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Sunspot Number Calibration by the "Magnetic Needle" Makes Sense

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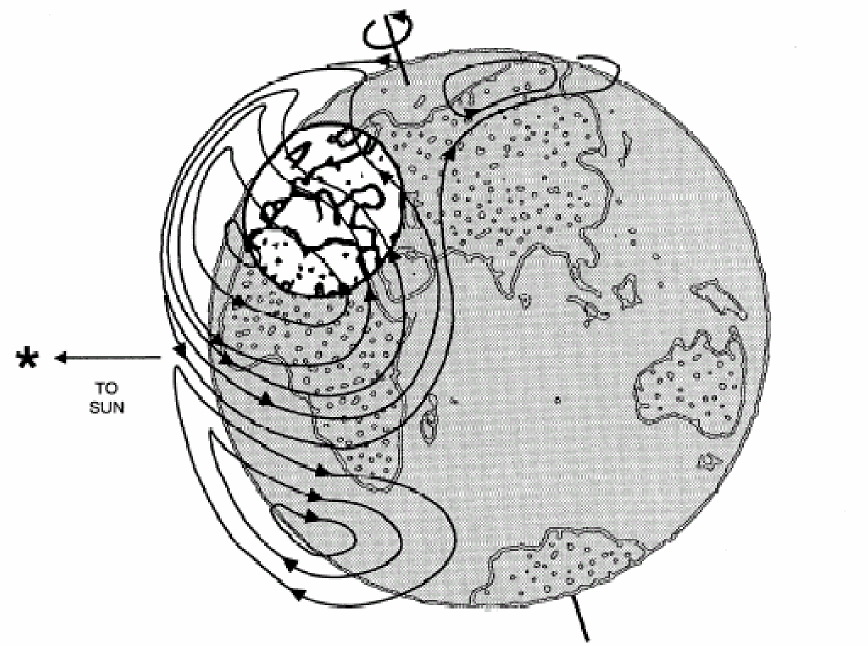
Abstract We show that the amplitude (dD) of the diurnal variation of the magnetic Declination is a reliable indicator of solar Far Ultraviolet radiation (FUV) and of its proxy, the sunspot Number, R [as was known already to Rudolf Wolf ~160 years ago]. FUV creates and maintains the E-layer of the ionosphere, determining the conductivity, and hence the strength of the current causing the diurnal variation. We show how the changes of sunspot observers are faithfully reflected as discontinuities in the relationship between dD and R. Comparisons with other sunspot indices bear this out in a clear manner. On the whole, sunspot numbers before 1947 should be adjusted upwards by 20% and before Wolf's death by another 30%, with the net result that 20th century solar activity does not seem significantly larger than that for the 19th.



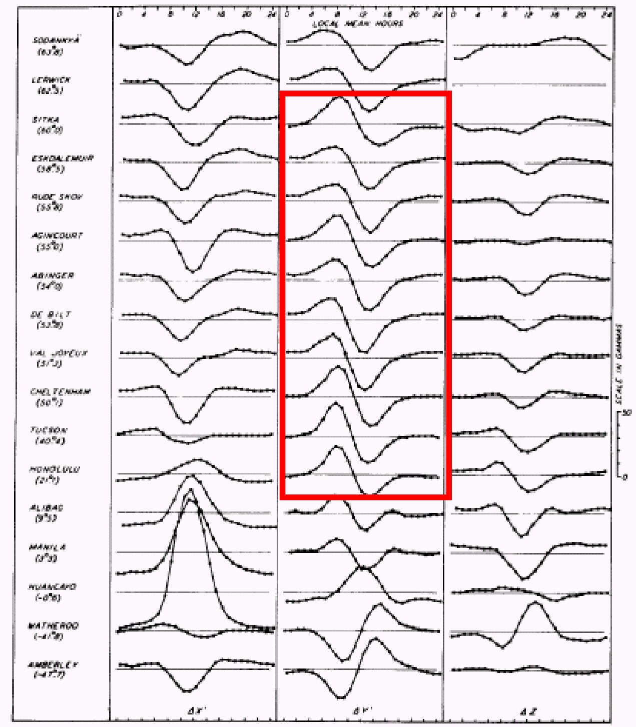
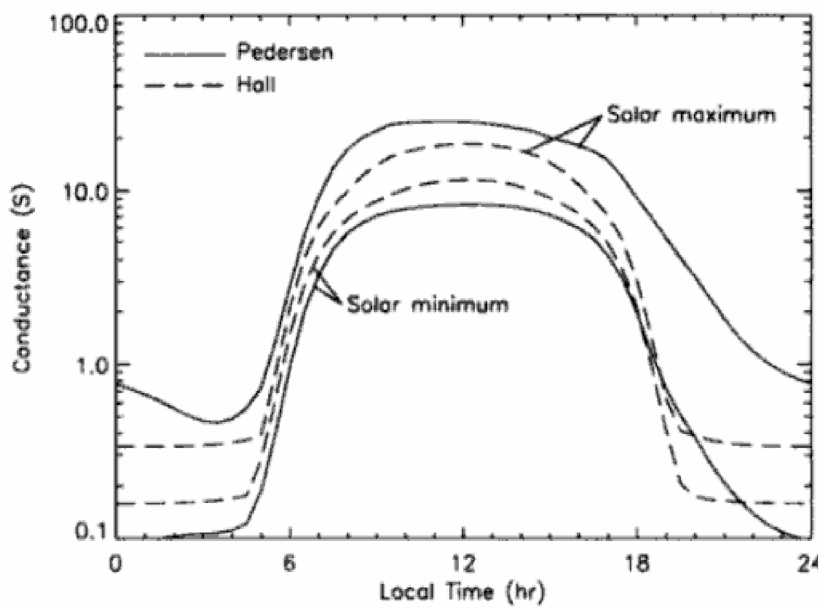


FIG. 69—SOLAR DAILY VARIATION ON QUIET DAYS (Sq), VARIOUS STATIONS, GEOMAGNETIC COMPONENTS, YEAR, 1922-33 (GEOMAGNETIC LATITUDES INDICATED IN PARENTHESES)

An ionospheric current [“Sq current” caused by thermal winds blowing across magnetic field lines] stays fixed with respect to the Sun and the Earth rotates underneath the current, giving rise to a characteristic variation through the local solar day. For the East-West component [or equivalently, the Declination of the “Magnetic Needle”] the variation is very uniform over a wide rang of latitudes.



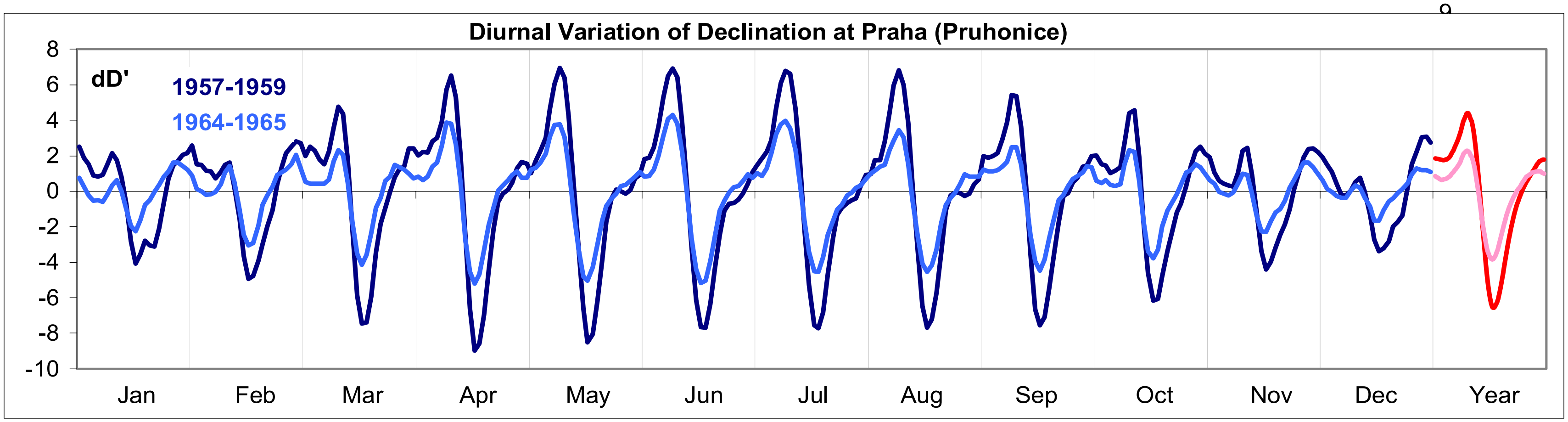
$$\int \sigma_P dz = (11\ \mathrm{S}) \left(\frac{S_a}{S_0}\right)^{1.1} \left(\frac{B}{B_0}\right)^{-1.6} (\cos\chi)^{0.5}$$

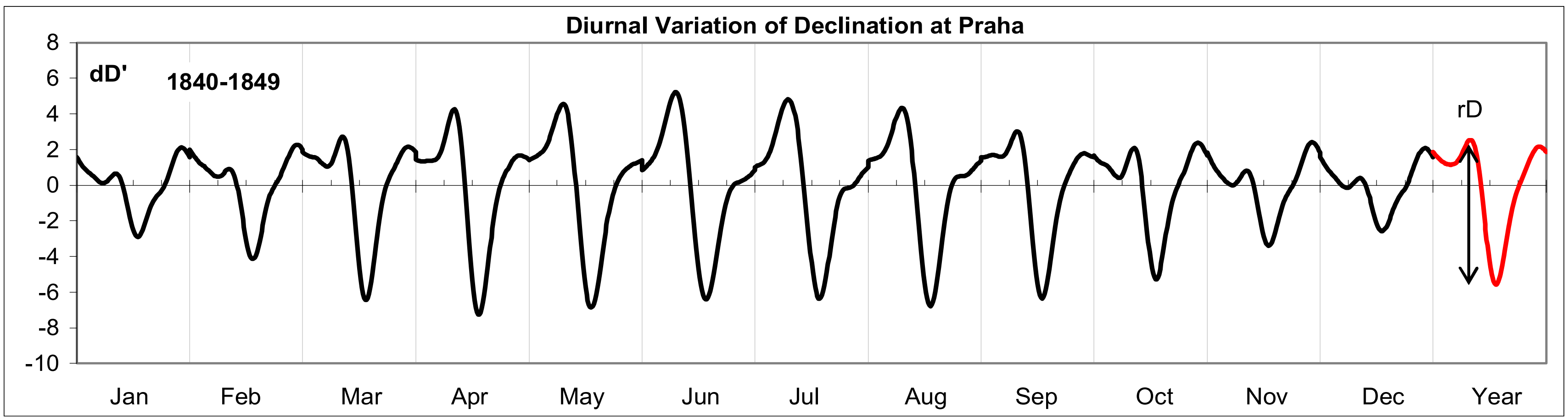
$$\int \sigma_H dz = (14\ \mathrm{S}) \left(\frac{S_a}{S_0}\right)^{0.5} \left(\frac{B}{B_0}\right)^{-1.3} (\cos\chi)^{0.8}$$

S0 = F10.7 Radio Flux = 100
B0 = Earth's Magnetic Field = 50,000 G
χ = Solar Zenith angle

Height-integrated Pedersen and Hall conductivities at 44.6°N, 2.2°E on March 21, for solar minimum

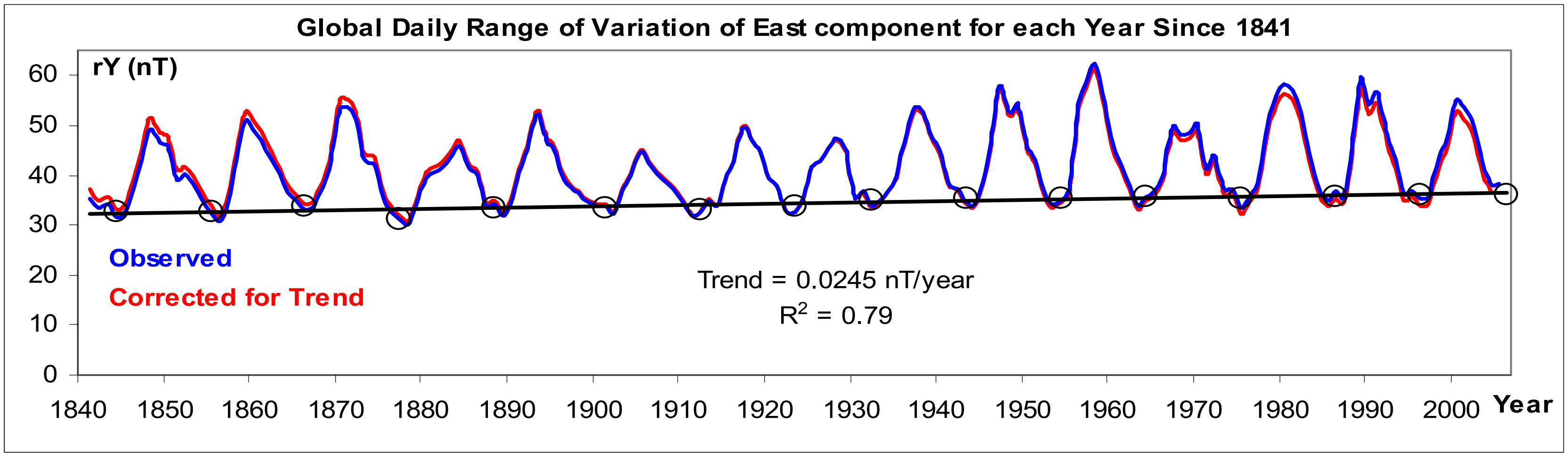
We *expect* the ionospheric conductance to increase with solar activity [e.g. the F10.7 radio flux]. And to vary ***inversely*** with the Earth's Dipole Moment, and finally to exhibit a strong seasonal dependence. The strength of the current and hence its magnetic effect is a bit more complicated to calculate [depending on height, magnetic field, and wind speeds], but should exhibit the same general characteristics. All this is well known and easily modeled. The essential fact is that the variations of a factor of two can be expected, as are indeed observed:

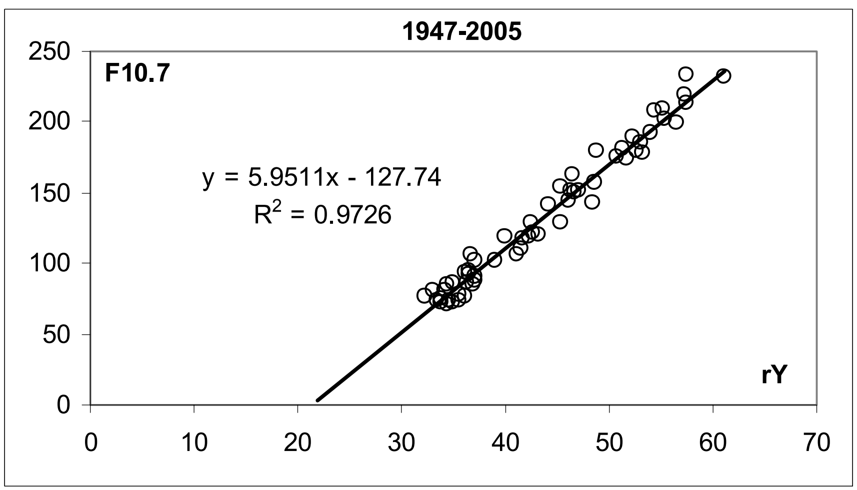




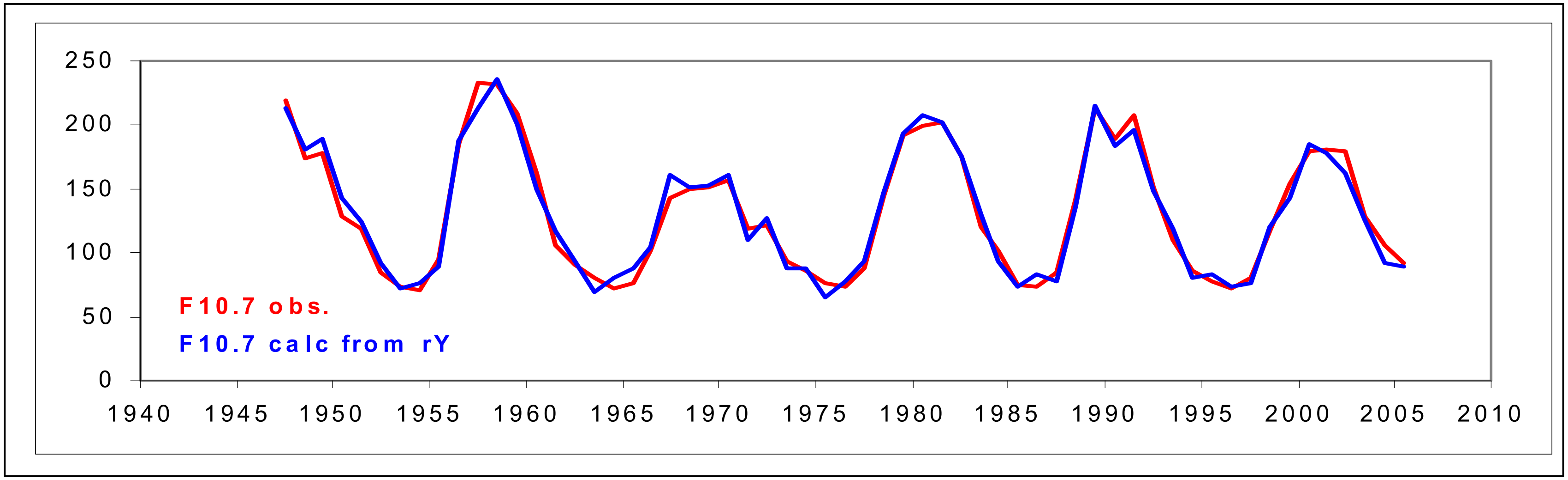
Since the East Component, *Y*, can be calculated from the Horizontal Force, *H*, and the *D*eclination, *D*: $\boldsymbol{Y = H \sin (D)}$, we can use *D* and *Y* interchangeably. *D* could be readily measured to the arc minute 200 years ago.

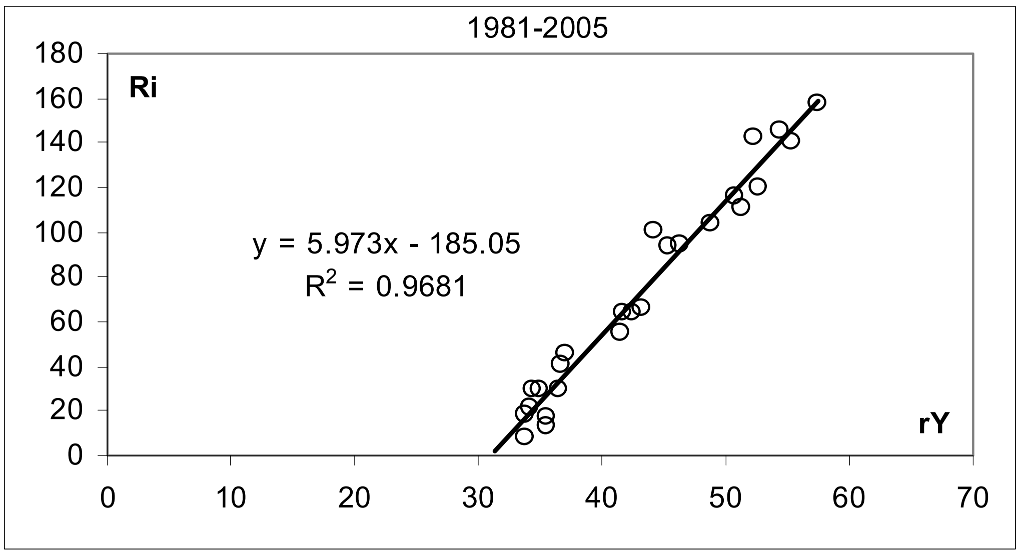
Using several stations (Oslo, Helsinki, Colaba, Prag, Greenwich, Potsdam, …) we can determine the yearly range of the East Component, *rY*, back to 1841:



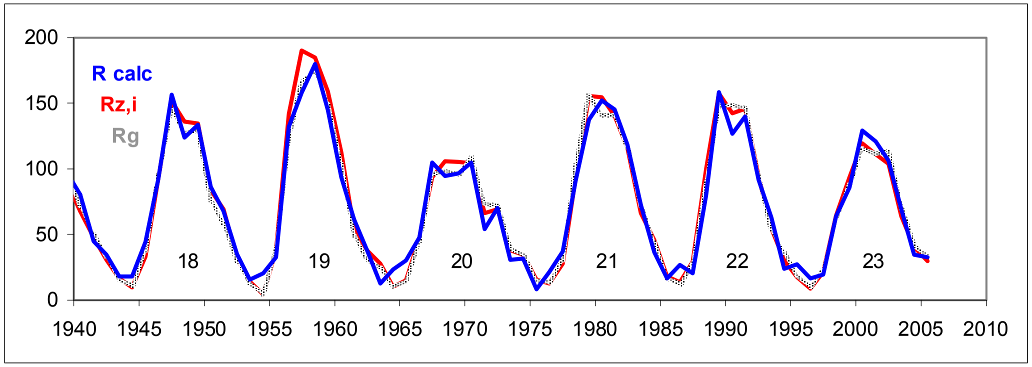


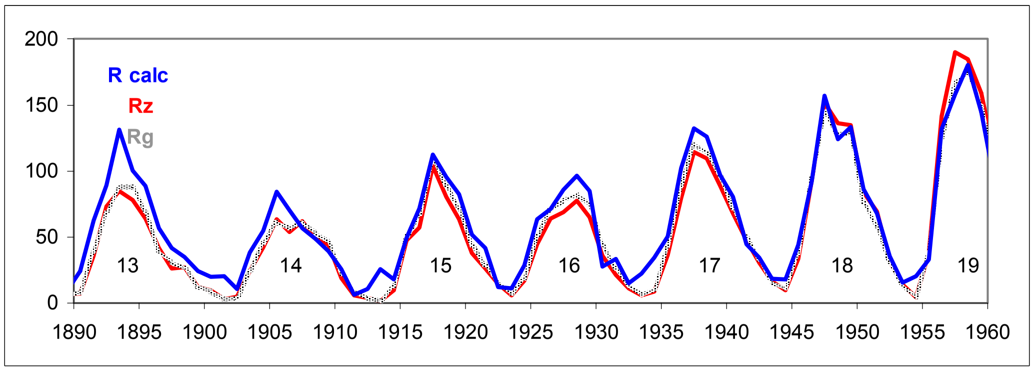
We see the expected trend in *rY* caused by the decreasing dipole moment, and the solar cycle variation. The correlation with yearly amplitudes of the F10.7 radio flux is also borne out by direct observations. [Left panel]

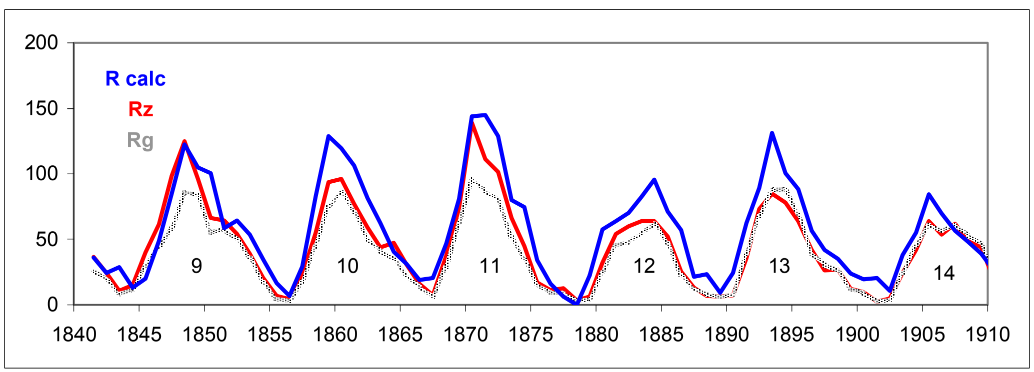




Here is the correlation with the International Sunspot Number, R_i, almost as good as F10.7. We'll now assume that this holds back in time for the whole *rY*-series [detrended by normalizing to its mean] and calculate reconstructed *Ri*-values:

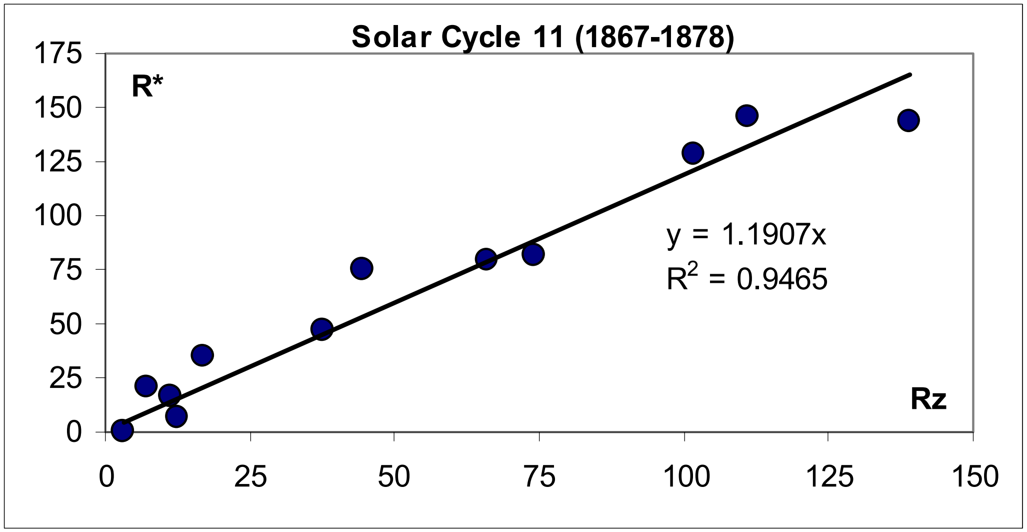






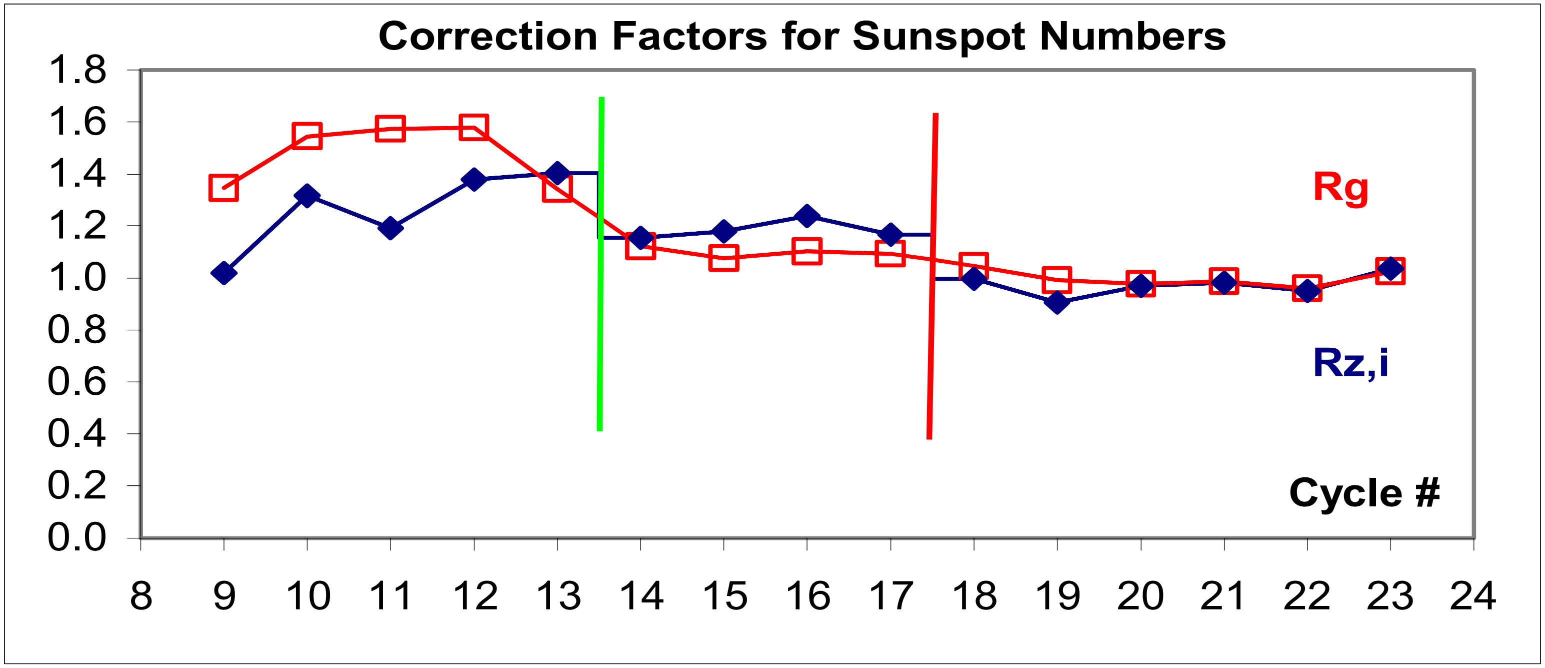
For solar cycles 18-23, the reconstruction is almost as good as for the F10.7 flux. Before that, the reconstructed values are generally *higher* than the observed *Ri*, Zurich Sunspot numbers *Rz*, and Group Sunspot numbers *Rg*.

For each cycle we now correlate the yearly calculated values with the observed values and find the scaling factor:



Cycle	Rg	Rz
9	1.347	1.020
10	1.545	1.317
11	1.572	1.191
12	1.580	1.379
13	1.343	1.403
14	1.121	1.156
15	1.075	1.180
16	1.103	1.238
17	1.093	1.166
18	1.046	0.996
19	0.991	0.905
20	0.978	0.970
21	0.986	0.982
22	0.961	0.948
23	1.026	1.036

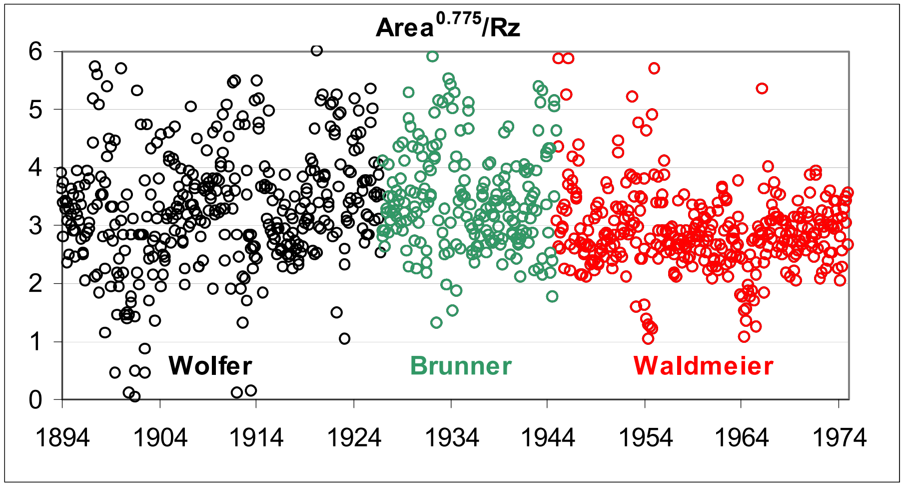
The example is for cycle 11. Inspection of the table of scale factors shows two major ‘jumps’ or discontinuities: one between cycles 17 and 18 and one between cycles 13 and 14. These correspond to changes of solar observers (Wolf’s death in 1893, and Waldmeier taking over in 1945). Graphics on next page:

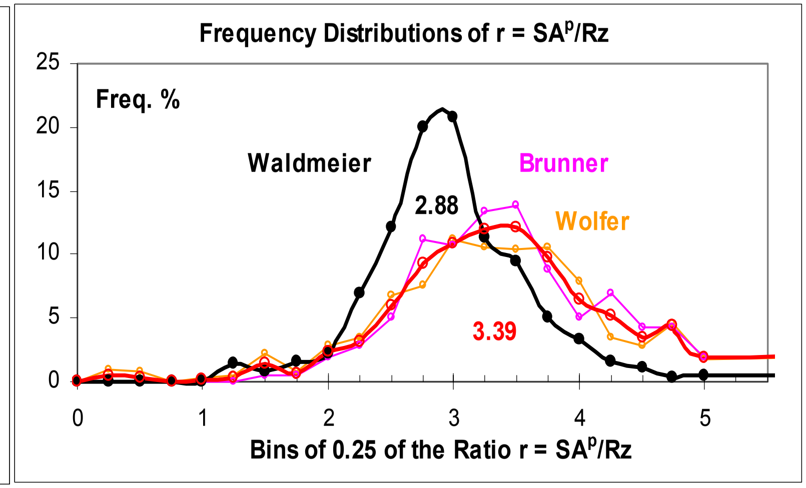


Because the changes are ***jumps***, the issue of detrending is now moot.

It is of interest to show that these discontinuities can be detected in other solar indices thus showing that the "Magnetic Needle"-method is sensitive enough and stable over the centuries to give reliable results.

First, let’s show that the Sunspot Areas show the same jump in ~1945:

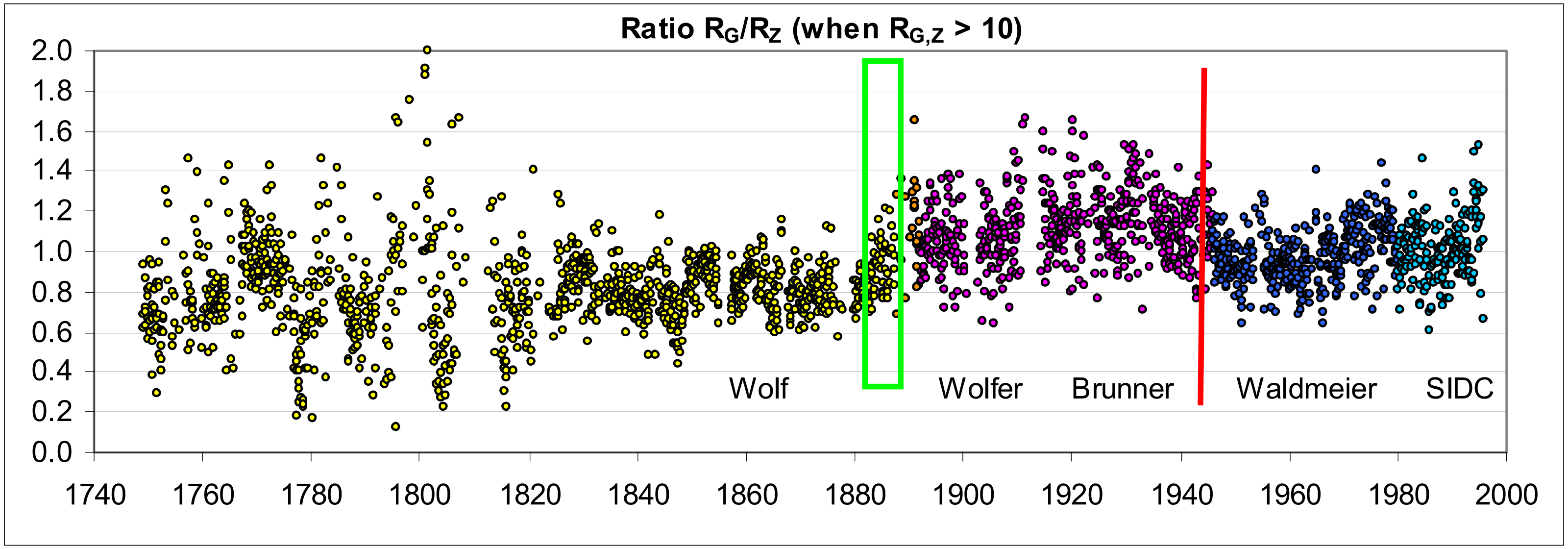




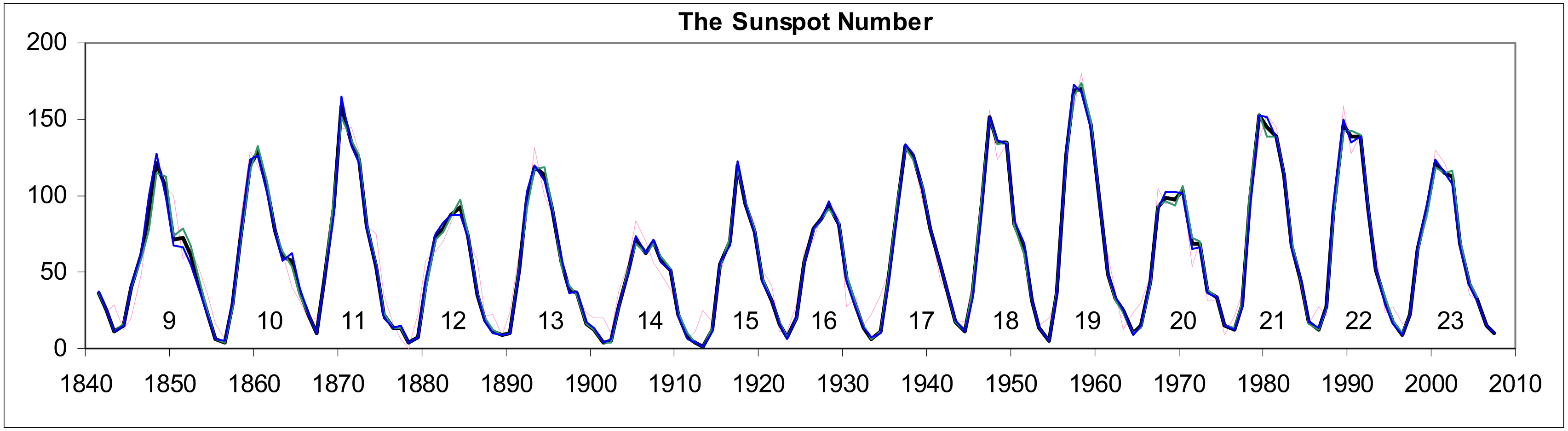
Observer	<$SA^{0.775}$>	<Rz>	<r>	1/<r>	Corr. Factor
Wolfer	123.71	36.50	3.3898	0.2950	1.175
Brunner	168.24	49.69	3.3859	0.2953	1.174
Waldmeier	223.45	77.46	2.8847	0.3467	1.000

The *rY*-method gave a jump of 23% and the Area/*Rz* ratio yields 17.5%, so a reasonable conclusion would be an upward ~20% correction, to be applied to all Rz values before ~1945 [or downward after 1945].

The ratio between the Group Sunspot Number, *Rg*, and the Zurich Sunspot Number, *Rz*, show the same jumps in ~1945 and ~1883-90:



Conclusion: It seems more reasonable to ascribe the changes that coincide with the change of observers to those rather than to changes in the Sun or in the response of the ionosphere or just noise. The “Magnetic Needle” unfailing knows when the observer changed and it therefore makes sense to trust the method as the time-honored technique it is [Rudolf Wolf himself used it to great effect]. With that, we can now show a suggested corrected sunspot number:



With this new perspective, we conclude that the Sun in the 20th and 21st centuries has not been particularly more active compared to activity in the 19th century.