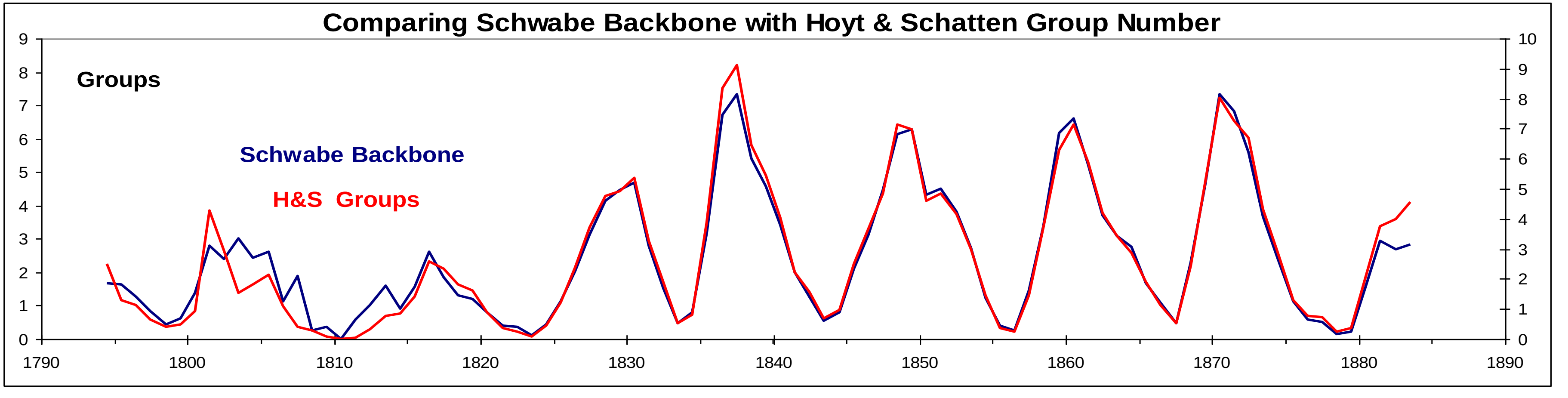




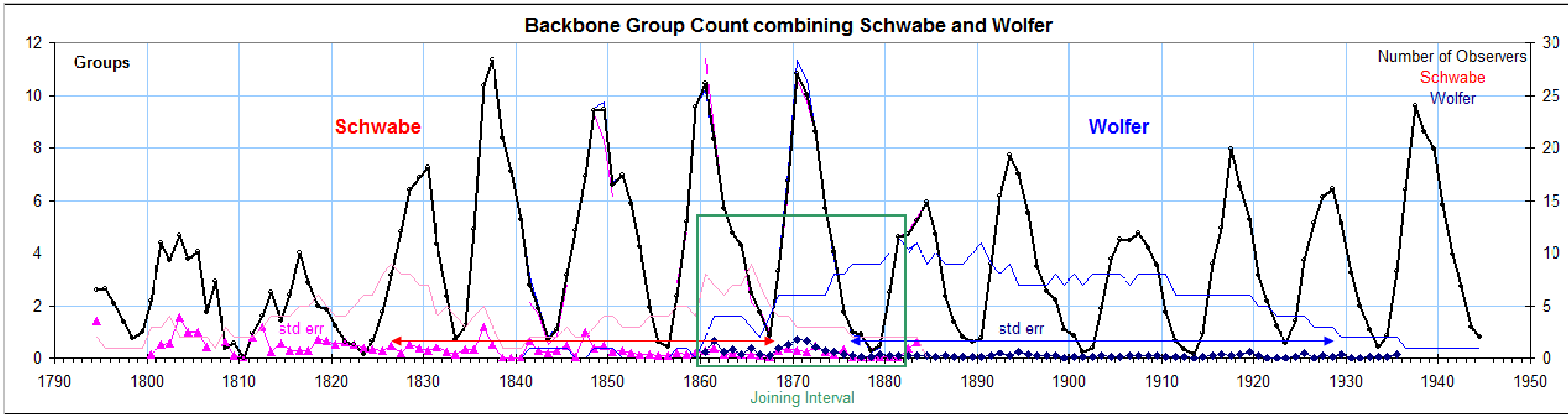
Etc… Lindener, Schwarzenbrunner, Derfflinger…

The Schwabe Group Backbone

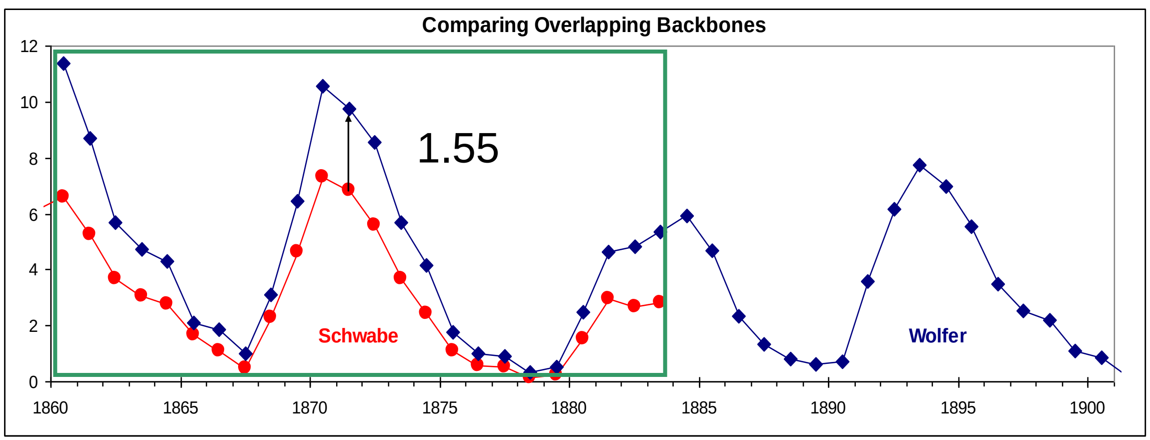


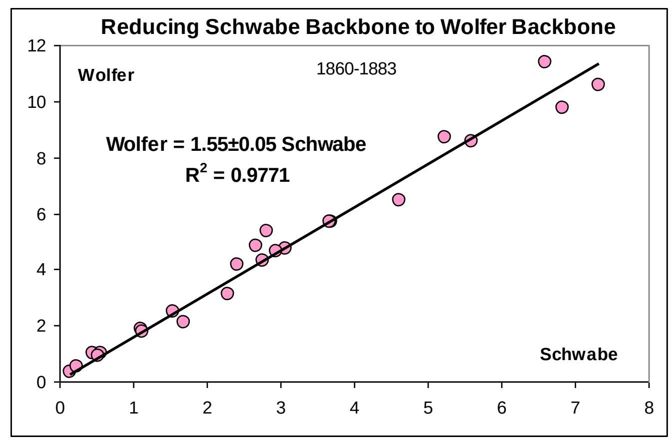


Joining two Backbones

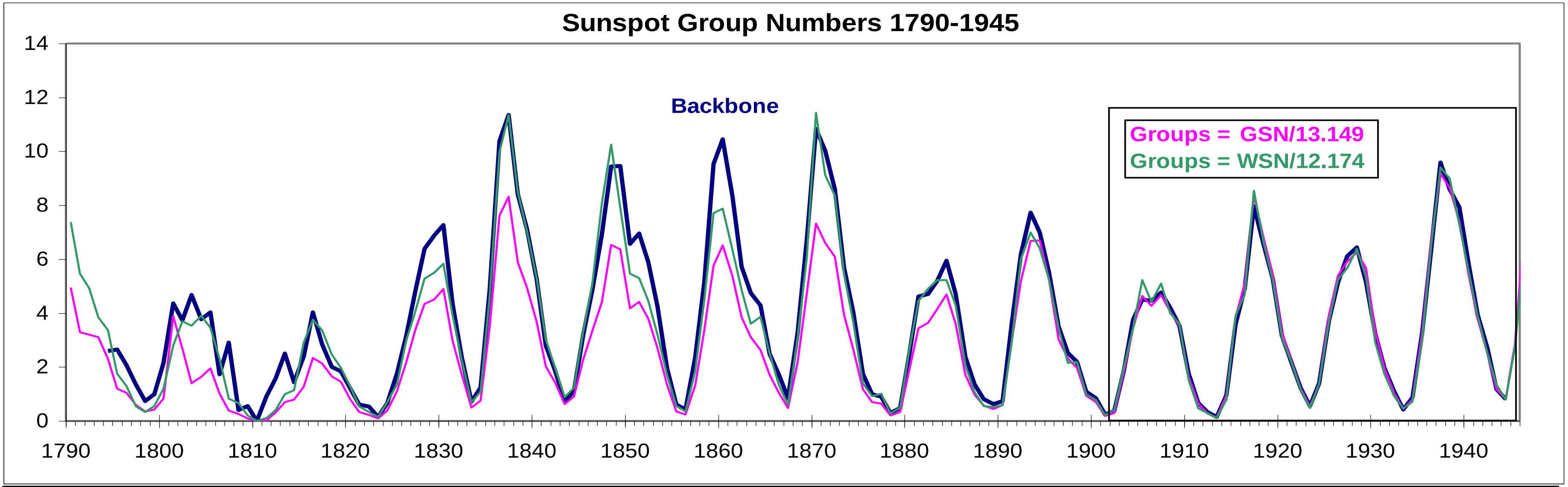


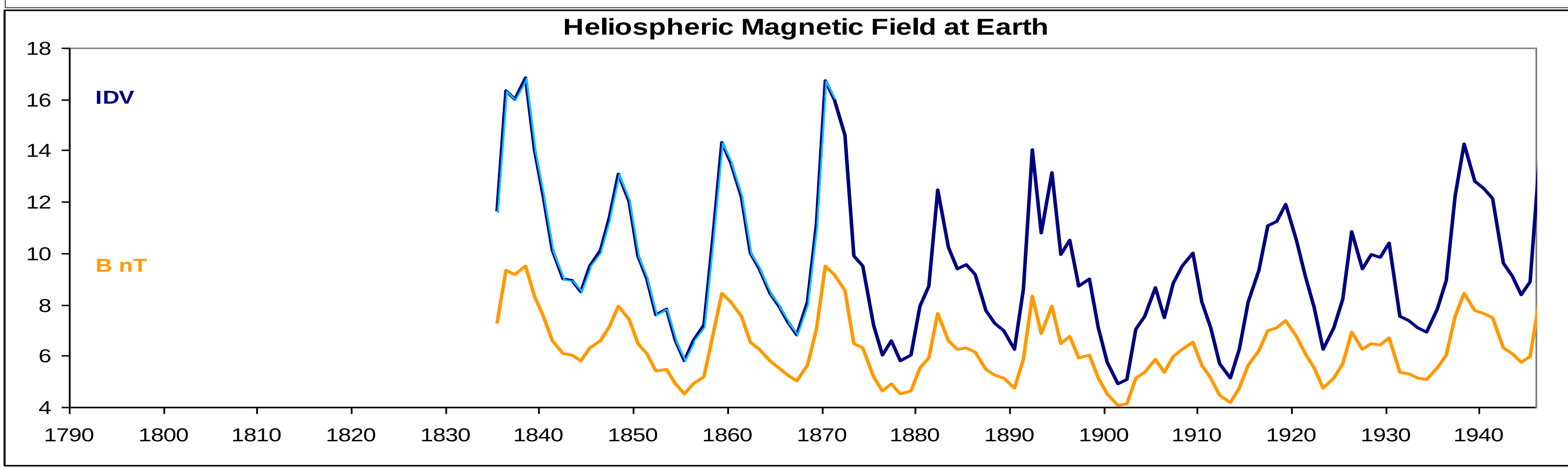
Comparing Schwabe with Wolfer backbones over 1860-1883 we find a normalizing factor of 1.55



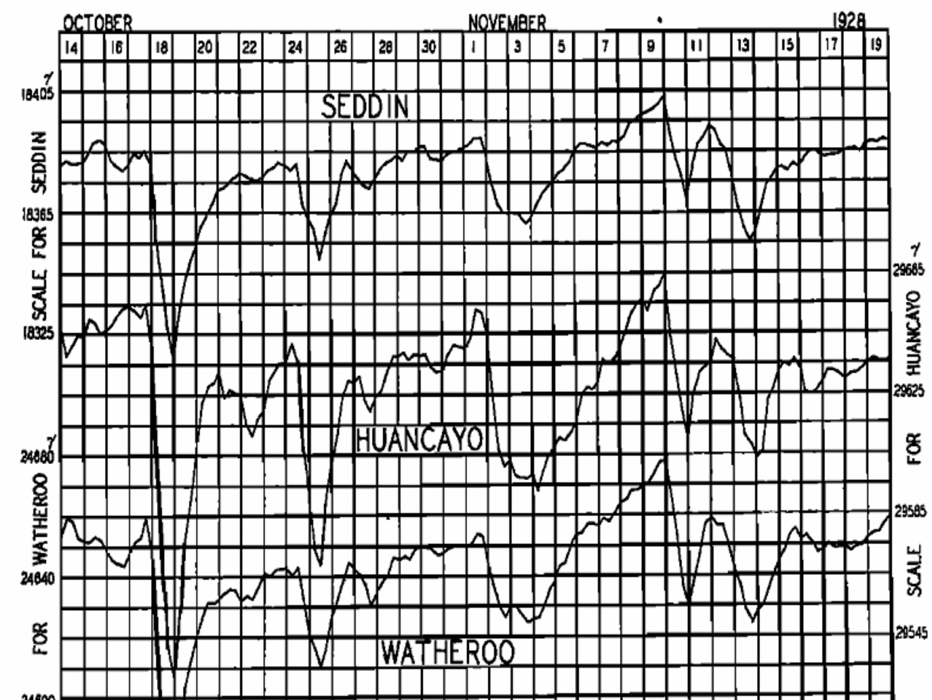


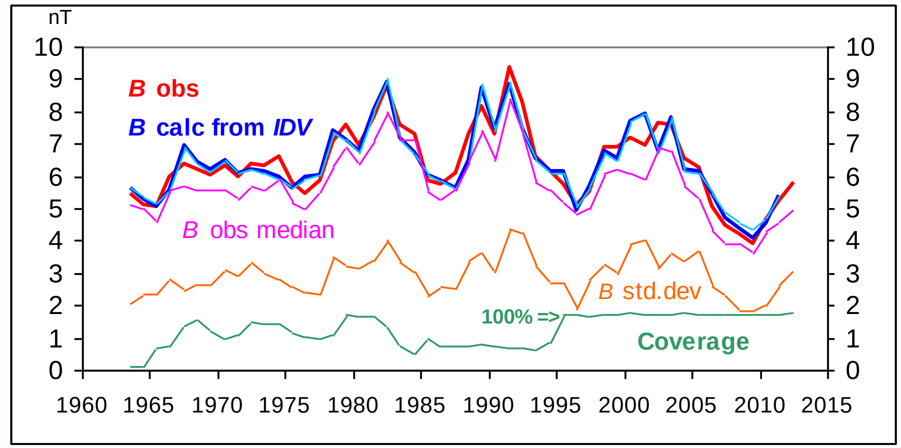
Comparison Backbone with GSN and WSN



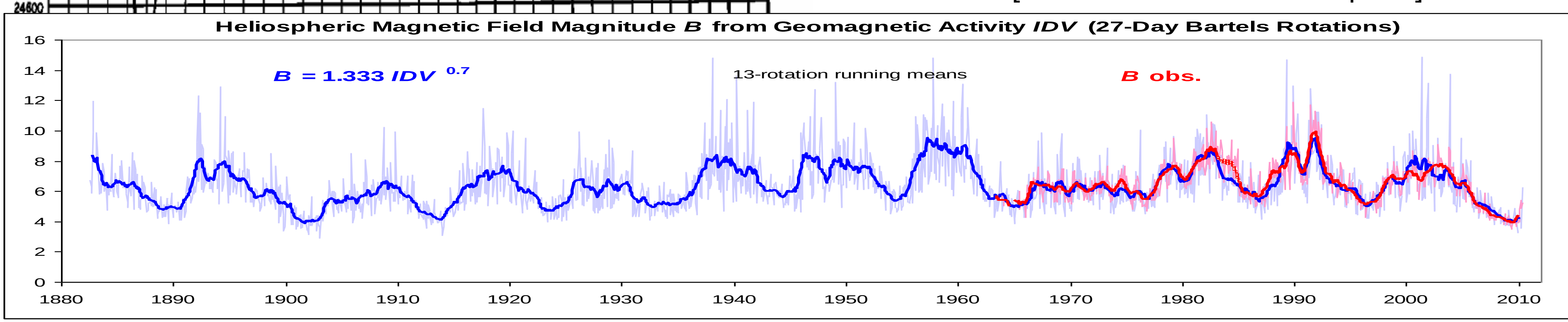


How do we Know HMF B?

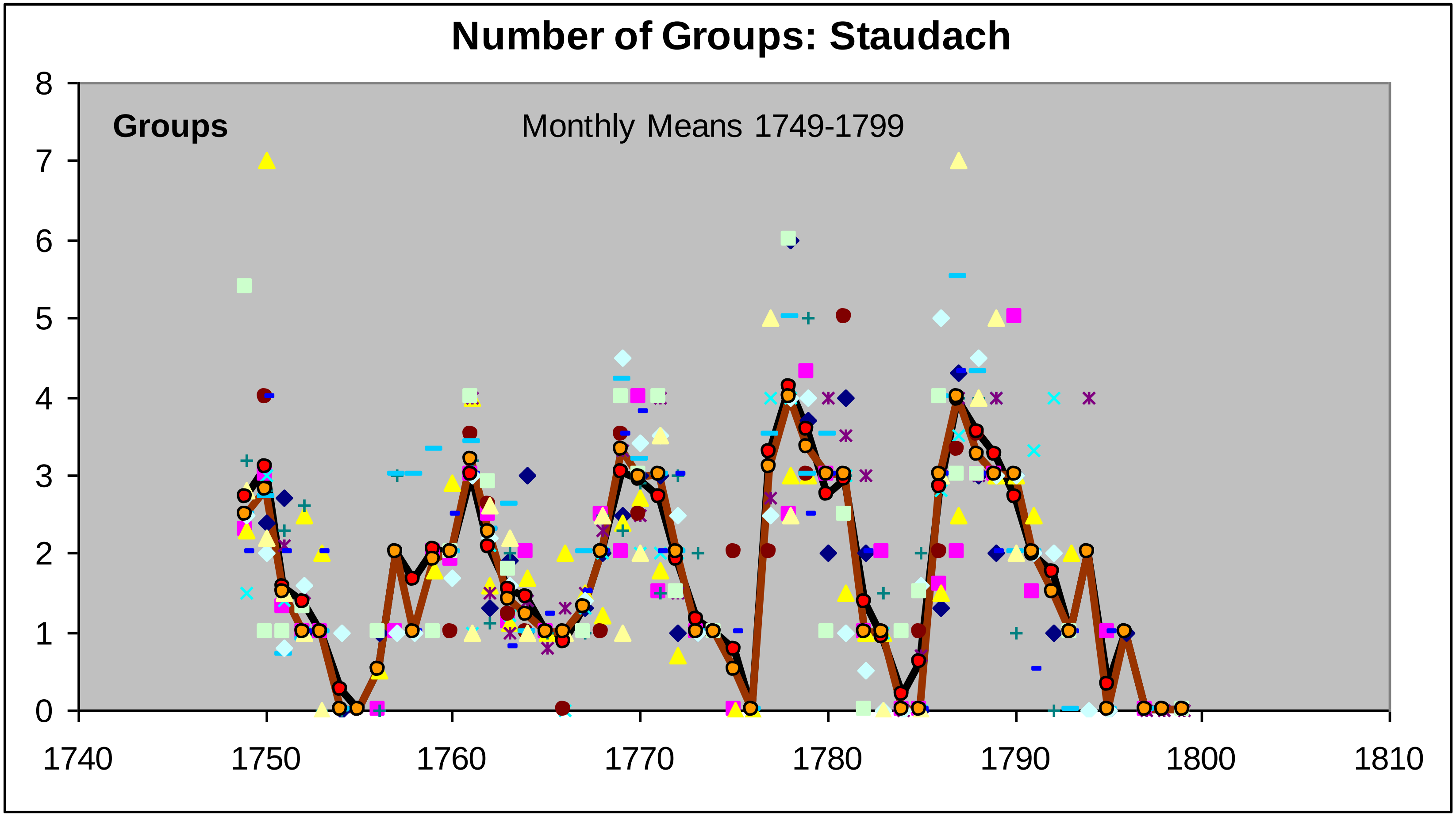




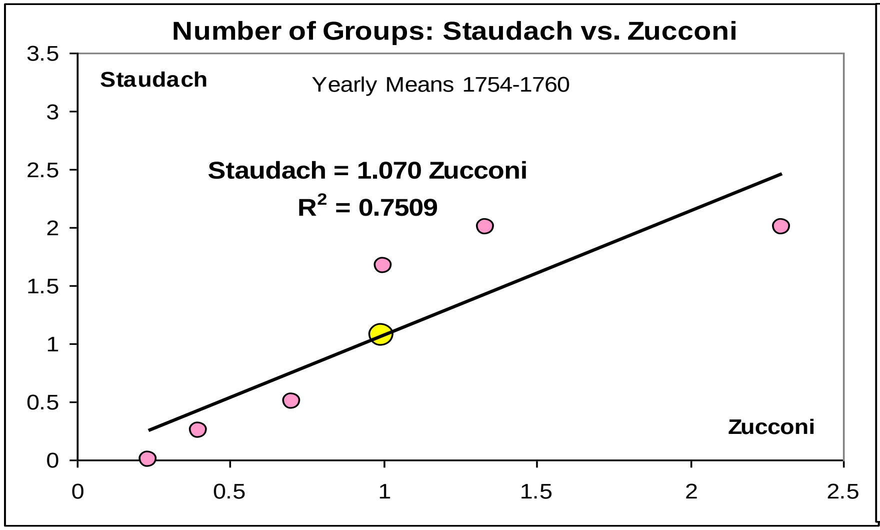
The IDV-index is the unsigned difference from one day to the next of the Horizontal Component of the geomagnetic field averaged over stations and a suitable time window. The index correlates strongly with HMF B [and not with solar wind speed]

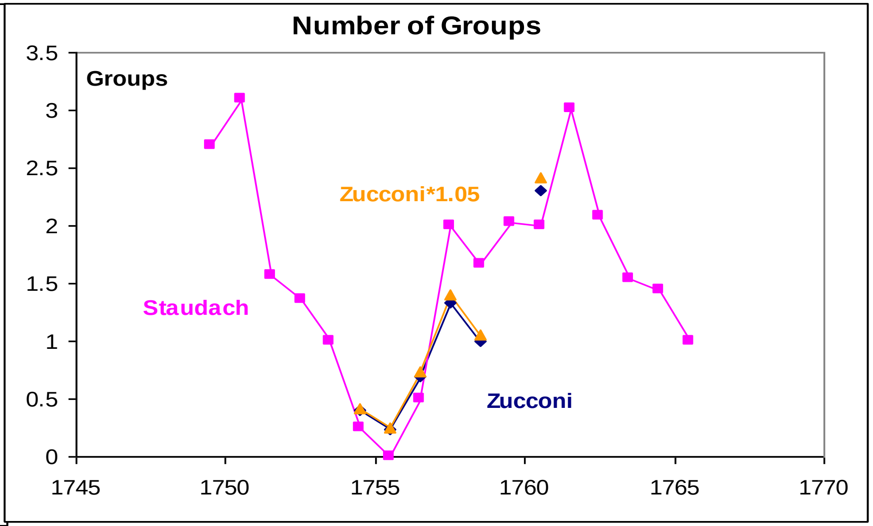


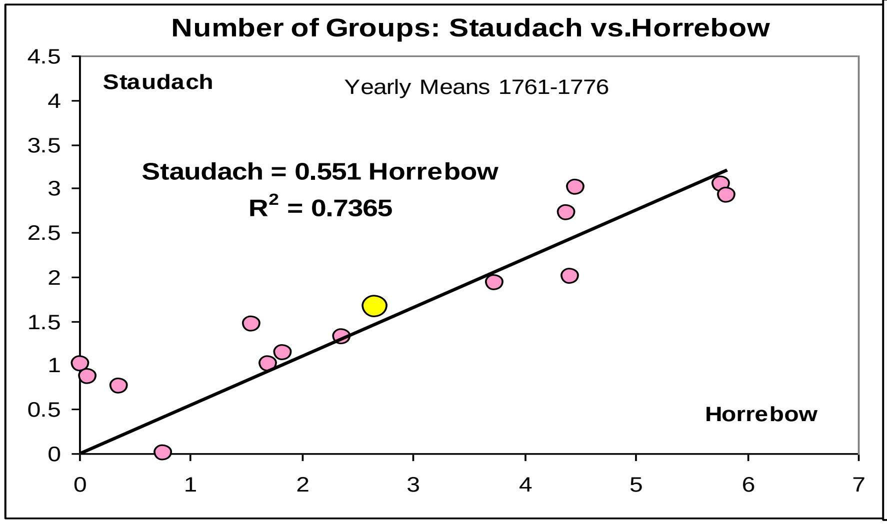
Staudach Observations

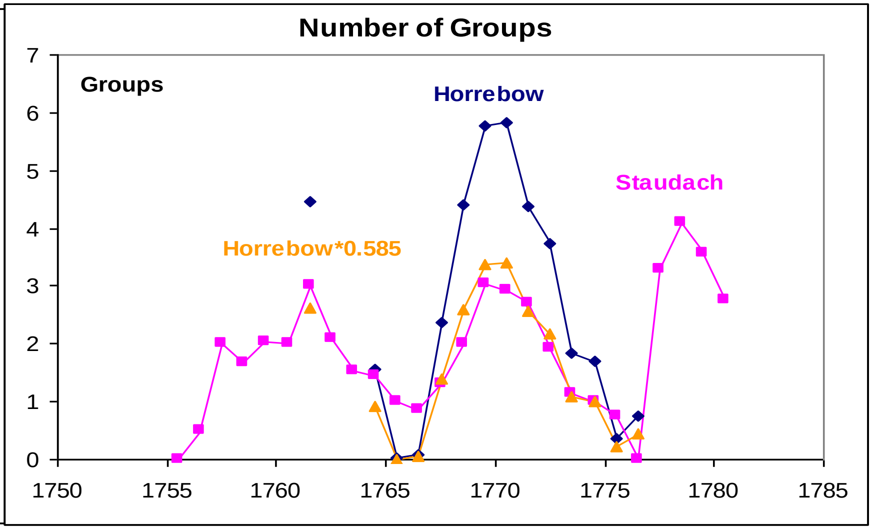


Zucconi, Horrebow









Staudach Backbone