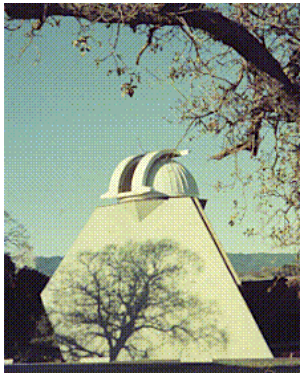

On Multiple Populations of Sunspot Group Numbers

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Stanford University

Sept. 2019

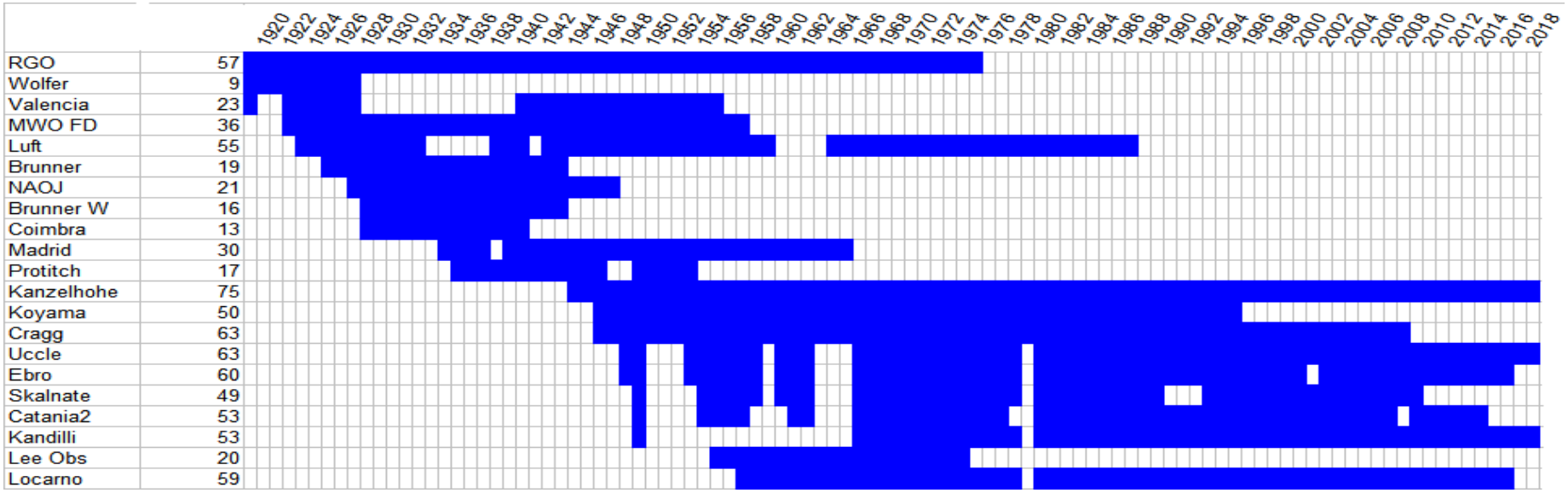
For ISSI 417, Bern

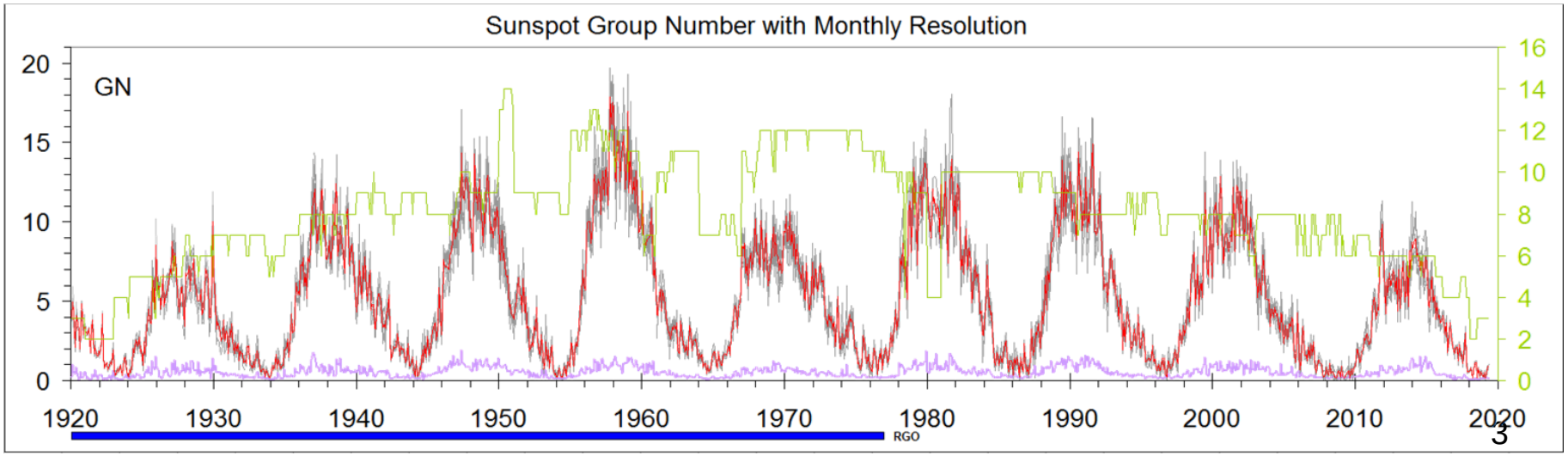
The Backbone Method, pro et con

- Limited to observers with long-term [and good] records in order to get a good enough regression [selection effects?]
- How to deal with non-linear regressions [if any] and with missing data
- No accumulation of errors within the backbone [only one comparison with the primary observer, i.e. no daisy chaining]
- Possibility of undetected intra-backbone drifts
- Refusal of some people to grasp the basic idea
- Each backbone can be treated as an independent unit: changes to one do not impact the others
- Because several observers contribute to each average [e.g. yearly or monthly], error bars can be estimated
- A small (about 3) number of backbones limits the effect of daisy chaining from one to the next, especially if the 'middle' one is chosen as the reference scale, so don't have many 'mini'-backbones
- Each solar minimum [with almost no spots] provides a 'reset' of the errors preventing the oft claimed run-away 'monotonic' increase with time
- Constructing a backbone is a fair amount of work, e.g. with quality control
- There are probably more cons…

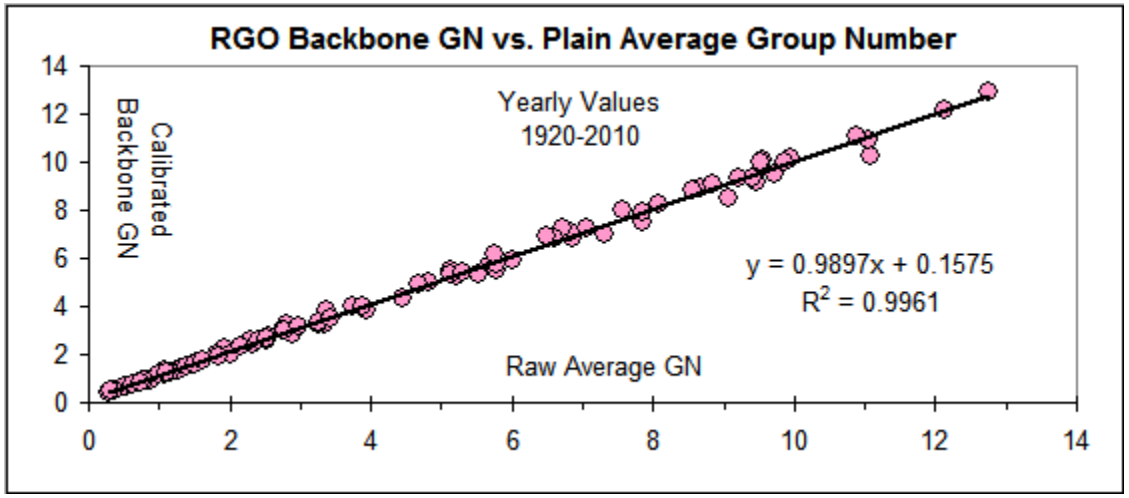
This talk will show that none of the above matters

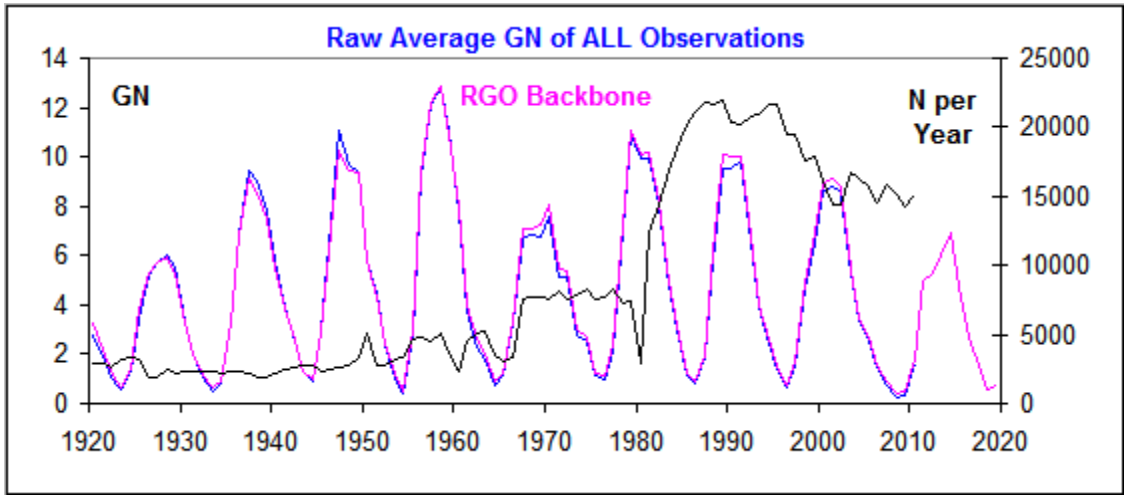
An Example: RGO Group Number Backbone





The Simple Average of ALL Observers is as Good as Our Carefully Constructed Backbones



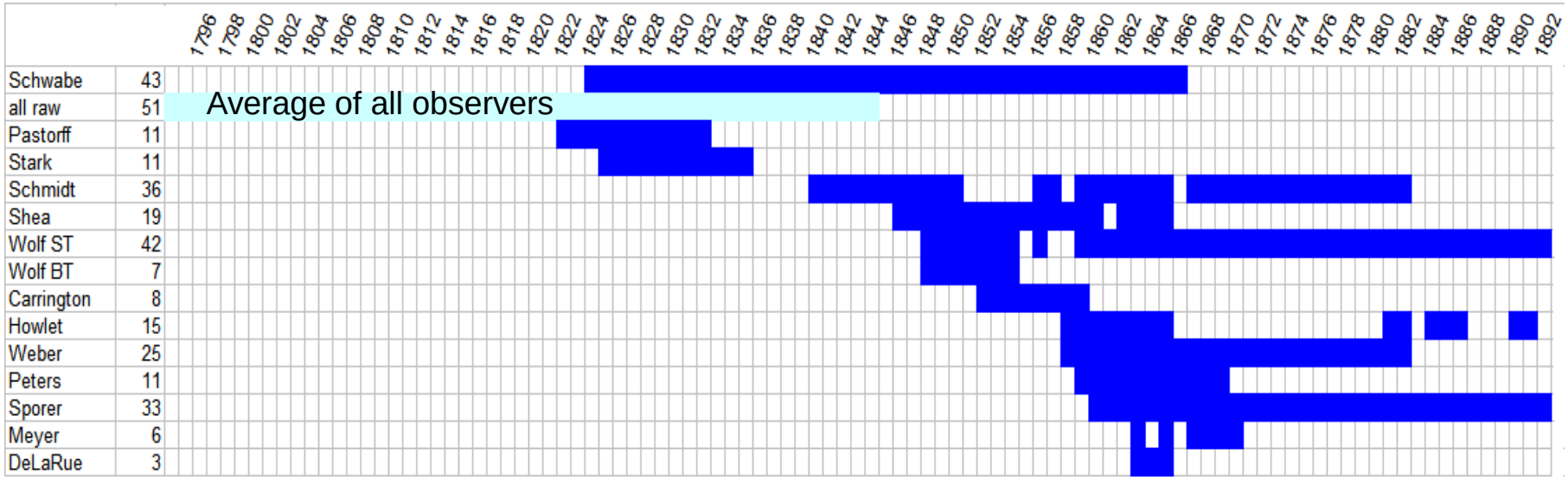


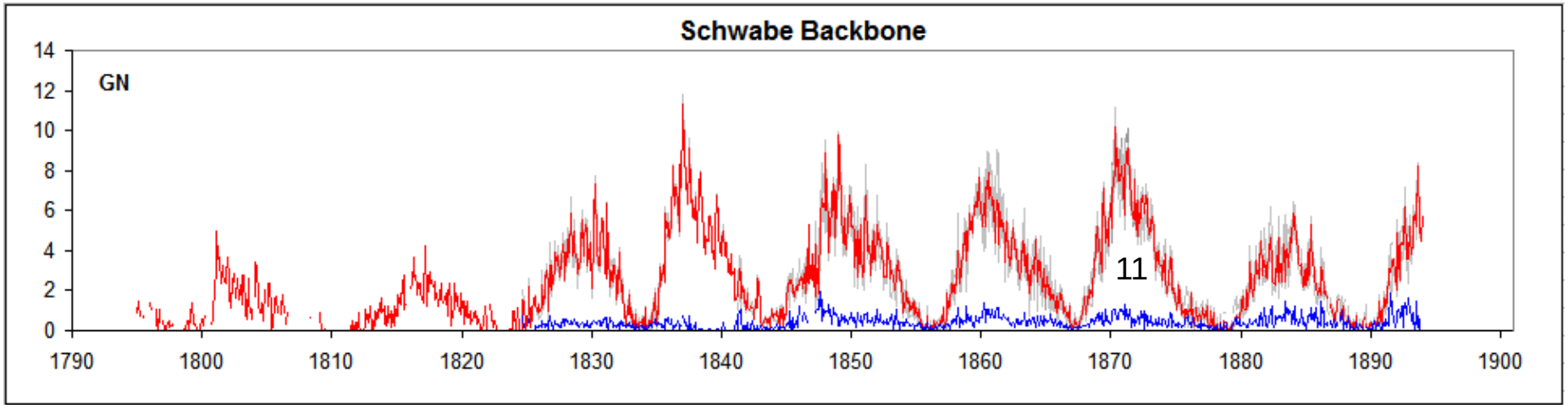
Observer #418 (MWO Central Disk) is, of course, omitted

As already remarked in S&S16 “It is remarkable that the average number of groups by all observers with no normalization at all closely matches the number of groups reported by H&S showing that their elaborate and obscure normalization procedures have almost no effect on the result.”

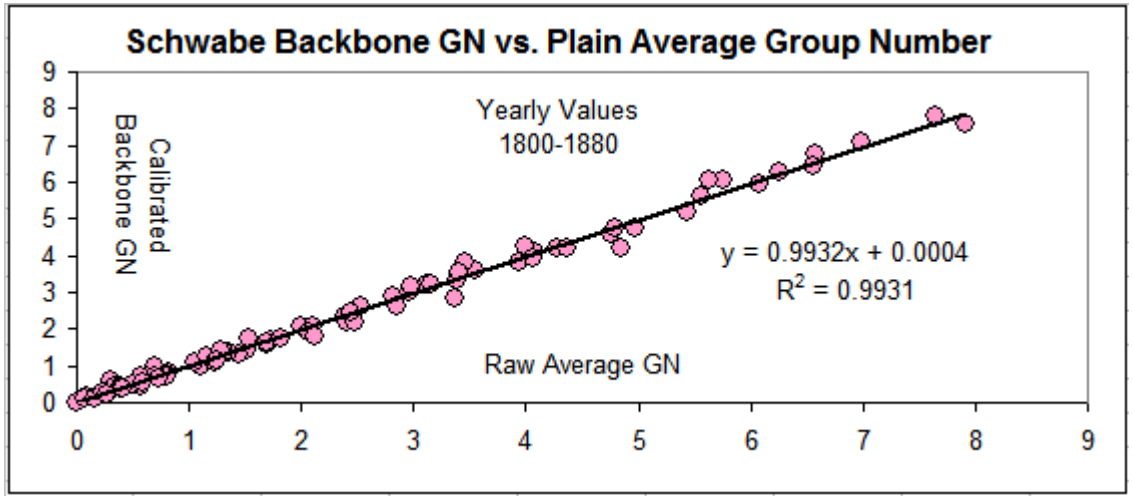
This is also true for our backbones, meaning that we could simply dispense with the normalization with its perceived potential problems.

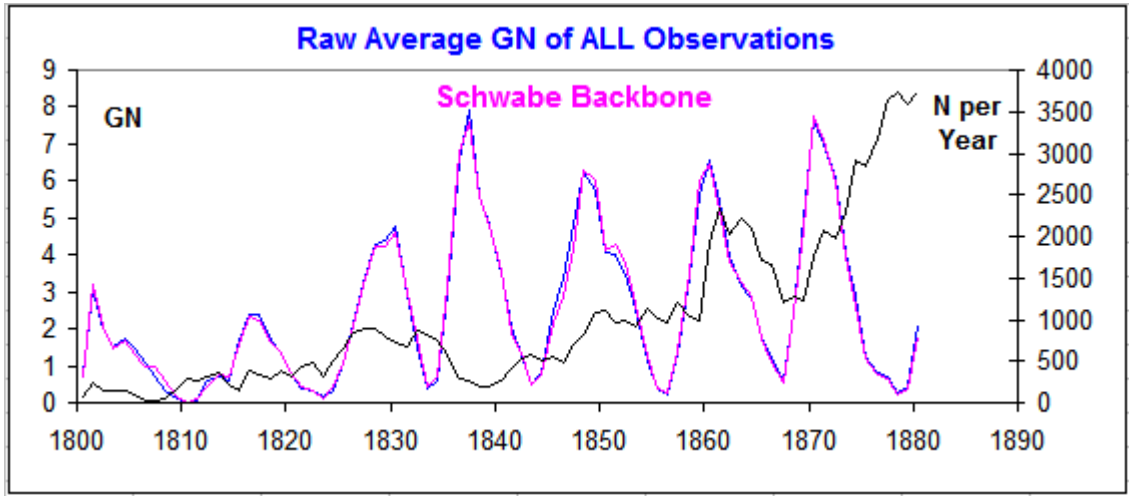
Schwabe Sunspot Group Number Backbone





The Simple Average of ALL Observers is as Good as Our Carefully Constructed Backbones





This holds also for the Schwabe Backbone. When the number of observations runs in the thousands, the statistical errors get very small.

So, it seems that we have a nice non-parametric, non-overlapping, non-k-value regression, no selection effect, no ranking, no pair-wise comparison, no ADF- or PDF-based, non-*whatever* method for constructing a backbone including estimating its time-varying error bars [from the spread of the observations]

```
class groups(min_obs):
    """ Extract data from Group database."""

    def get_data():
        """ Read the table of input values."""

        def sf(f, width=6, decs=2):
            """ Format floating point number."""
            if f == f:
                form = "{:."+str(decs)+"f}"
                return(form.format(f)).rjust(width)
            else:
                return("   NaN".center(width-1))

        def si(i, width=6):
            """ Format small integer number."""
            return(str(i).rjust(width))

        def print_avg(year, gsum, gnbr, pop):
            """ print yearly averages."""
            ysum = ynbr = 0
            for m in range(1,13):
                if gnbr[m] > min_obs:
                    ynbr += gnbr[m]; ysum += gsum[m]

            import statistics as st
            if ynbr:
                gavg = ysum / ynbr
                err = st.pstdev(pop)/ynbr**0.5
            else:
                gavg = err = float("NaN")

            print(year, si(ynbr), sf(gavg), sf(err))
```

Python Code to Process the Group Database

Sample Input:

2010	12	20	633	1	0
2010	12	20	639	1	0
2010	12	20	675	1	0
2010	12	20	685	1	2
2010	12	20	688	1	1
2010	12	20	693	1	0
2010	12	20	701	1	0
2010	12	20	708	1	0
2010	12	20	713	1	2
2010	12	21	505	1	1

Year	month	day	station#	Obs	Groups
0	1	2	3	4	5

José et al. maintain the current database [as a text file] with all observers' daily group count

The Code Tells Exactly What Was Done. Wish that All Analyses were so Explained

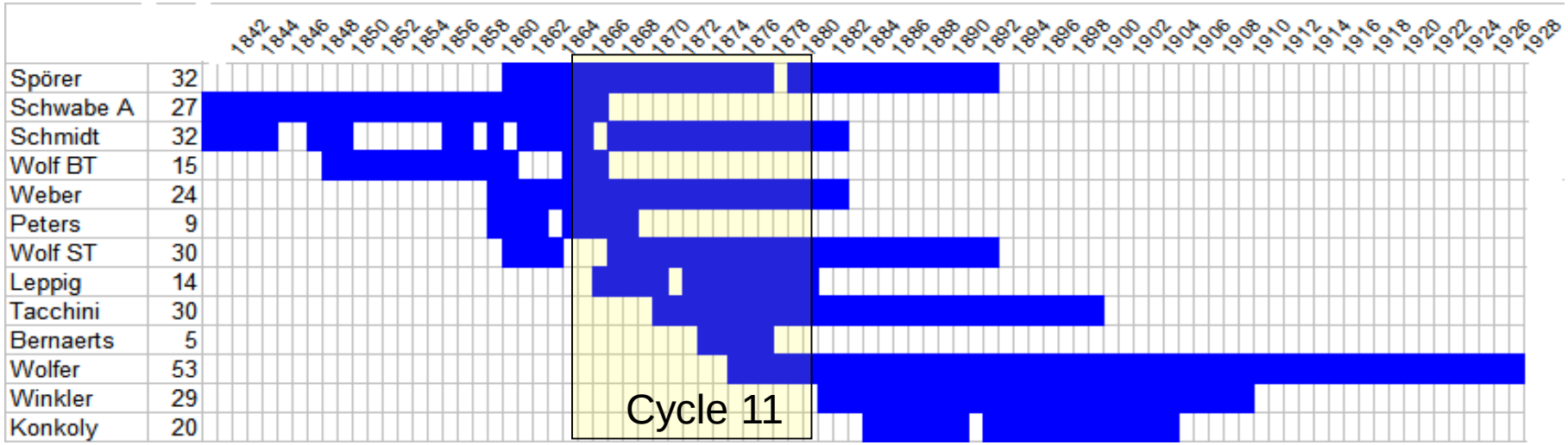
```
    PATH = "C:/gsn/"
    DB = PATH+"GN-D"+".TXT" # José Vaquero's daily database
    lyear = 0

    for line in open(DB, 'r'):
        words = line.split()
        if len(words):
            if words[0].isdigit():
                year = int(words[0])
                if year > lyear:
                    if lyear: print_avg(lyear, gs, gn, pop)
                    gn = [0]*13; gs = [0]*13; pop = []
                    lyear = year

                station = int(words[3])
                if station != 418: # Omit MWO Center of disk
                    month  = int(words[1])
                    groups = int(words[5])
                    if groups > -1:
                        gn[month] += 1
                        gs[month] += groups
                        pop.append(groups)

    print_avg(lyear, gs, gn, pop)

groups.get_data(5)
```

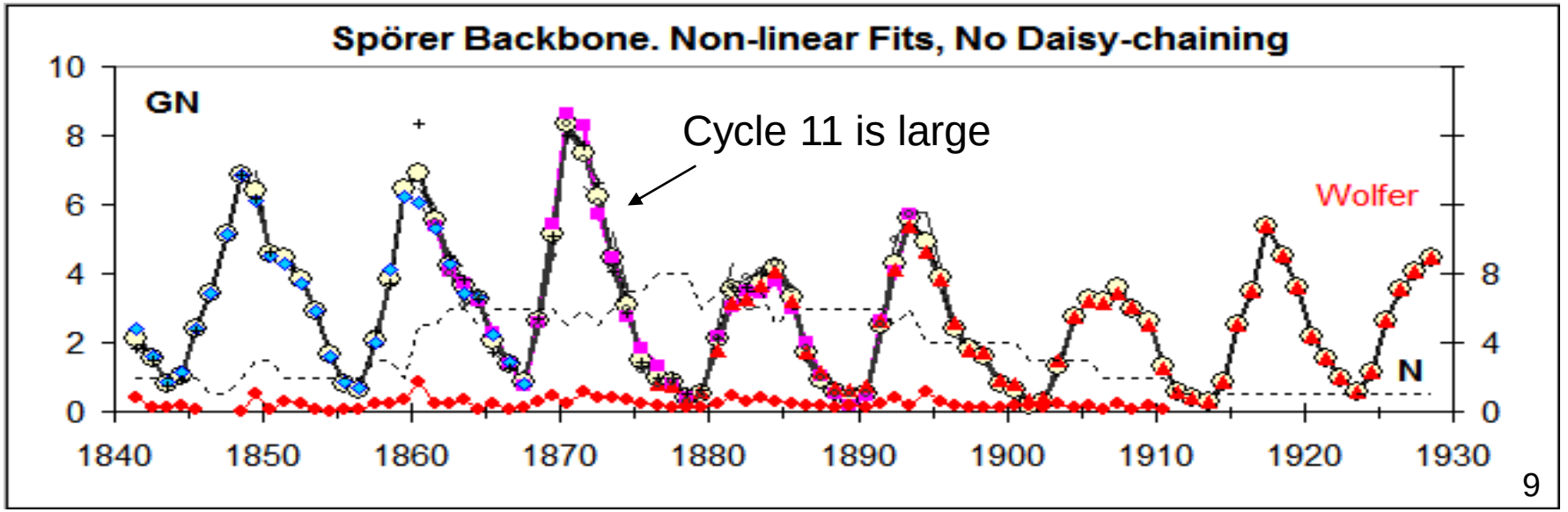
Sample Output:

1990	20309	9.52	0.03
1991	20181	9.86	0.02
1992	20789	6.61	0.02
1993	20886	3.89	0.01
1994	21665	2.42	0.01
1995	21638	1.39	0.01
1996	19501	0.62	0.01
1997	19419	1.54	0.01
1998	17590	4.68	0.02
1999	17834	6.48	0.02
2000	16154	8.66	0.03
2001	14334	8.83	0.03
2002	14358	8.56	0.02
2003	16701	5.30	0.02
2004	16227	3.44	0.01
2005	15714	2.52	0.01
2006	14500	1.49	0.01
2007	15814	0.74	0.01
2008	15136	0.28	0.00
2009	14193	0.32	0.00
2010	15141	1.61	0.01

Year N <GN> stderr

Spörer Backbone Around Cycle 11





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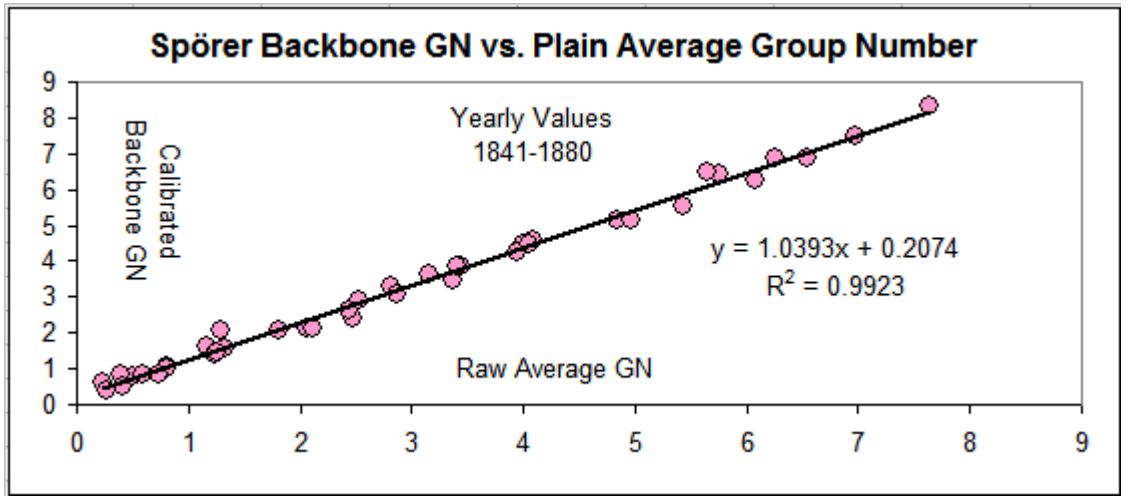
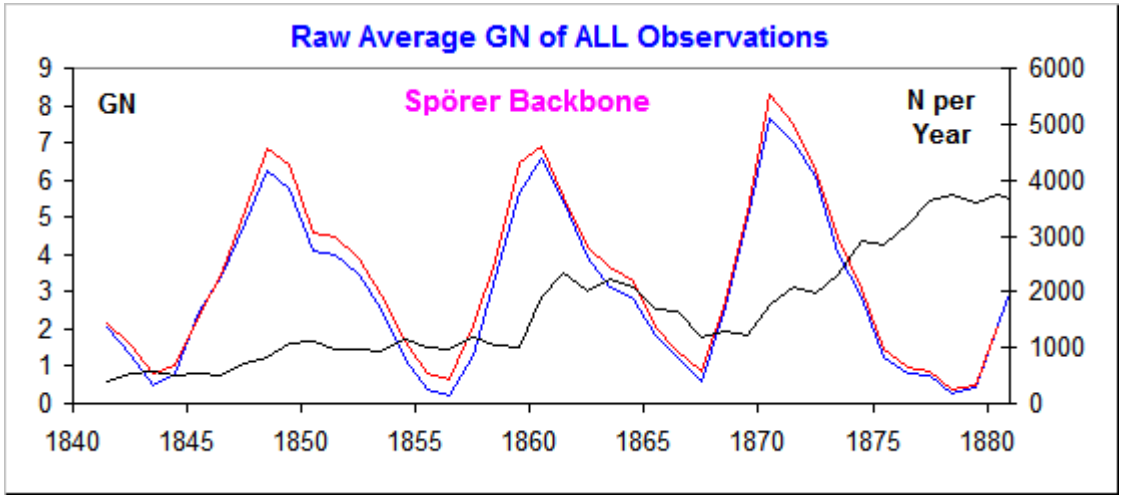
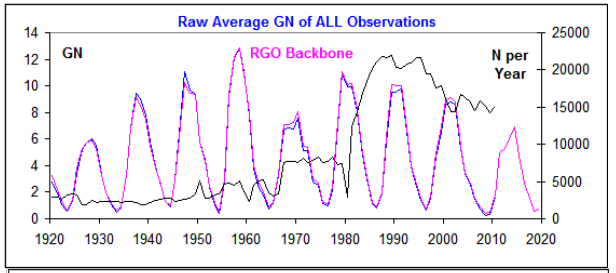
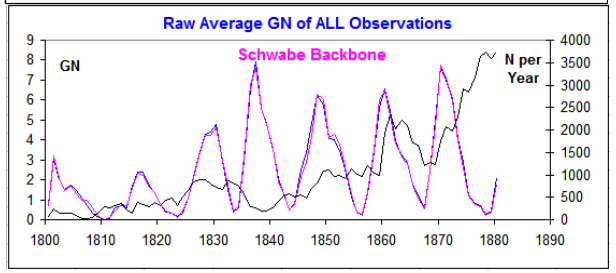




For the RGO and Schwabe Raw [ALL] averages we were lucky that the two 'observers' [RGO and Schw.] evidently were [seeing and] reporting group numbers close to the typical [and hence average] observers of their time:





But it doesn't have to be so for all our backbone observers. Spörer is an example, seeing slightly more [reddish curve] than the average observer[10]

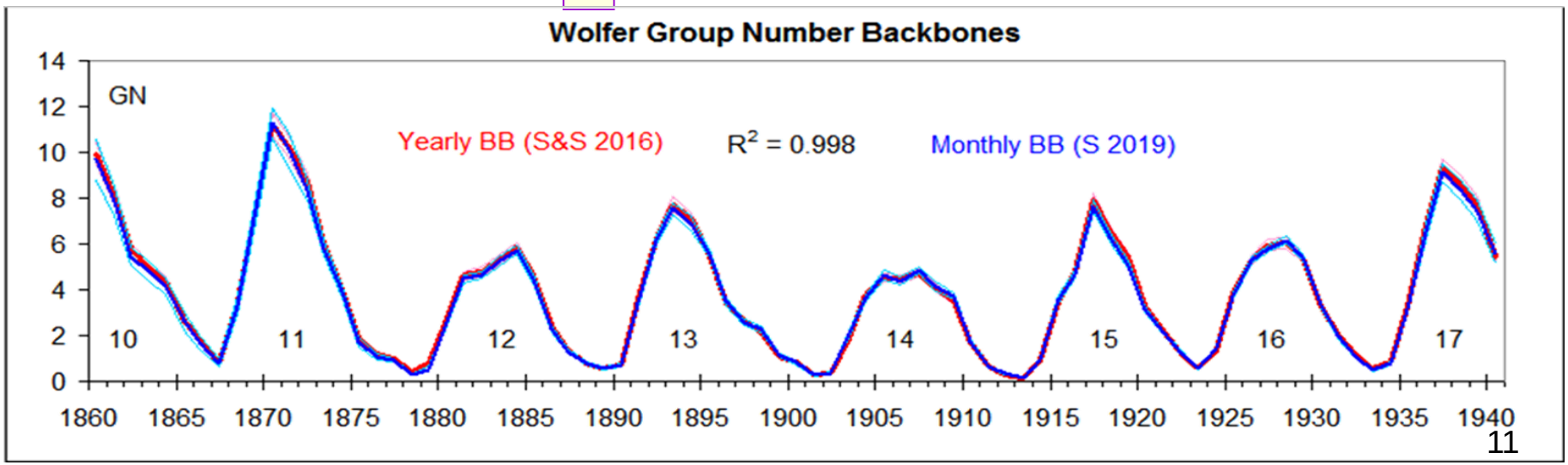
New Wolfer Backbone (Monthly)

Observer	Months
Wolfer	62
Schmidt	246
Wolf.ST	426
Weber	280
Spörer	388
Dawson	135
Leppig	131
Tacchini	350
Moncalieri	213
M.W.Review	115
Ricco	143
Winkler	340
Konkoly	247
ETH	582
Quimby	390
Hadden	311
Catania	311
Broger	470
Woinoff	184
Guillaume	284
Batavia	191
Moye	180
Buttlar	90
RGO	372
Stonyhurst	180
MWO.FD	216
Brunner	175

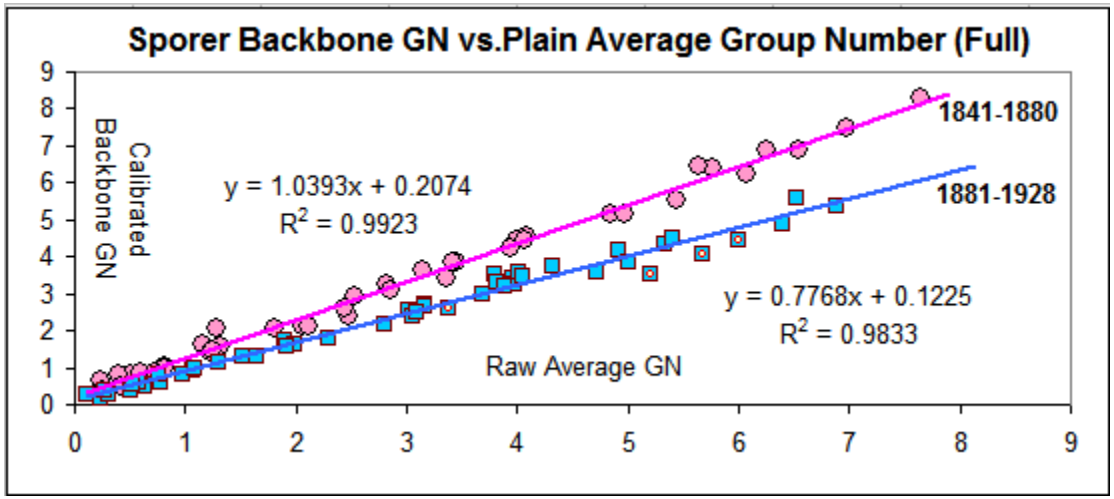
1860 1874 1928 1940

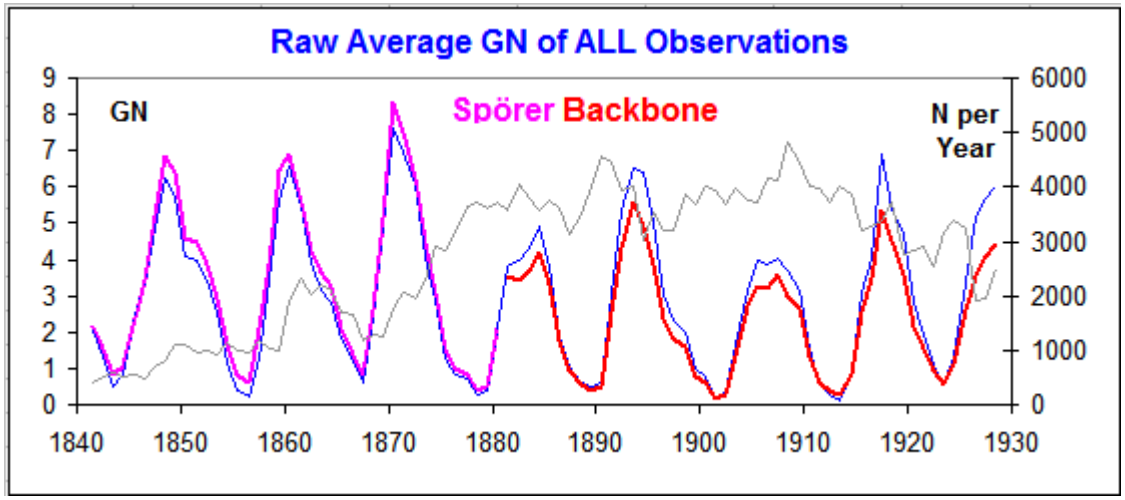
Disagreements

Agreements



Full Spörer Backbone 1841-1928



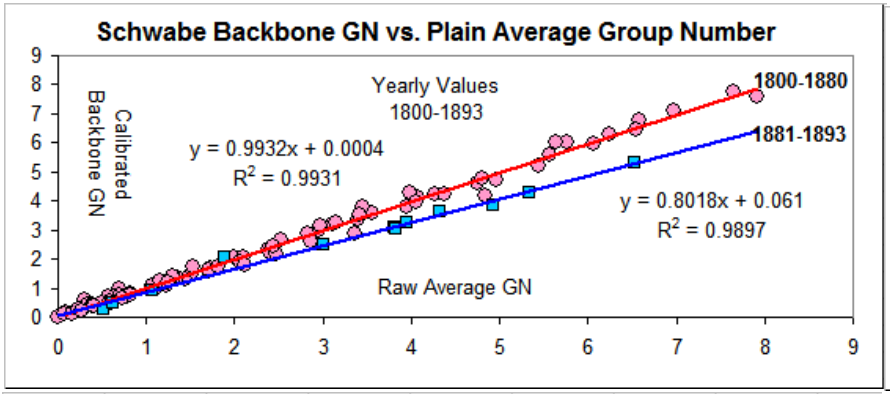


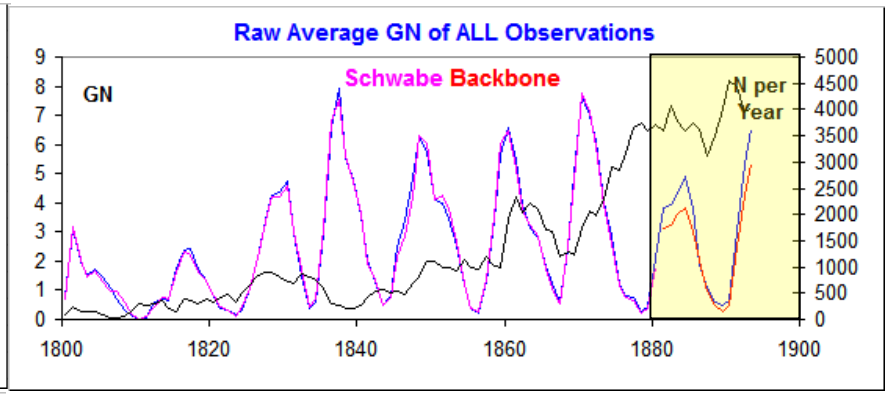
The difference between Spörer and the overall average seems to increase with time after 1880.

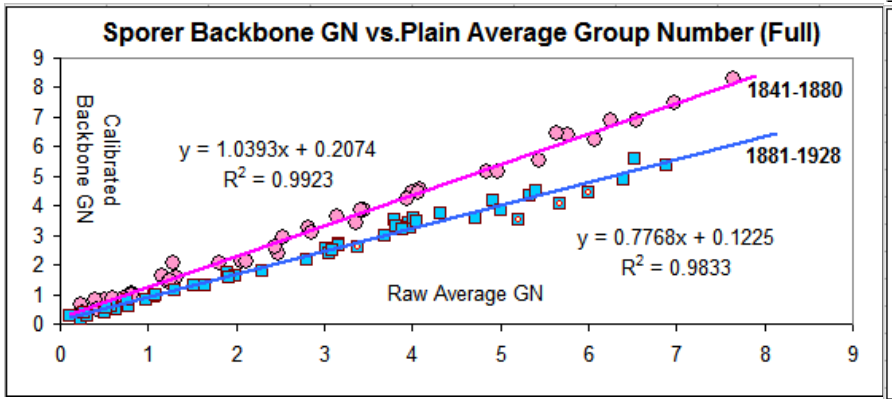
Before 1881, Spörer's group count was 4% larger than average, but abruptly that changed by 1881 so that Spörer's count became increasingly smaller than average as time went on.

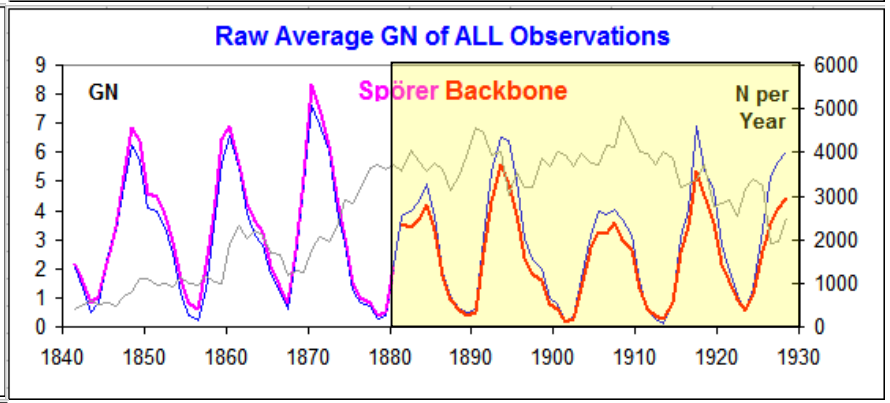
The simplest explanation would be that Spörer changed his telescope and/or his way of counting groups. On the other hand, other backbones show the same discontinuity around 1881, suggestive of the (at first sight unlikely) possibility that observers at large after 1880 were using better telescopes and/or had developed a better understanding of what is a group.

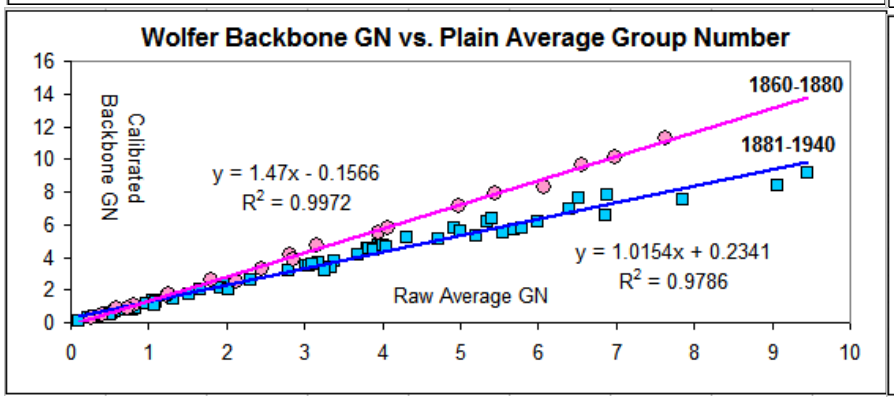
The 1881 Discontinuity

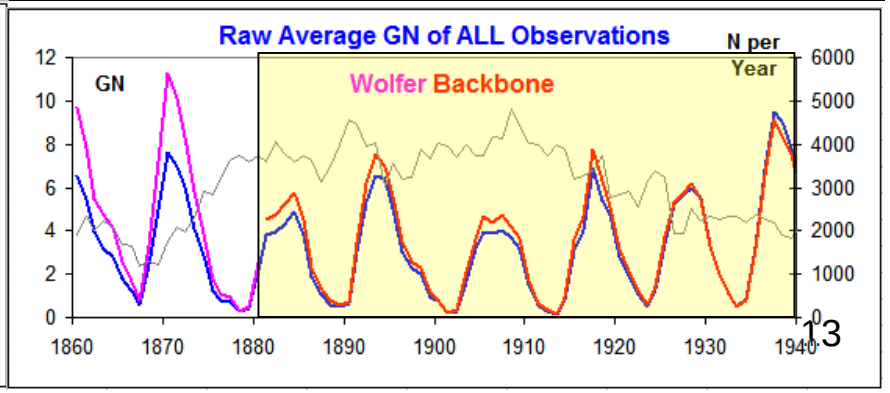




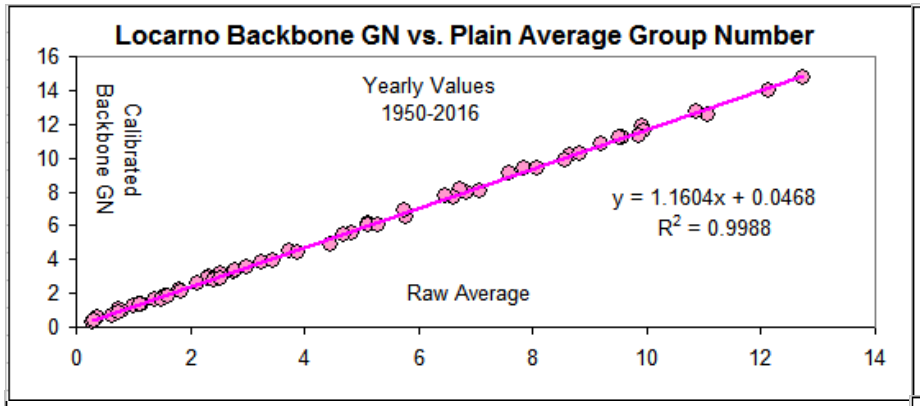


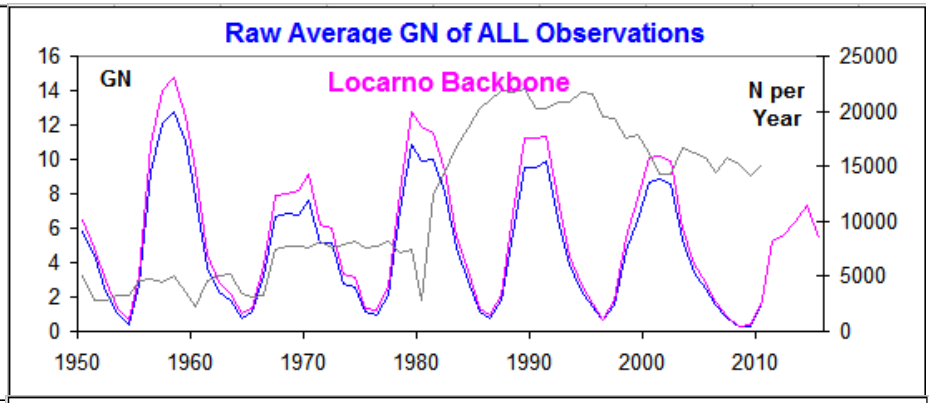


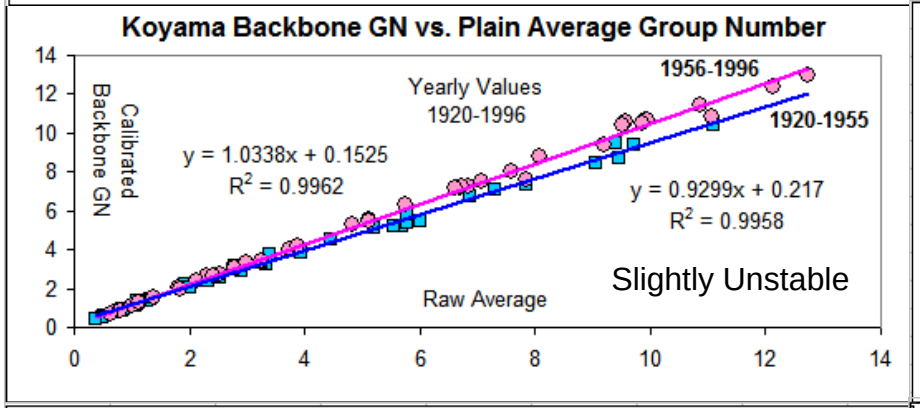


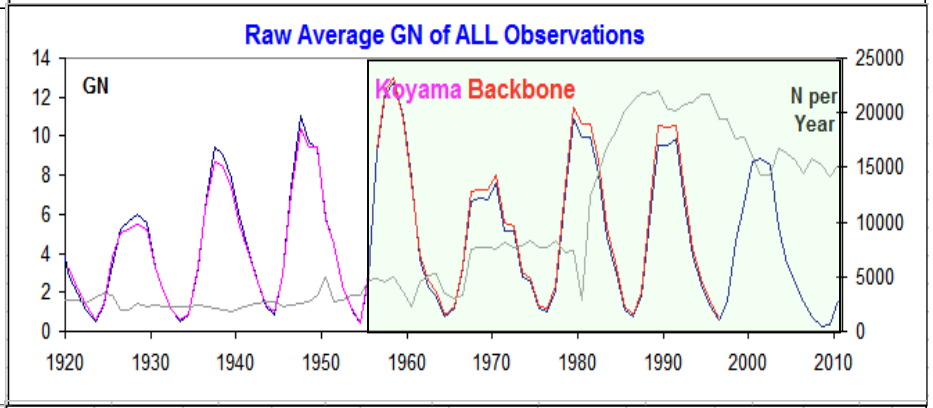


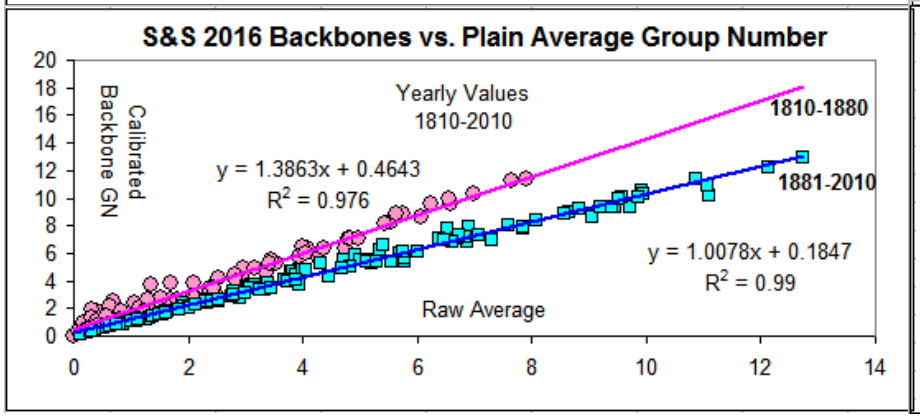
More Backbones vs. Raw Averages

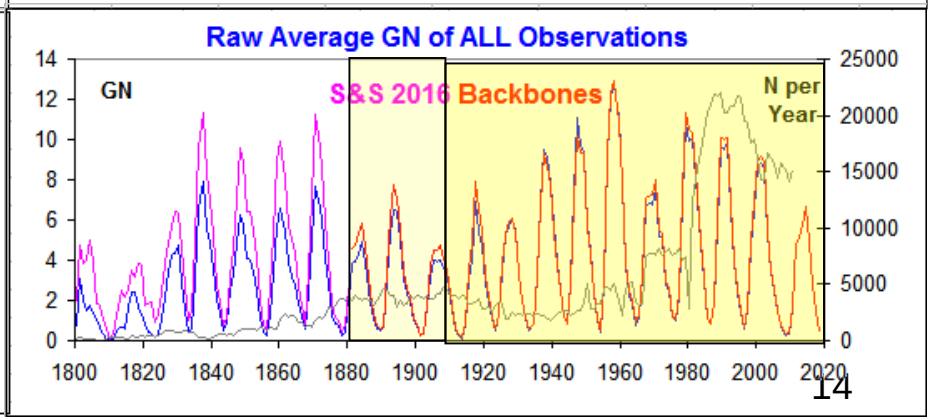




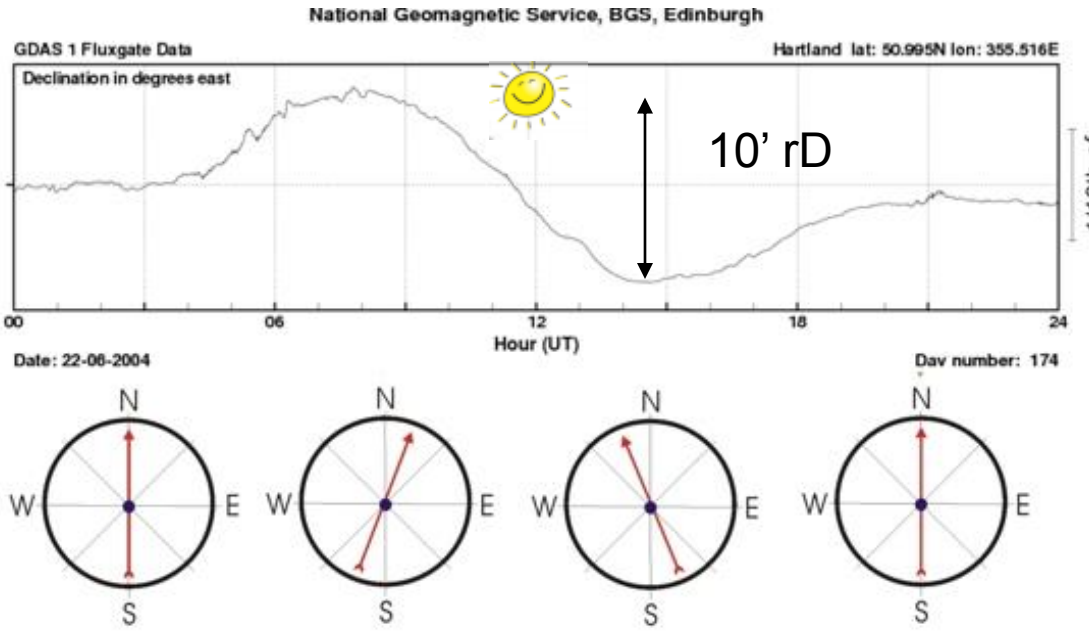






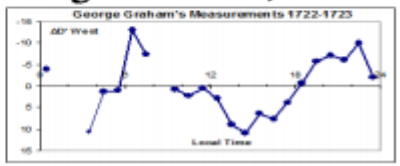


The Diurnal Variation of the Direction of the Magnetic Needle

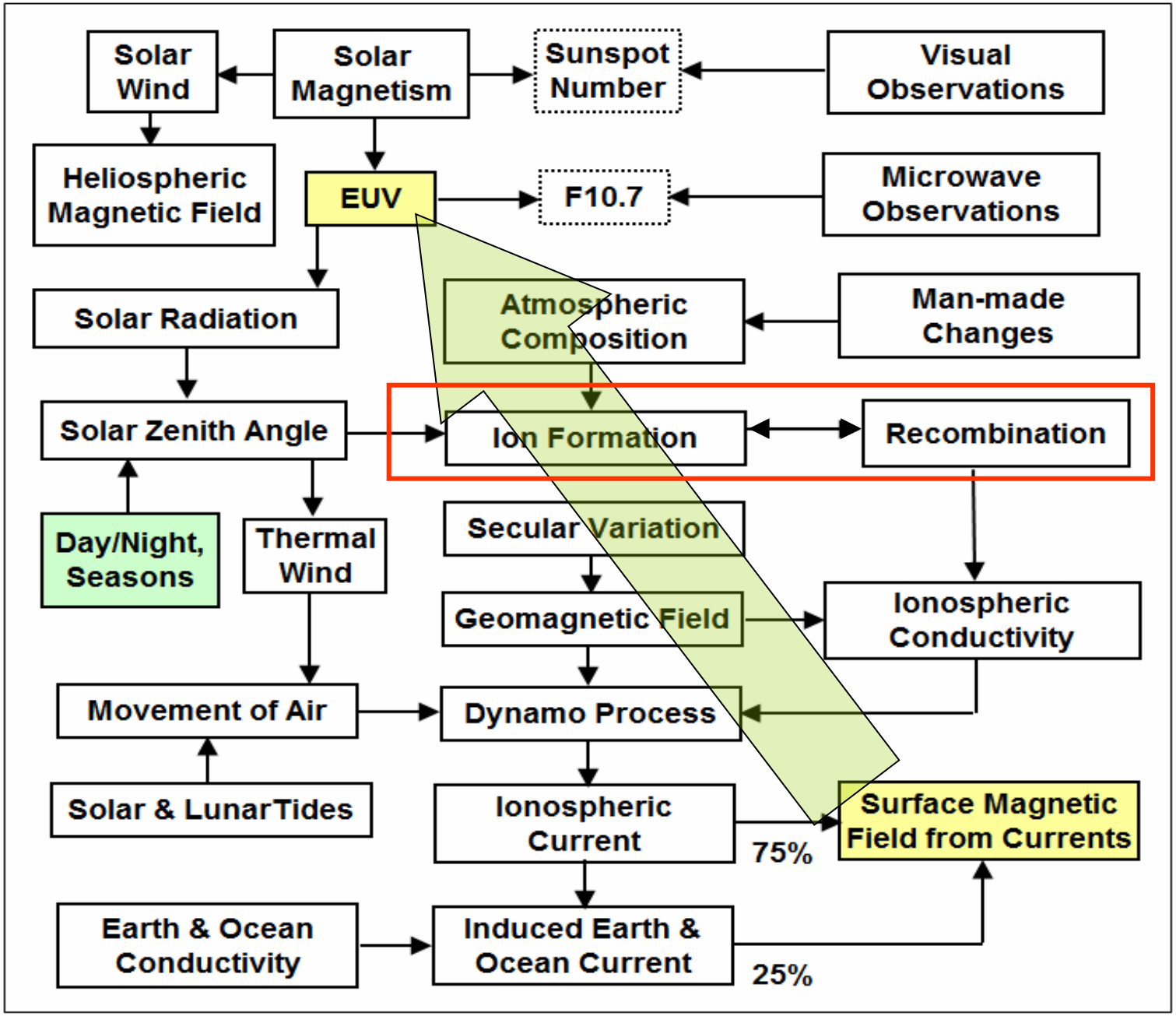


IV. *An Account of Observations made of the Variation of the Horizontal Needle at* London, *in the latter Part of the Year* 1722, *and beginning of* 1723. *By Mr.* George Graham, *Watch-maker, F. R. S.*

Made ~1000 observations



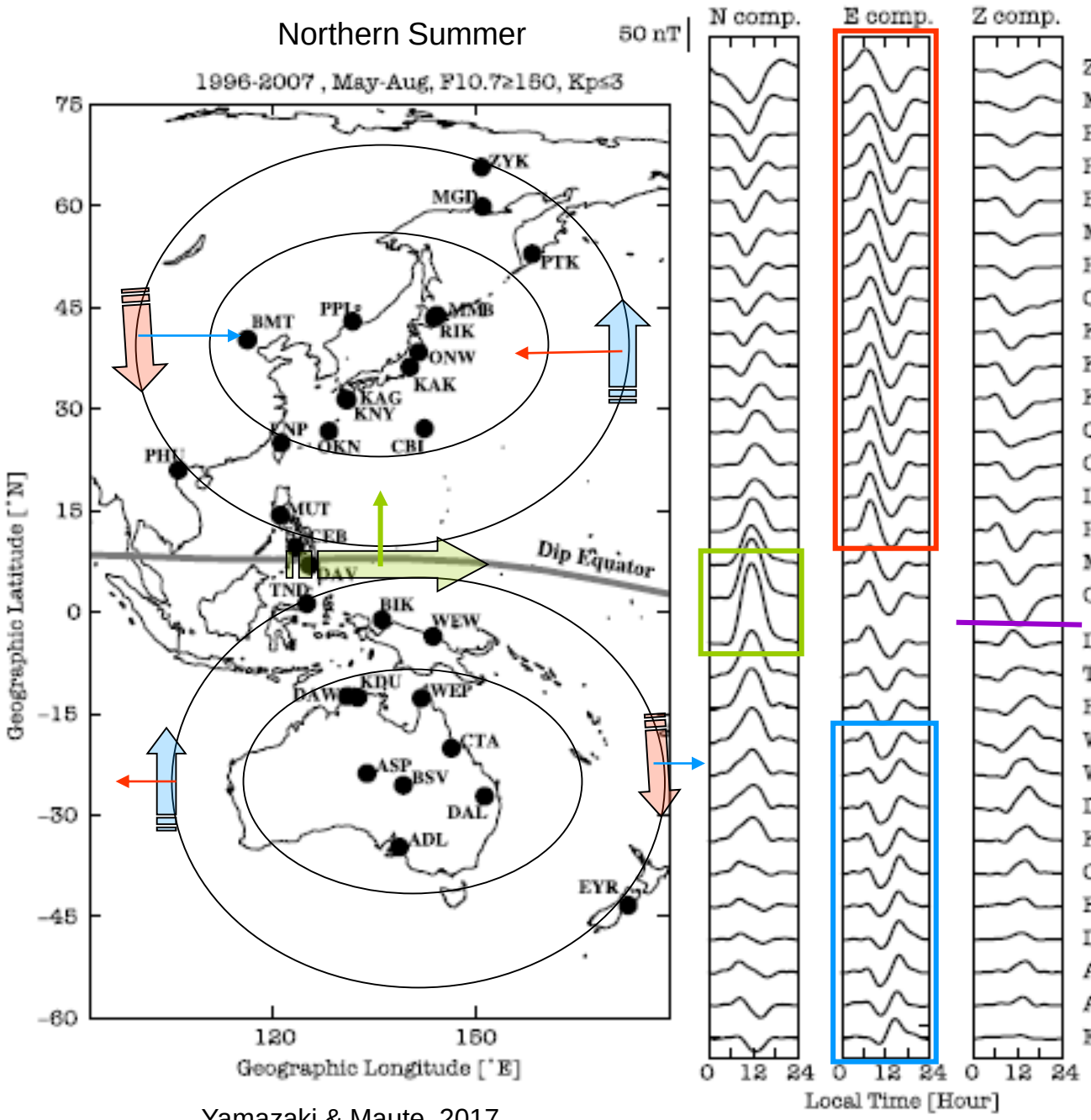
George Graham [London] discovered [1722] that the geomagnetic field varied during the day in a regular manner.



Determining EUV Flux from the magnetic effect of dynamo currents in the E-region of the ionosphere

The physics of the boxes is generally well-known

We can determine the EUV from the magnetic effects

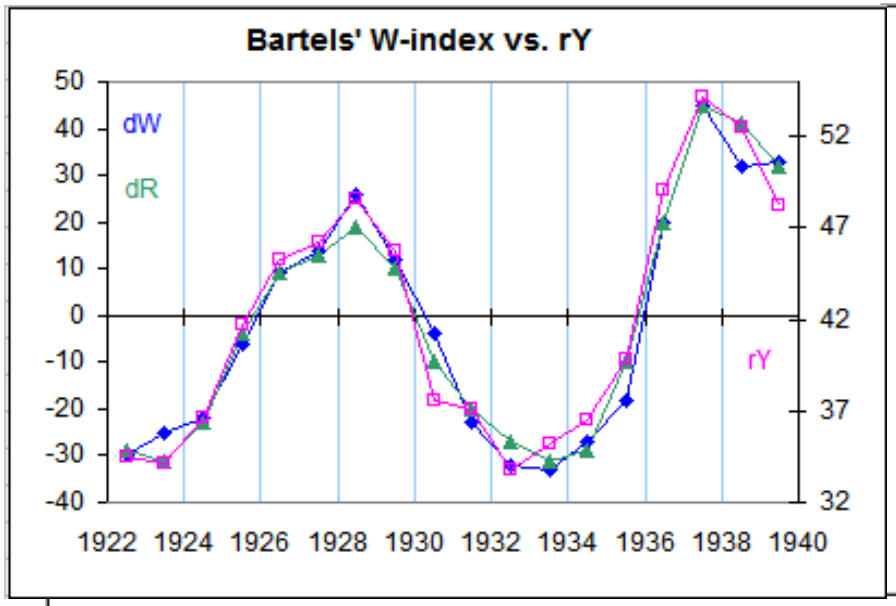


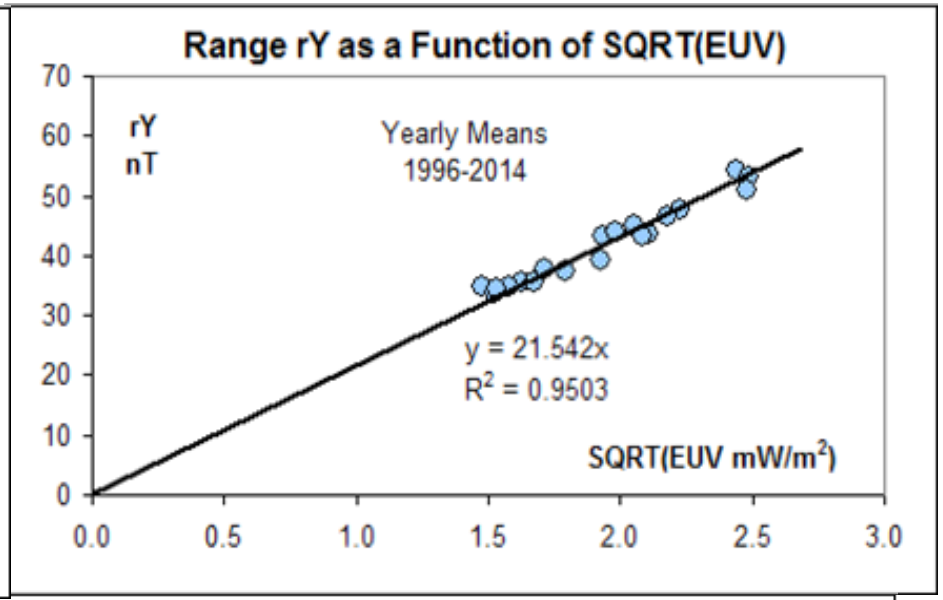
Yamazaki & Maute, 2017

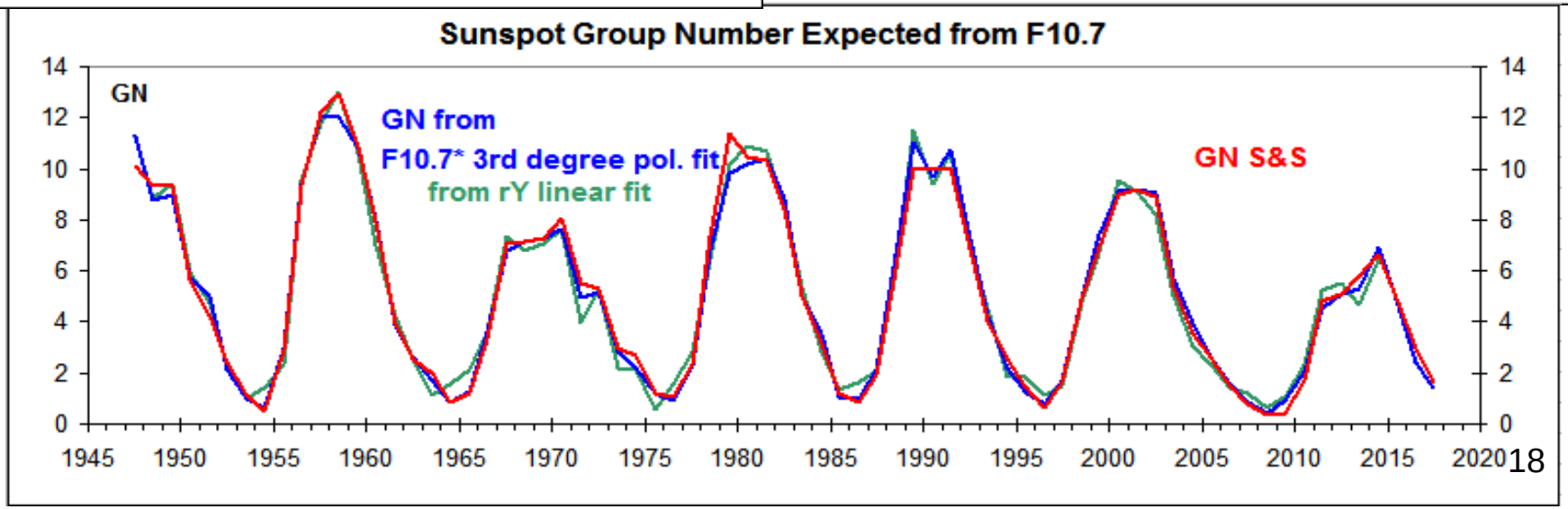
Diurnal Variation of Geomagnetic Field

Already Julius Bartels (1946) emphasized the importance of the diurnal variation: "The correlations between R and his W (wave-radiation)… are the **closest found so far** between solar and terrestrial phenomena"

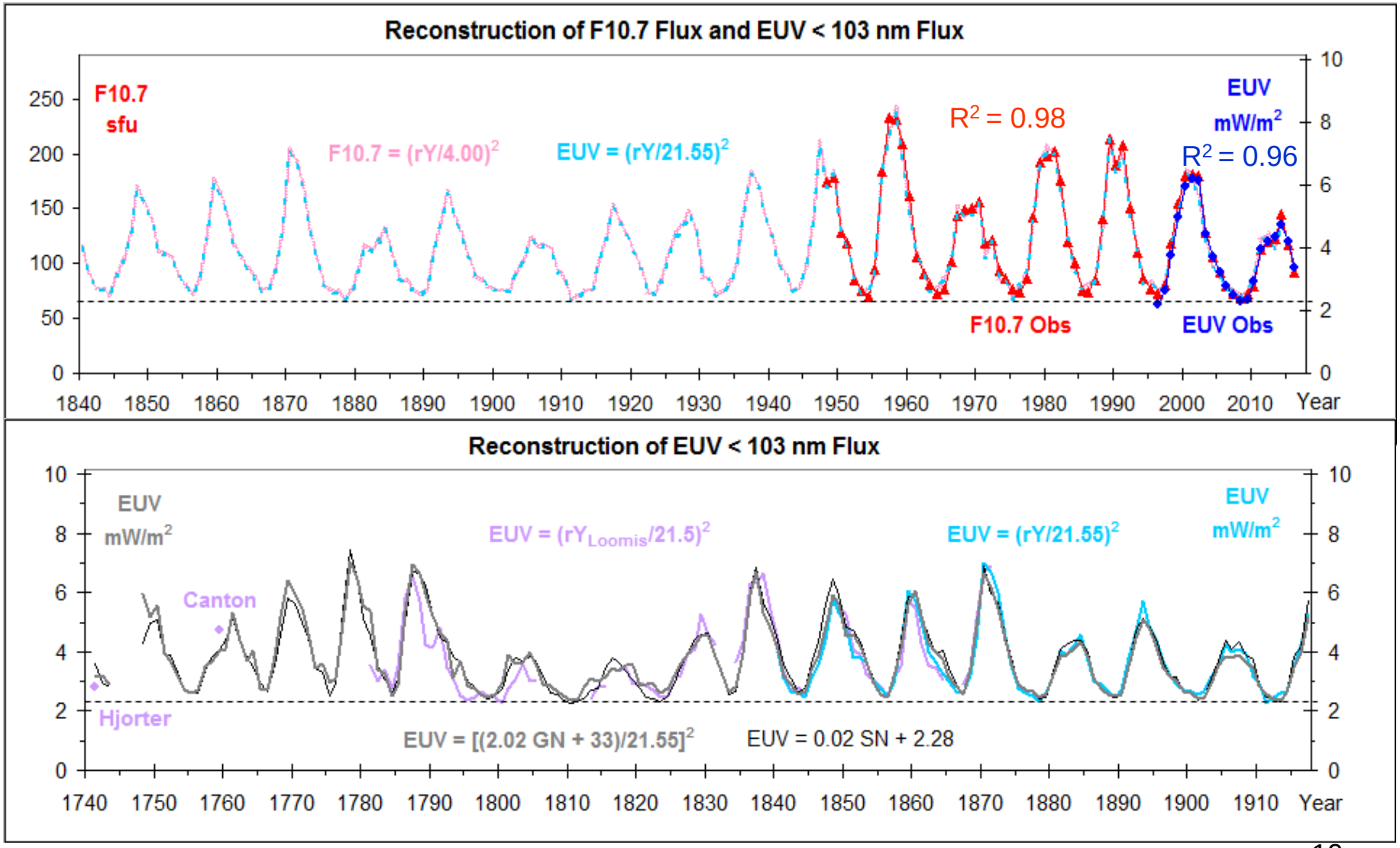
W-index, Rz, rY and GN Correlations



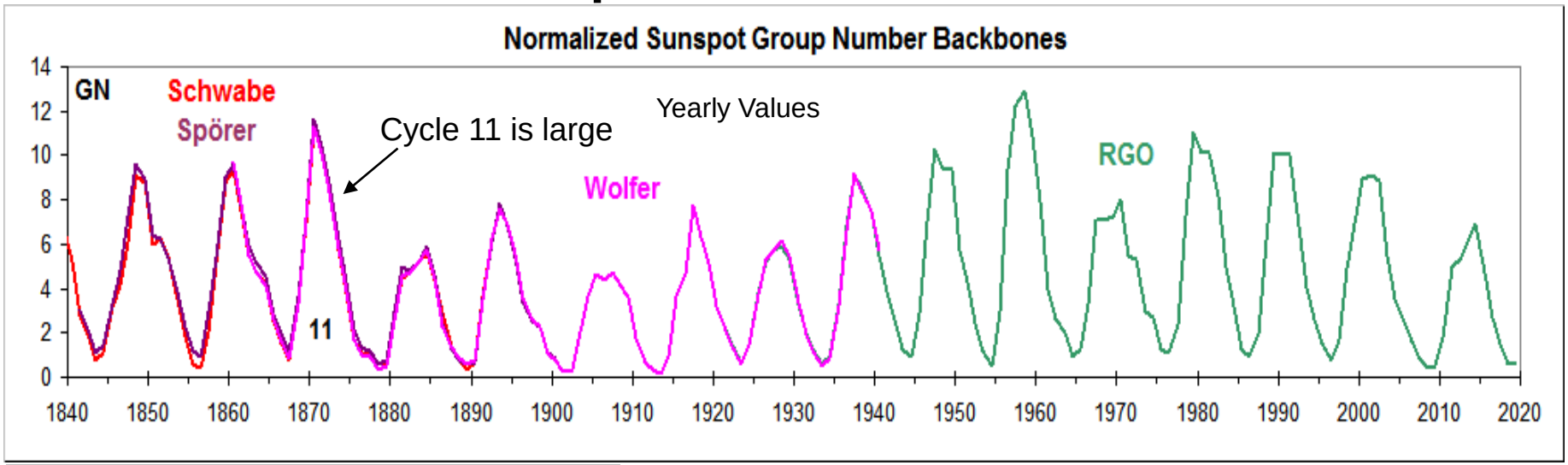


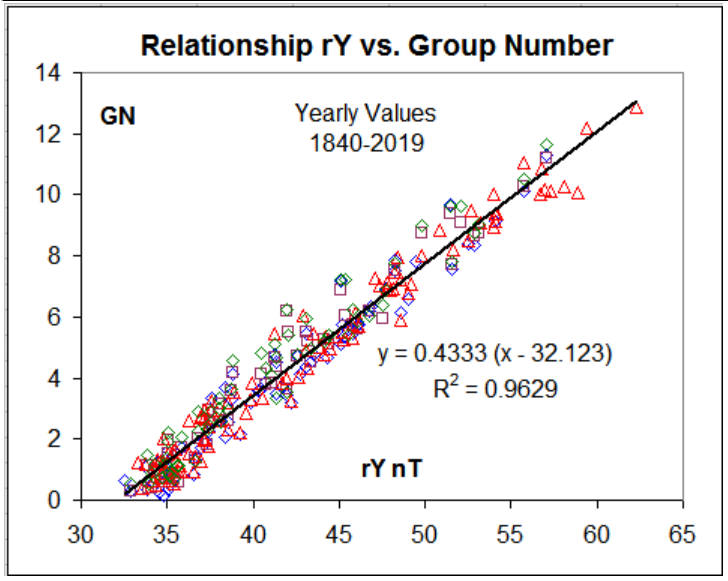


Reconstructions of EUV and F10.7



Composite Normalized Sunspot Group Number Series





The Schwabe, Spörer, and RGO backbones overlap with the anchor Wolfer Backbone and can thus be scaled to that reference Backbone. The scaling is found to be linear to high accuracy. The new composite is statistically indistinguishable from the published S&S 2016 composite

The four individual new backbones each have the same relationship with the geomagnetic diurnal range variation [at left with different colors]

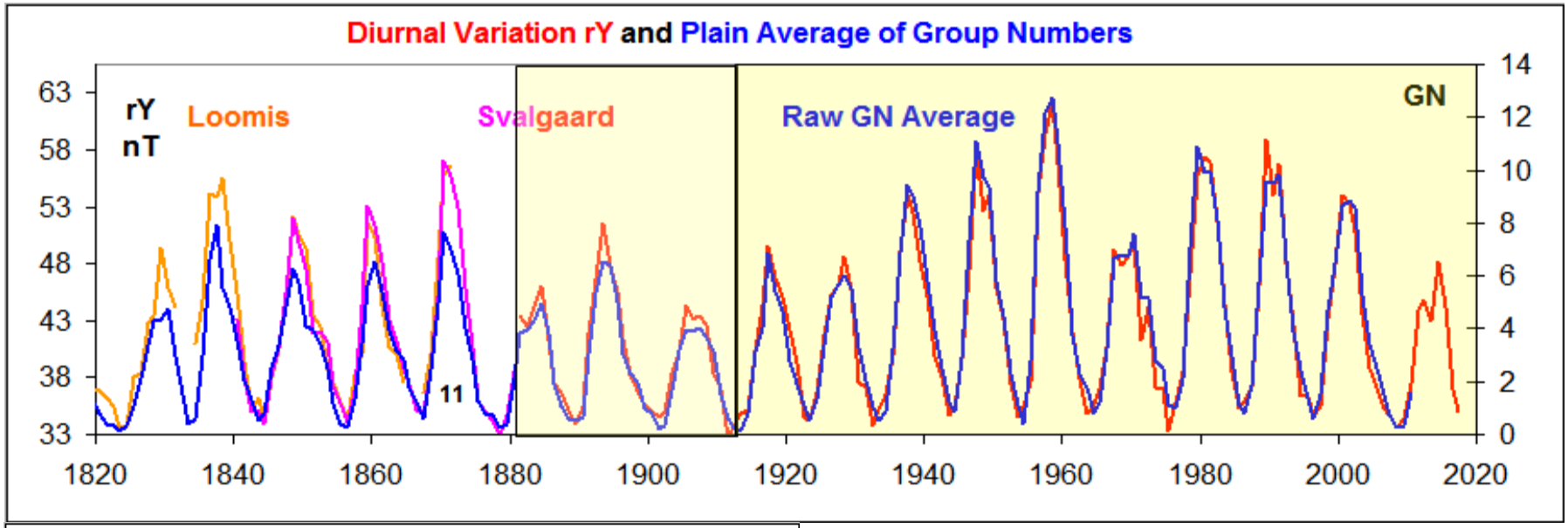
Choose the Lesser Miracle

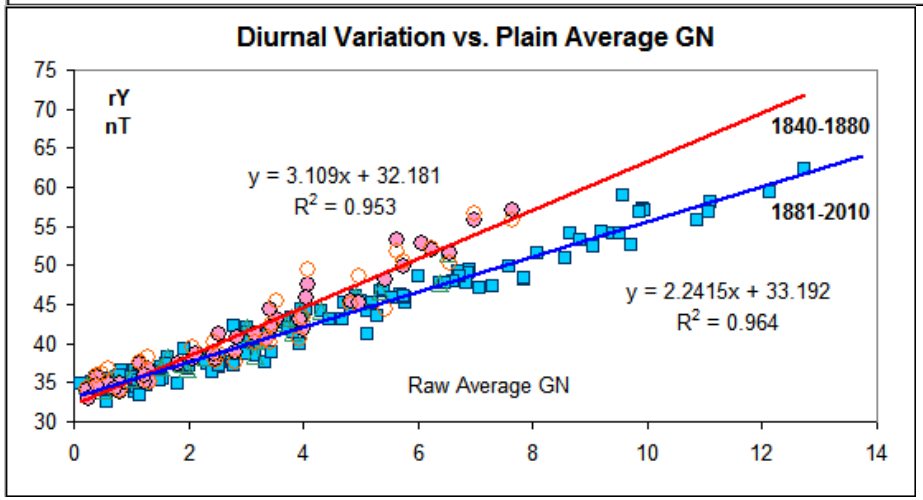
Any researcher [*nn*] who claims he has a method to dowse or divinate solar activity can express his result as a time series of Group Numbers (GN[*nn*]), or equivalently of Sunspot numbers (SN[*nn*]), with yearly resolution. GN derived from the diurnal variation (GN[*rY*]) as shown on the previous slide are the values we would expect, assuming that the terrestrial response has not undergone a dramatic [~40%] change in 1881. So we must expect GN[*nn*] ≈ GN[*rY*] within their respective error bars. If it is not, we have two possibilities:

A: Researcher *nn* is mistaken and his method does not work as claimed, or
B: The response of the terrestrial upper atmosphere to solar activity changed dramatically in 1881 (this would be an unexpected, new solar-terrestrial effect)

David Hume (in Section X of *Enquiry Concerning Human Understanding* [1748]) argued that a rational person should never believe that a miracle (he is using the word 'miracle' in the everyday sense, meaning something that is merely out of the ordinary) had actually taken place unless it would be a greater miracle that the person reporting the miracle (i.e. that GN[*nn*] is not ≈ GN[*rY*]) is simply mistaken. We should always believe whatever would be the *lesser miracle*, which in our case would be choice A.

The Diurnal Variation Shows the 1881 Discontinuity Very Clearly

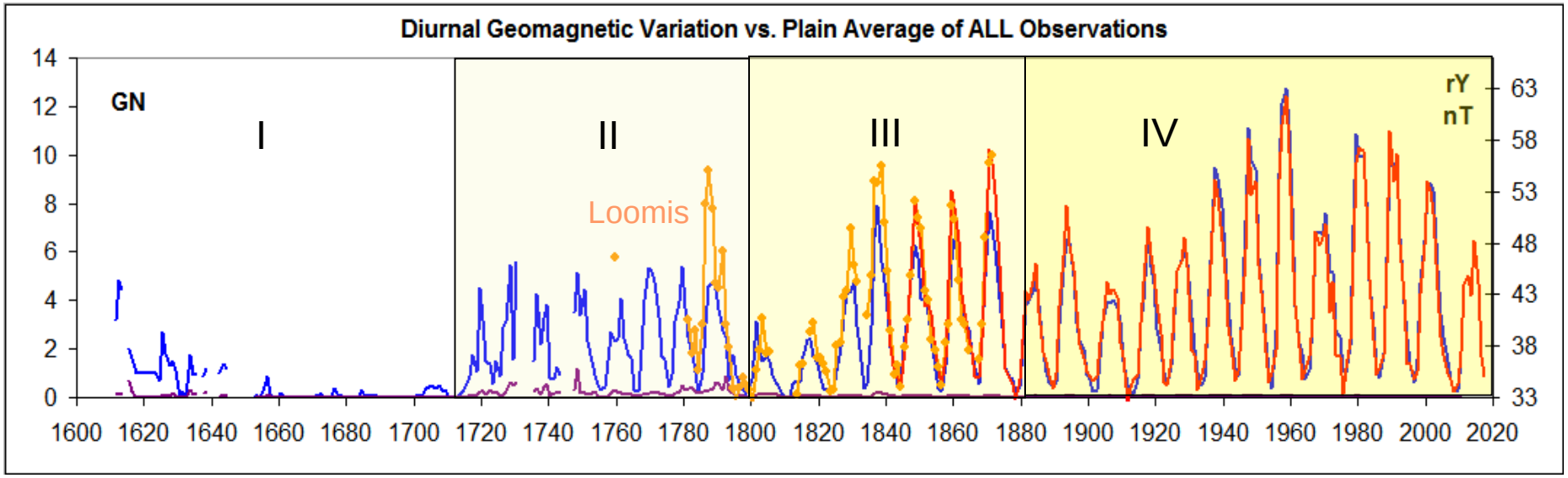




We see the same two populations: one before 1881 and one after ~1910 with a transitional period 1881-1910. This means that one cannot assume the statistical properties of the latter population to hold about the former.

The ratio between slopes is 1.39

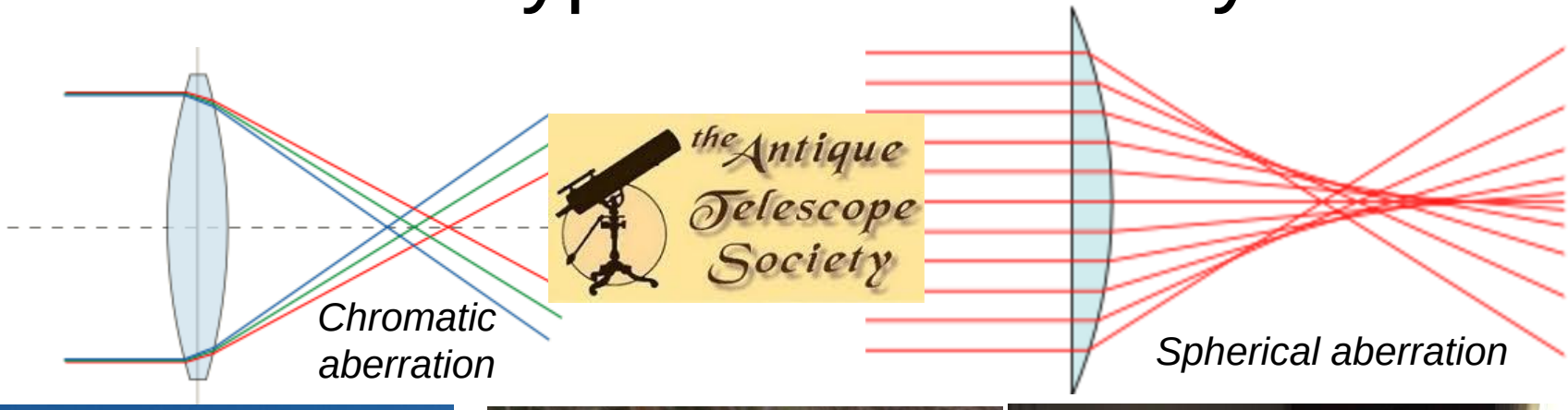
Four Speculative Populations of GNs

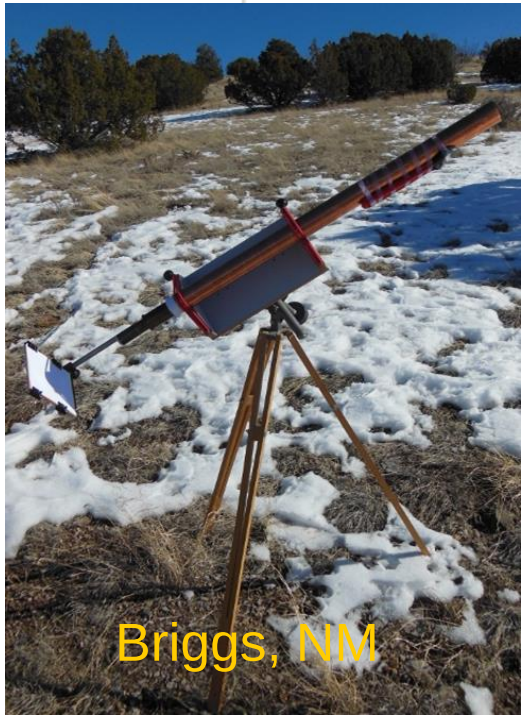


The different populations are the result both of evolving technology, e.g achromatic lenses, and of improved understanding of the definition of a group (blue curve). The diurnal variation (reddish curves) of the East component of the geomagnetic field relies primarily on measurements of an angle [the Declination] and as such does not require calibration and thus does not evolve with time. We speculatively identify four populations as shown above.

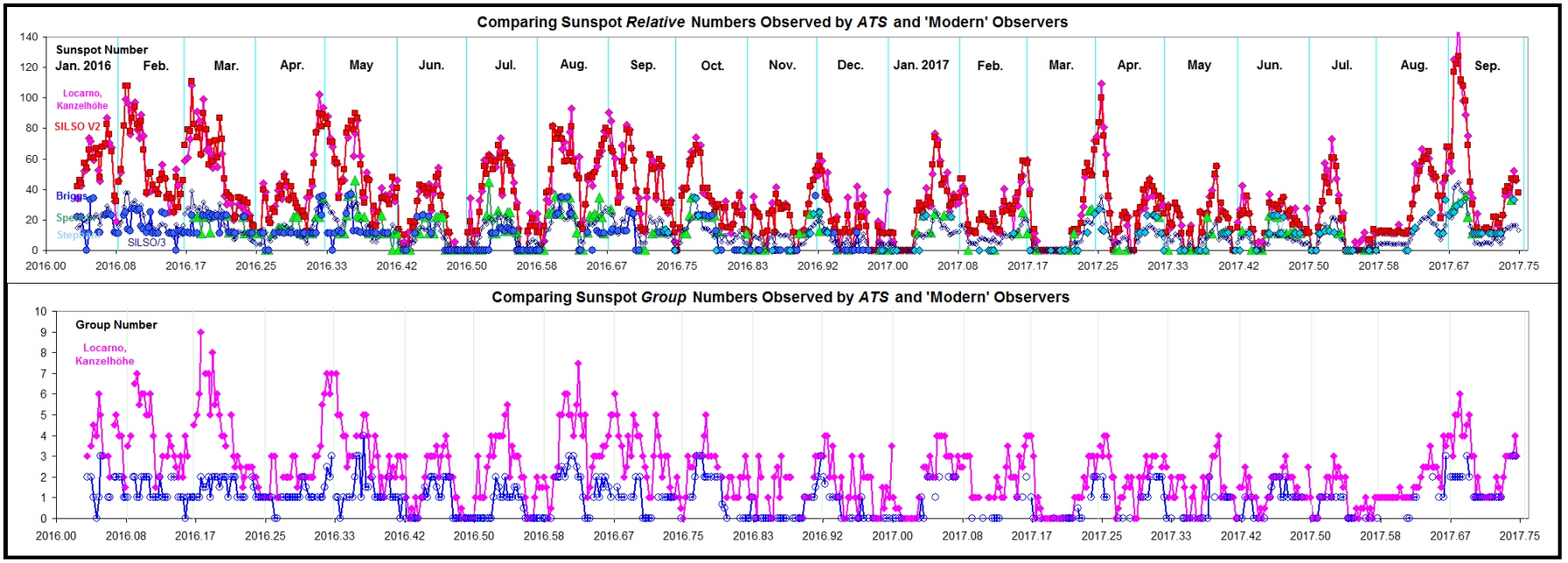
Because of the evolving populations, the backbones themselves [no matter how constructed] must be normalized to a common standard [Wolfer's].

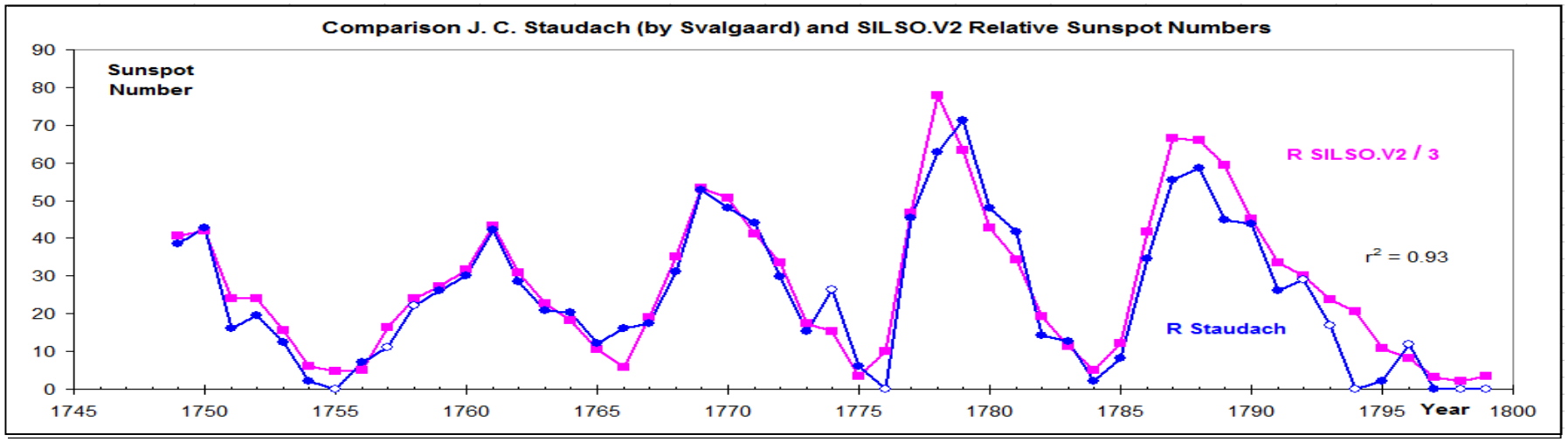
Construct Telescopes with the Same Flaws as Typical 18th Century Ones



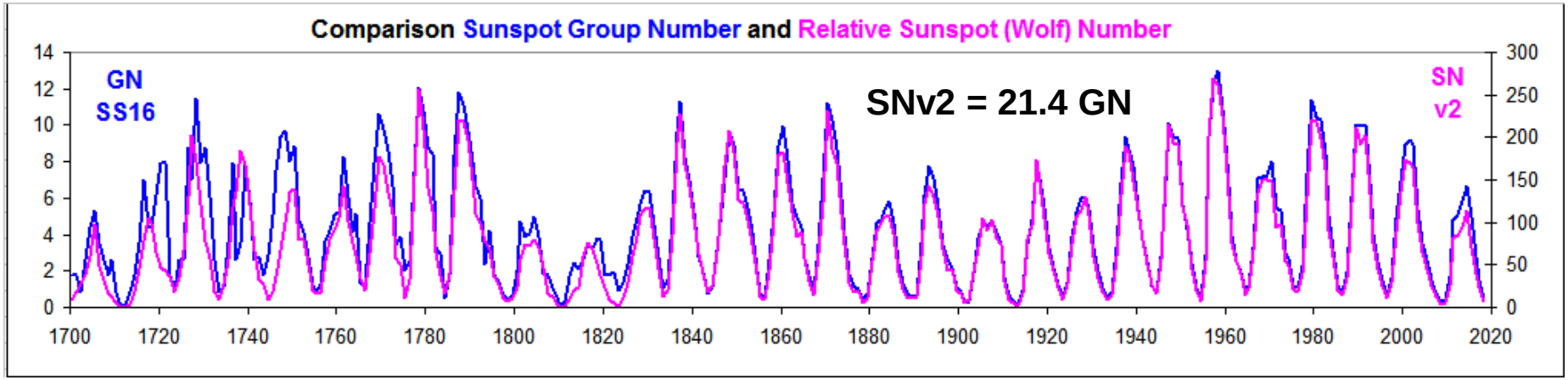


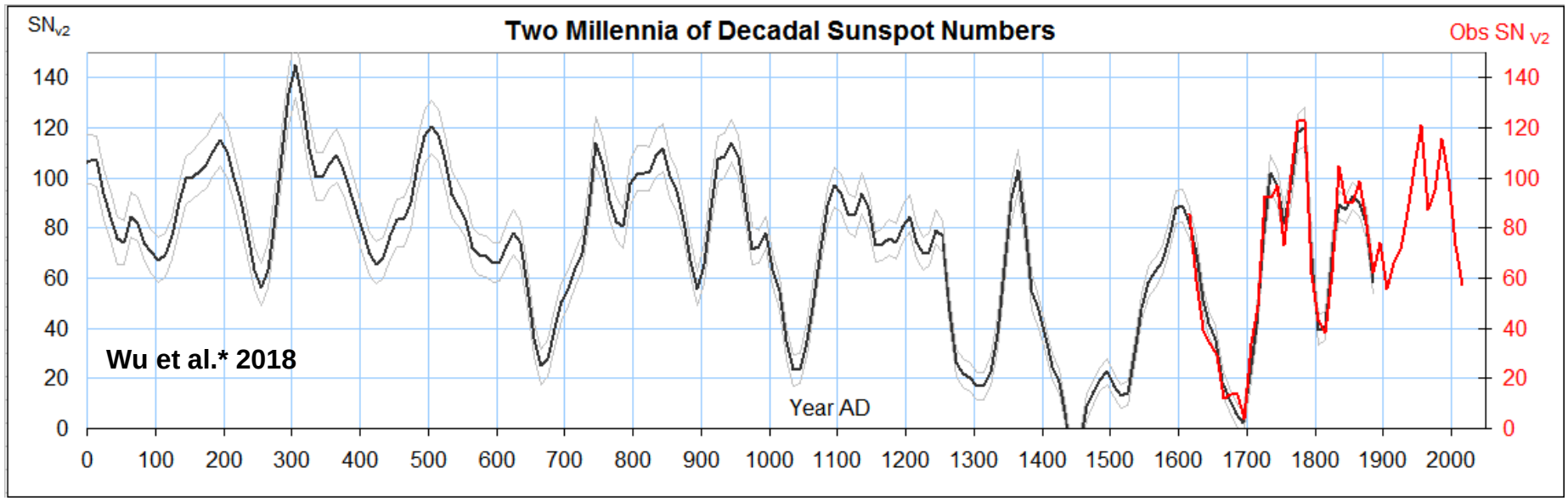
Modern Observers See Three Times as Many Spots as The Old Telescopes Show





Brewing Consensus: GN vs. SNv2





It is clear the series before, say, 1750 needs more work

Conclusions

- There are [at least] ***two*** different 'populations' of sunspot group counts by observers over time. One cannot blindly assume the statistical properties of one population to hold about the other. Speculatively we identify four populations the last 400 years.
- One major population belongs to years before 1881 followed by another major one after ~1915, separated by a transitional period between 1881 and ~1915. The major populations differ by ~40%. The difference is poorly understood, but may be due to evolving telescope technology and/or increasing understanding of what constitutes a group.
- The average number of groups over a year by **all** observers with no normalization at all closely matches (i.e. are proportional to) the yearly numbers of groups in backbones constructed within each population showing that elaborate normalization procedures have almost no effect on the result. This means that we can dispense with the normalization altogether; although adjacent, overlapping backbone segments still have to be stitched together by par-wise comparison.
- So, it seems that we have a nice non-parametric, non-overlapping, non-k-value-regression, no selection effect, no ranking, no pair-wise comparison, no ADF- or PDF-based, non-*whatever* method for constructing a backbone segment including estimating its time-varying error bars [from the spread of the observations].
- We can determine the EUV Flux from the magnetic effect of dynamo currents in the E-region of the ionosphere on the diurnal variation of the geomagnetic East Component. The variation and the group numbers are linearly related to high accuracy and individual backbones each have the same relationship with the geomagnetic diurnal range variation allowing a single composite to be constructed. The new composite is statistically indistinguishable from the published Svalgaard & Schatten 2016 series.
- Constructing and using replica telescopes with the same flaws as typical 18th century ones (chromatic and spherical aberrations) show that modern observers see three times as many spots as the old telescopes, yielding an independent calibration of the scale.