Comparison of New & Old Sunspot Number Time Series

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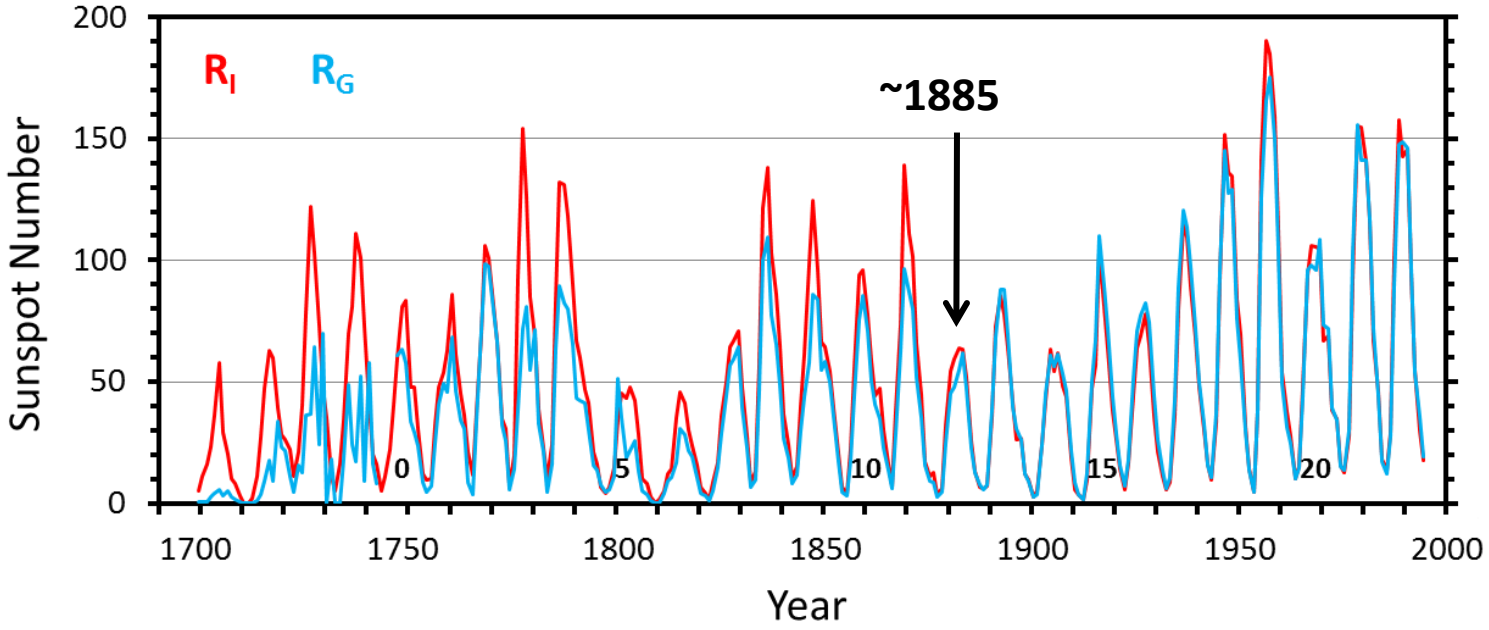
Wolf & Group Sunspot Numbers

Rudolf Wolf (1816-1893)

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

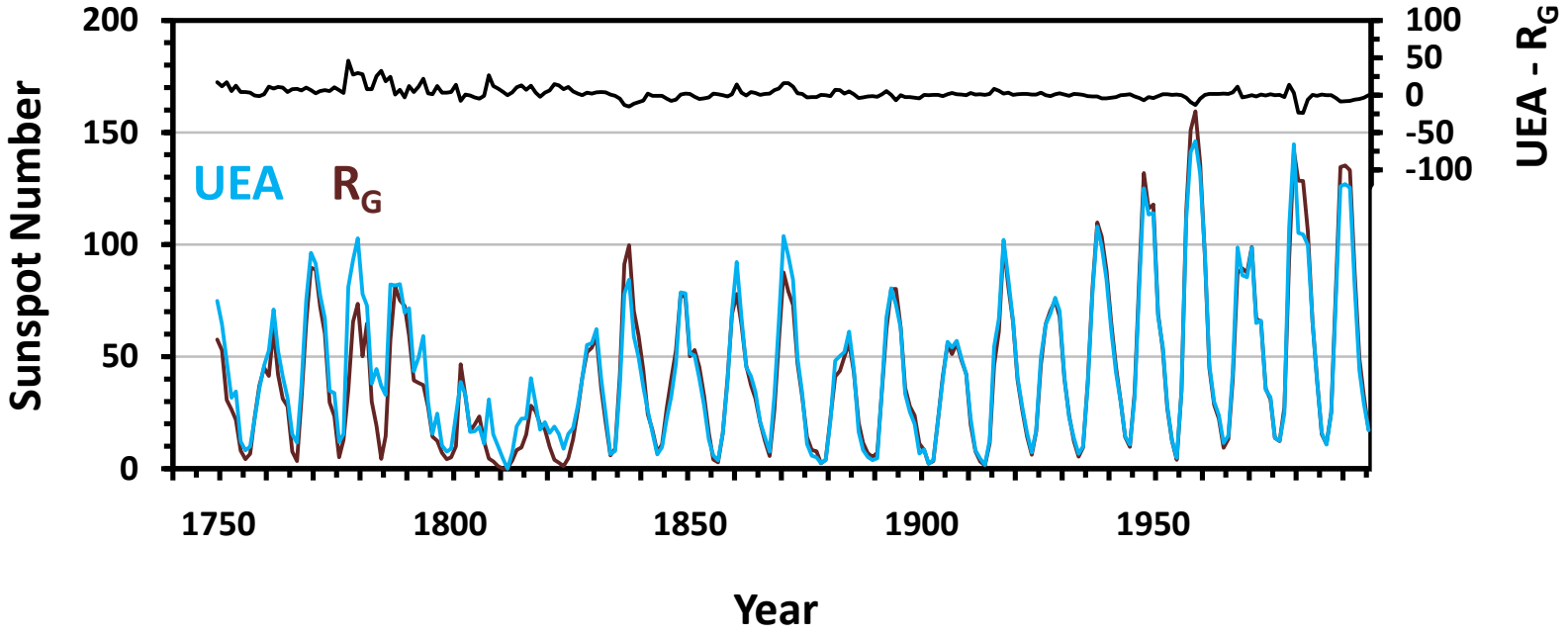
- Group Number = 12 k_G G

Ken Schatten



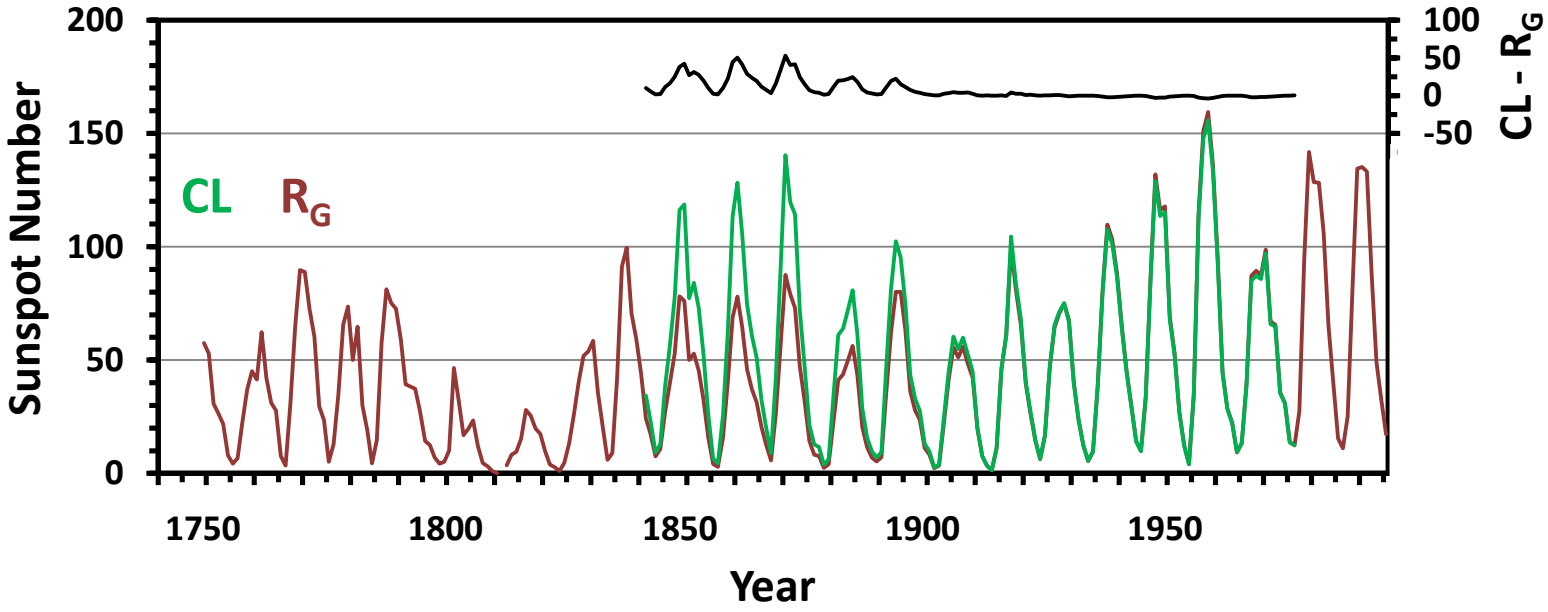
Four newly proposed SN time series (3 group; 1 international)

- Usoskin et al. (2016) **UEA** (G) active day fractions
- Cliver & Ling (2016) **CL** (G*) modified H&S
- Svalgaard & Schatten (2016) **SS** (G) backbones
- Clette & Lefèvre (2016) **S_N** (I) primary observers



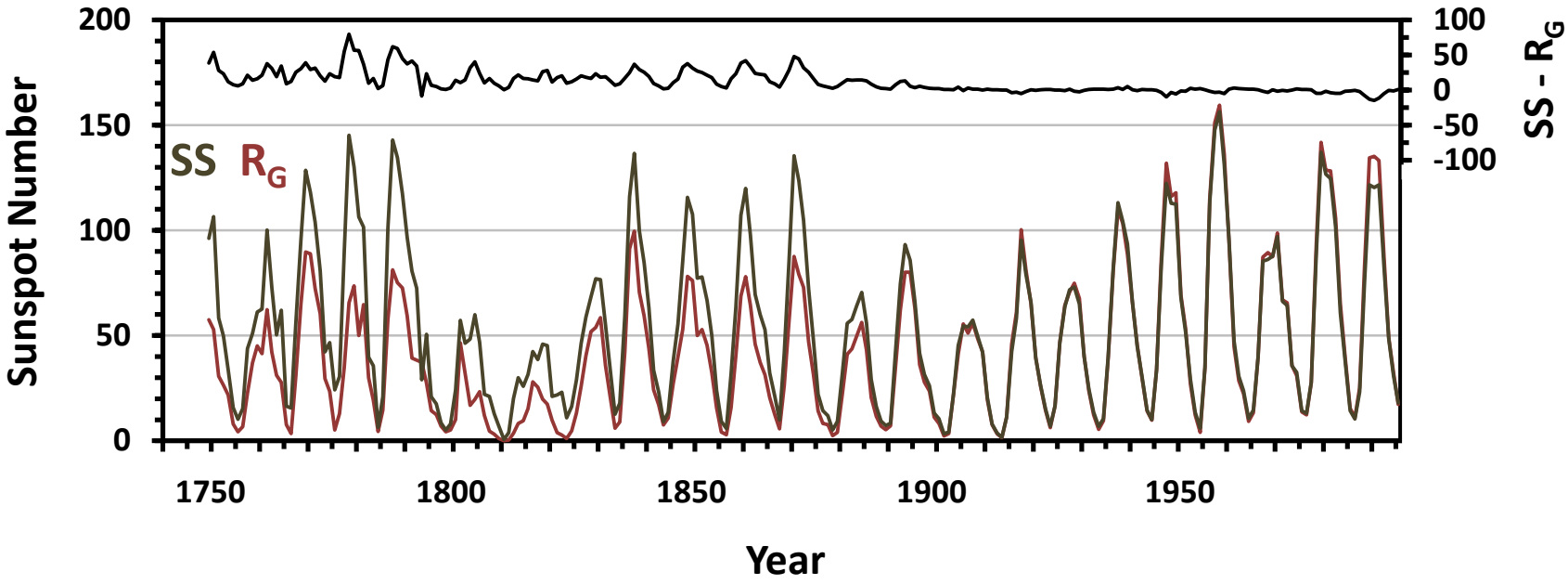
Usoskin et al. (2016) & Hoyt & Schatten (1998)

UEA **R_G**



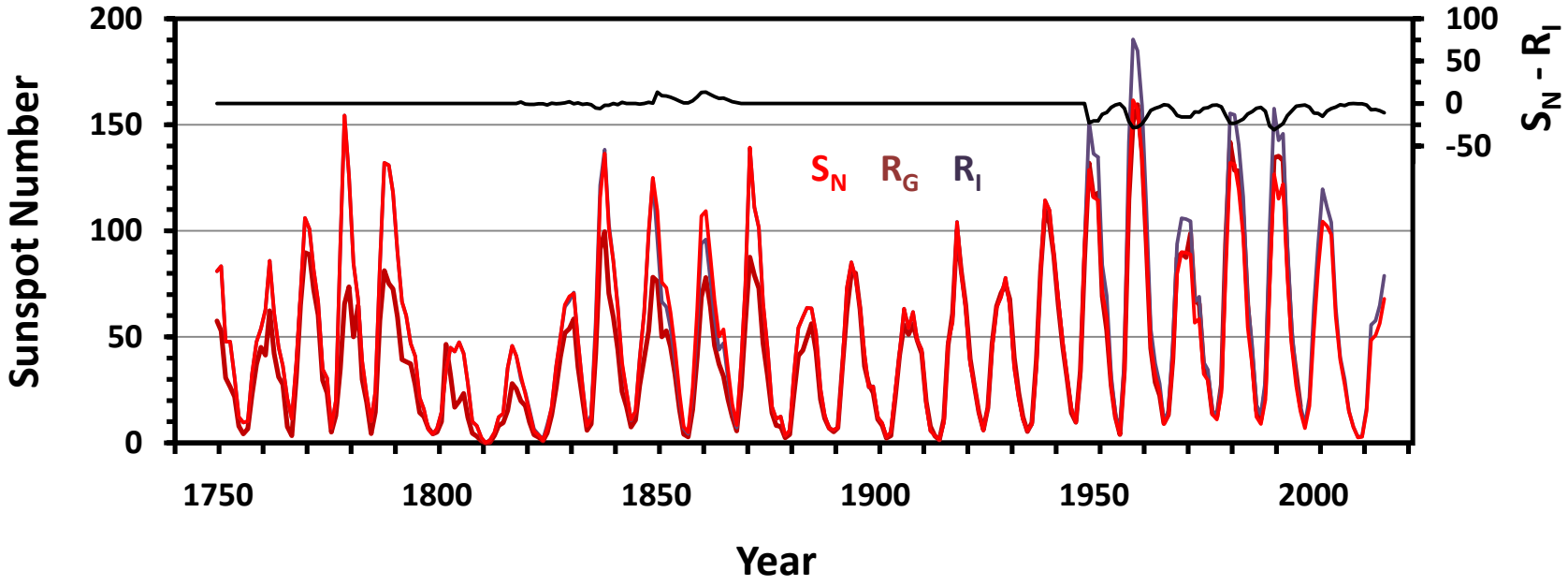
Cliver & Ling (2016) & Hoyt & Schatten (1998)

CL **R_G**



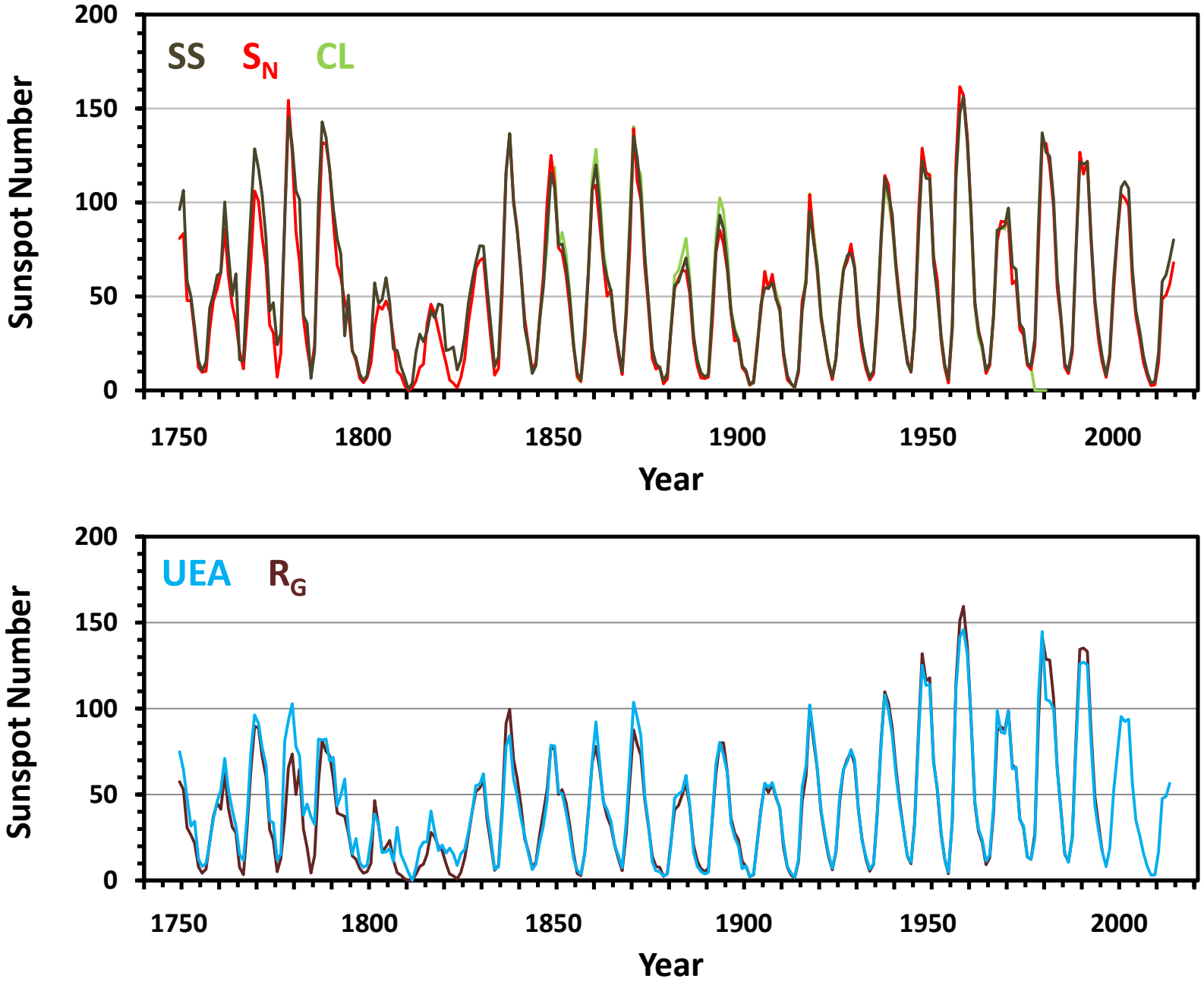
Svalgaard & Schatten (2016) & Hoyt & Schatten (1998)

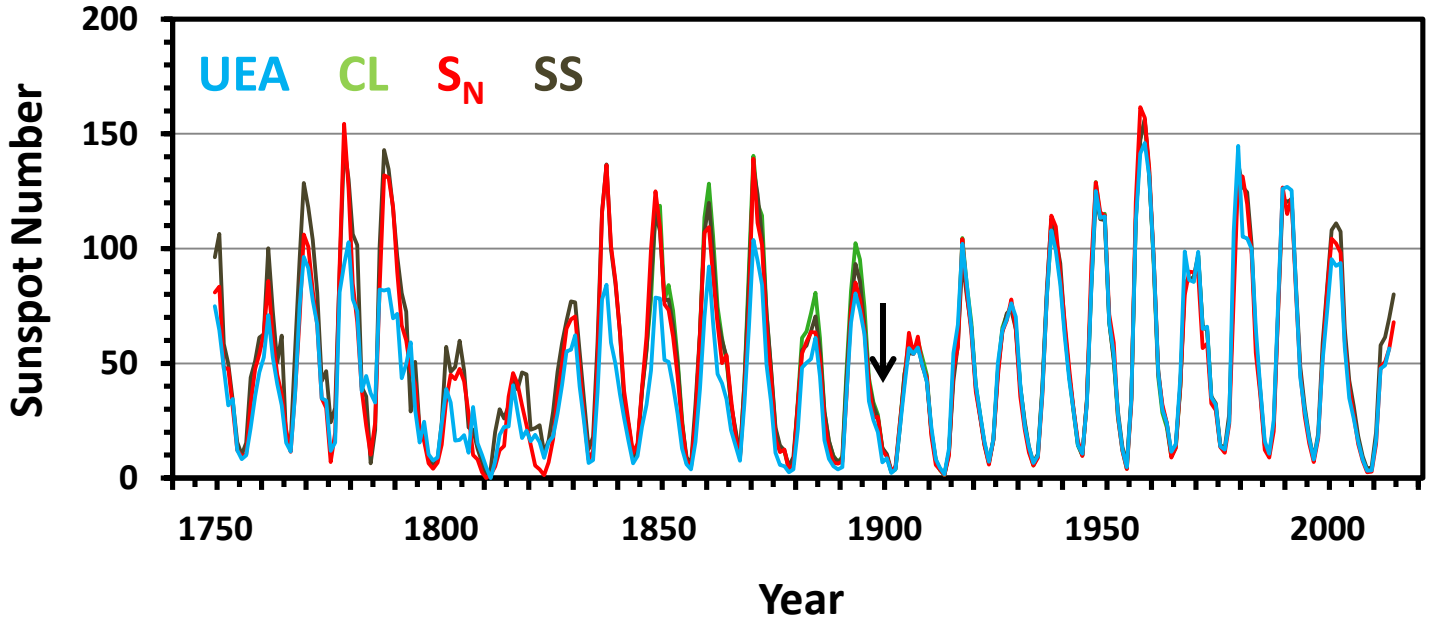
SS **R_G**



Clette & Lefèvre (2016) & Hoyt & Schatten (1998) & Old International SSN

S_N R_G R_I


SS
S_N
CL
Sunspot Number
200
150
100
50
0
1750
1800
1850
1900
1950
2000
Year
UEA
R_G
Sunspot Number
200
150
100
50
0
1750
1800
1850
1900
1950
2000
Year



Two groupings

Diverging before ~1900

All with different normalization schemes

But agreeing reasonably well during the 20th century

Hoyt & Schatten (1998) R_G

H&S k-factor: k = ratio formed by dividing the total number of sunspot groups observed by the comparison observer and by RGO, limiting the ratio to those days when both observers saw one or more sunspots

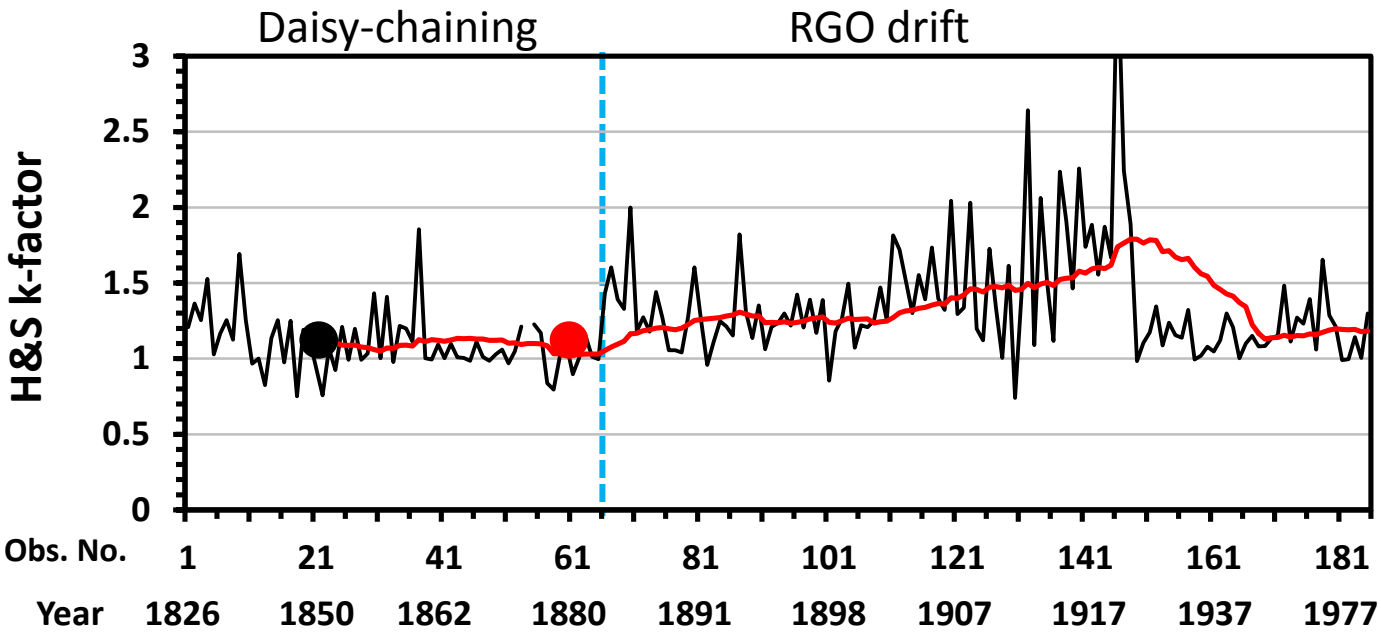
$$k = \Sigma Gp/\Sigma Gs \quad \text{(common days with } G \neq 0\text{)}$$

$$S' = k \times S$$

331	1872	1874	282	1.211	.068	2	SAWYER, E.F., CAMBRIDGEPORT
332	1874	1976	37472	1.000	.001	2	ROYAL GREENWICH OBSERVATORY
333	1874	1893	3598	1.227	.146	2	MONCALIERI
334	1874	1875	107	1.170	.064	2	MAIN, RADCLIFFE OBS., OXFORD
335	1876	1879	997	.838	.008	2	BILLWILLER AND WOLFER, ZURICH
336	1876	1882	1940	.796	.049	2	AGUILAR, MADRID
337	1877	1886	2383	1.021	.063	2	MONTHLY WEATHER REVIEW
338	1880	1928	12536	1.094	.016	2	WOLFER, ZURICH
339	1880	1892	3709	.896	.026	2	RICCO, PALERMO
340	1882	1882	88	1.007	.052	2	MIETHE, POTSDAM
341	1882	1910	6161	1.148	.162	2	WINKLER, JENA
342	1882	1887	1164	1.014	.031	2	JANESCH, LAIBACH
343	1883	1896	3221	.997	.000	2	MERINO, MADRID
344	1884	1886	965	1.429	.000	1	KOKIDES, ATHENS
345	1885	1905	3531	1.604	.000	1	KONKOLY, OGYALLA
346	1886	1886	162	1.392	.000	1	VOGEL, POTSDAM
347	1886	1935	4534	1.329	.000	1	STONYHURST COLLEGE OBS.
348	1887	1887	52	2.000	.000	1	WILSING, POTSDAM
349	1888	1892	1359	1.180	.000	1	SCHMOLL, PARIS
350	1888	1899	2063	1.274	.000	1	HAVERFORD COLLEGE OBS., PA
351	1888	1890	326	1.178	.000	1	YENDELL, P.S., BOSTON
352	1889	1921	10860	1.440	.000	1	QUIMBY, PHILADELPHIA
353	1889	1892	523	1.270	.000	1	CARLETON COLLEGE OBSERVATORY
354	1889	1890	262	1.055	.000	1	FROST, E.B., DARTMOUTH
355	1890	1891	258	1.056	.000	1	SMITH OBSERVATORY
356	1890	1890	67	1.040	.000	1	HADDEN, D.E., ALTA, IOWA

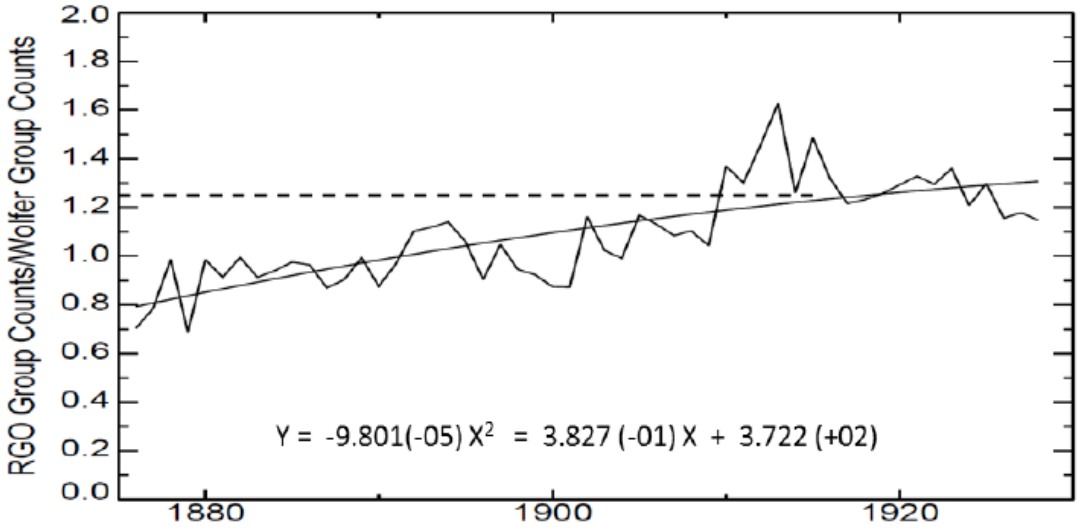
Daisy-chaining before 1884

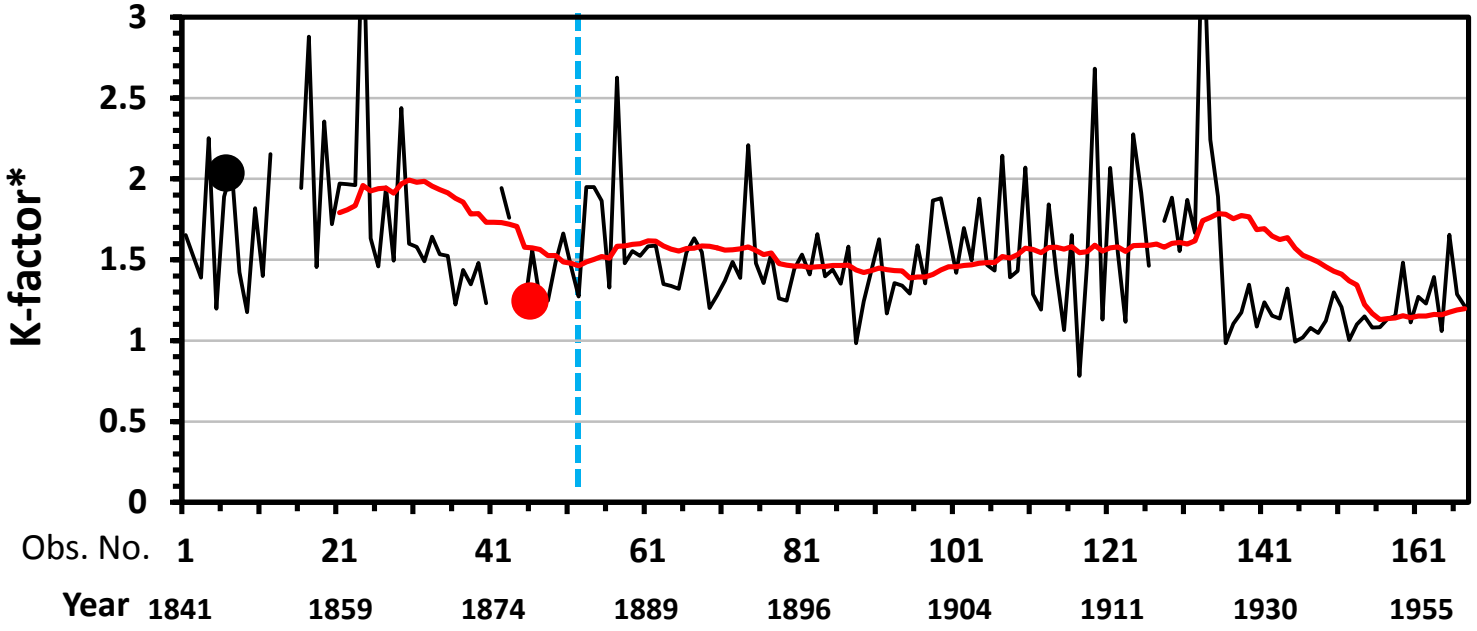
Direct comparison with RGO



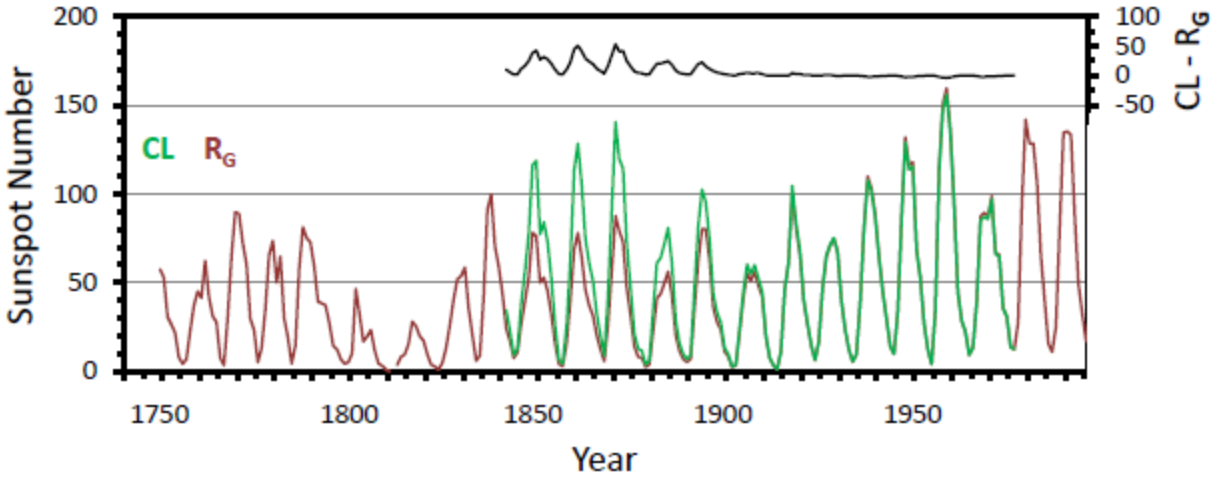
Increase in k-factors beginning in 1884 => observers counted more spots before this year than after

Wolfer Counted 65% more spots than **Wolf**, but their k-factors are ~equal

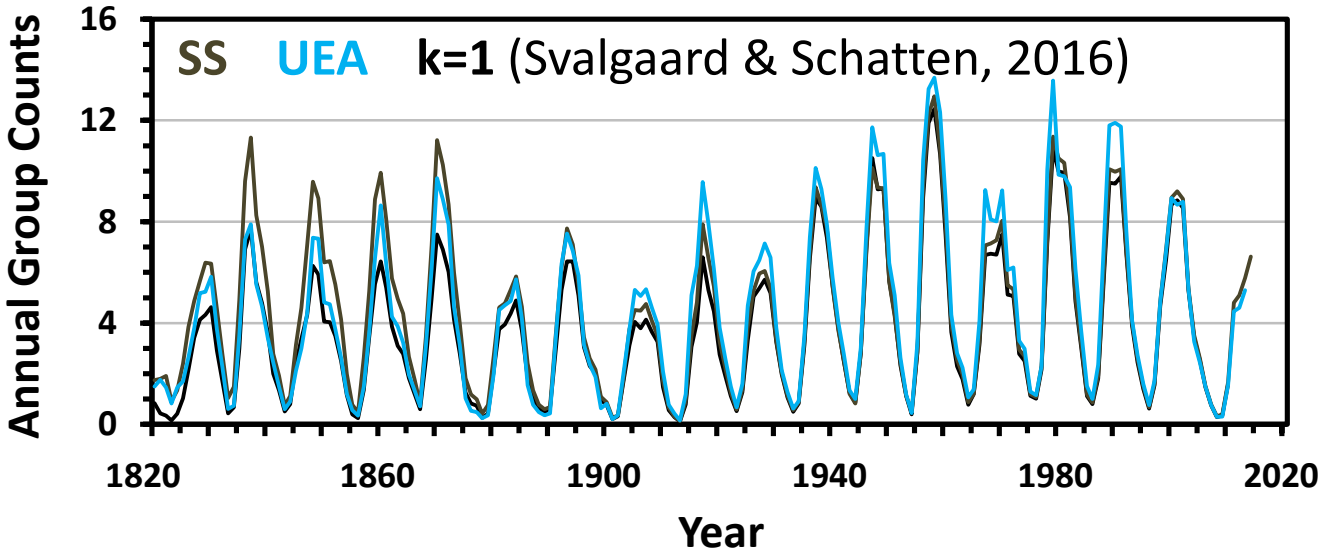




The increase in k after ~1885 is removed



An un-normalized sunspot number (SN) series (k=1 for all observers)

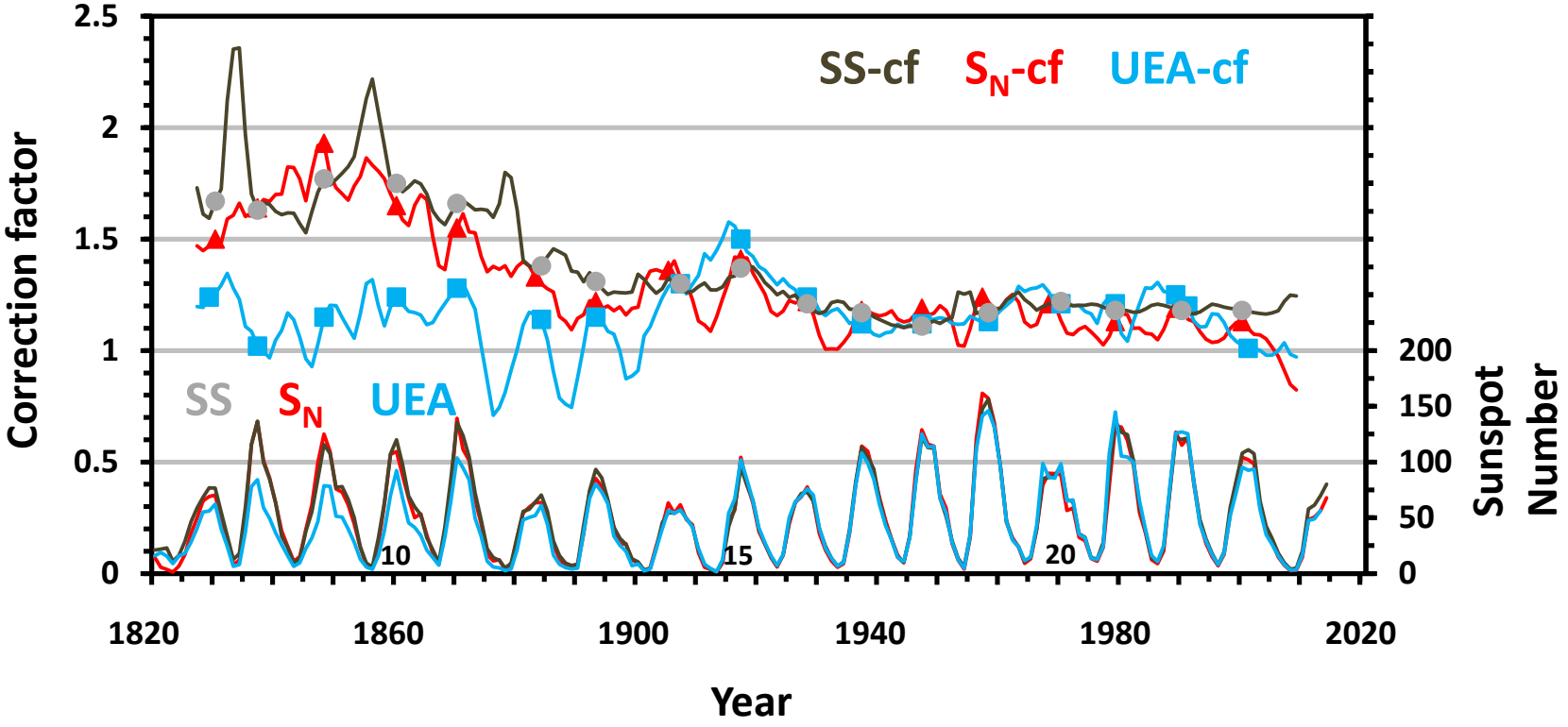


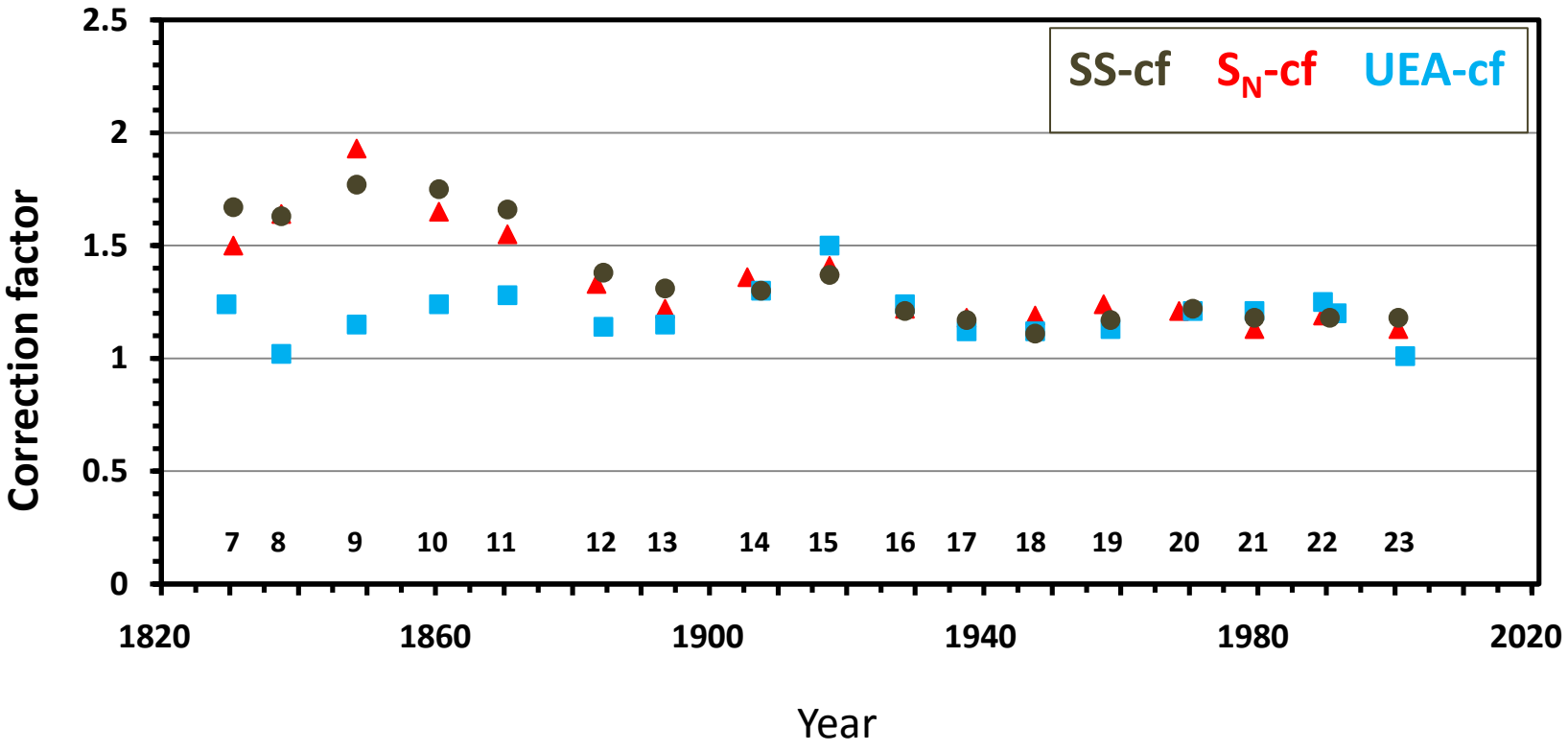
Correction-factor time series

- Defined to be the ratio of any sunspot number time series to the k = 1 series

$$cf = SN/k=1$$
$$SN = cf \times k=1$$

- Useful tool to assess validity of time series when there are ample observers
- Sharp changes indicate problems with reference series
- Long-term changes should be in accord with expectations


SS-cf
S_N-cf
UEA-cf
SS
S_N
UEA
Correction factor
Sunspot Number
Year
2.5
2
1.5
1
0.5
0
200
150
100
50
0
1820
1860
1900
1940
1980
2020
10
15
20


SS-cf
S_N-cf
UEA-cf
Correction factor
2.5
2
1.5
1
0.5
0
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
1820
1860
1900
1940
1980
2020
Year

Conclusions

- Began with two time series (R_I & R_G) that diverged before ~1885

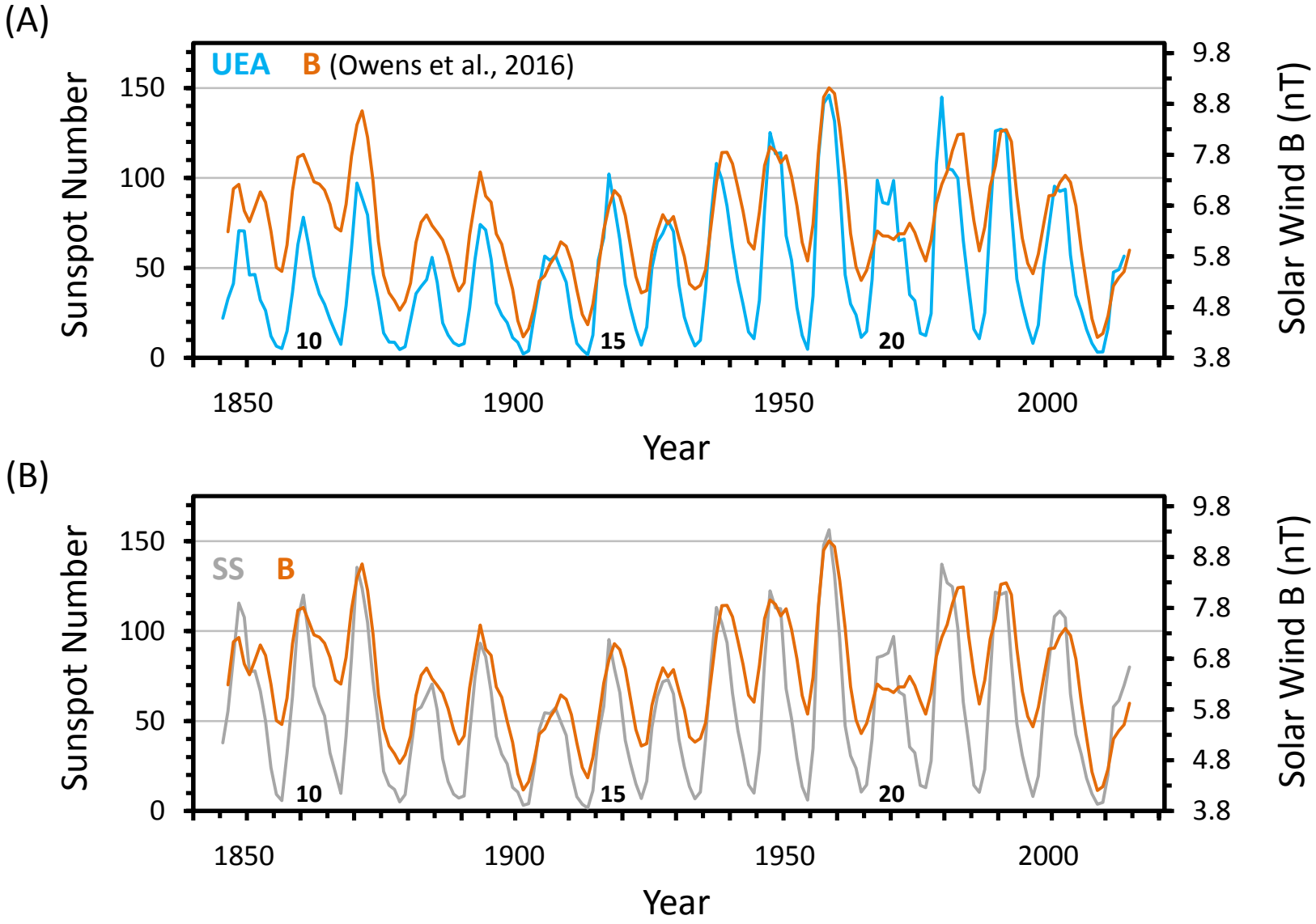
- Now have two groups of series (S_N, SS, R_I & UEA, F, R_G) that diverge before ~1900

- k-factor analysis of original group sunspot number series => inhomogeneity across the ~1885 divergence between R_I & R_G

- A correction-factor time series, based on un-normalized sunspot counts, favors the S_N, SS, R_I grouping, and can be used generally to assess the validity of new time series or individual observers

- Collaborative work needed to understand and resolve differences between the new sunspot series

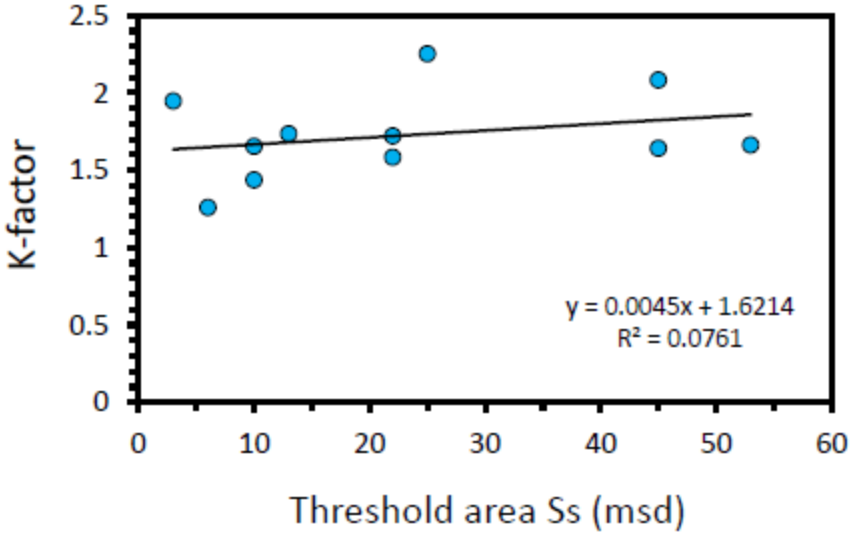
Discussion Slides


(A)
UEA
B (Owens et al., 2016)
Sunspot Number
Solar Wind B (nT)
150
100
50
0
9.8
8.8
7.8
6.8
5.8
4.8
3.8
10
15
20
1850
1900
1950
2000
Year
(B)
SS
B
Sunspot Number
Solar Wind B (nT)
150
100
50
0
9.8
8.8
7.8
6.8
5.8
4.8
3.8
10
15
20
1850
1900
1950
2000
Year

Usoskin et al. (2016) UEA

Observer quality factor S_S corresponds to the smallest area spot group the observer would detect, with the assumption that, on average, the observer reports all groups with area > S_S , and no groups with area ≤ S_S .

In other words, observers with low S_S values should have correspondingly low k-factors.



Only weak correlation between S_S values and K-factors for common observers from 1840-1900.