Discussion of

CALIBRATING 100 YEARS OF POLAR FACULAE MEASUREMENTS: IMPLICATIONS FOR THE EVOLUTION OF THE HELIOSPHERIC MAGNETIC FIELD

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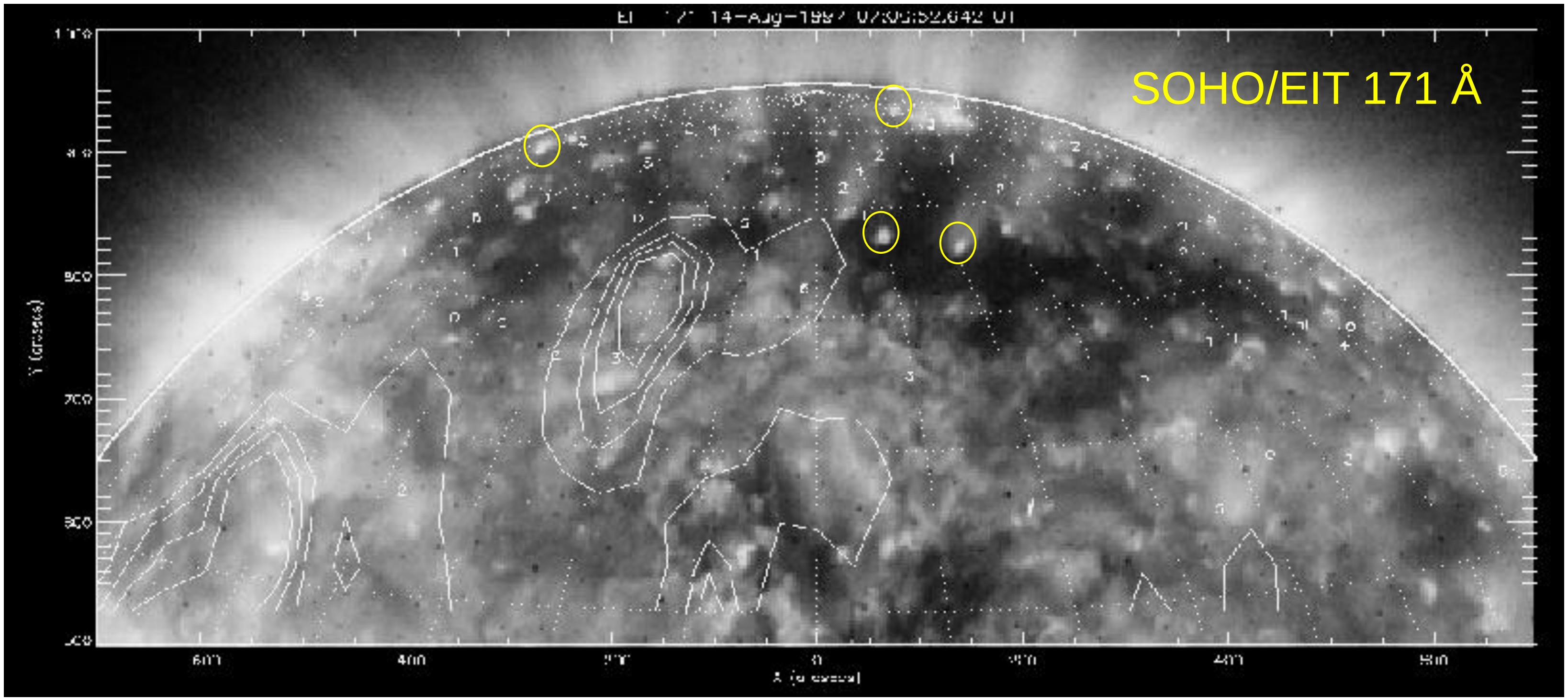
Leif Svalgaard

Stanford University, Feb. 7, 2013

What are Polar Faculae?



PFe are **stable** phenomena, with lifetimes of several hours to days, and harbor magnetic fields of kilo-Gauss strength. *Yet their role for the global magnetic field at the solar poles is unknown*. Total magnetic fluxes in PFe fall **short by an order of magnitude** from those found in the literature for the fluxes at the polar caps. With the present spatial resolution of 0.4−0.5”, PFe represent the “large-scale” end of a distribution of **unipolar** strands near the solar poles. Rodríguez et al. A&A *474*, 251, 2007

Faculae at the poles of the Sun

1. It has been possible to demonstrate **directly** with the strongly Zeeman-sensitive infrared line at 1564.8 nm that PFe may harbor kilo-G magnetic fields

2. The magnetic polarity in the overwhelming part, 85%, of PFe with strong fields is of the **same sign** as that of the global magnetic field around the solar poles

3. **Not all** bright structures at the poles with magnetic fields identified as PFe exhibit strong fields, above one kilo-G. Many have lower field strengths in the 500 G range or lower

4. The bimodality indicates the existence of **two populations** of PFe, one with field strengths ≥1000 G and one with a distribution around 500 G with fields also in the range of 250 G and with a possible extension into the kG range

5. The fields of lower strength are **more balanced** in polarity than those with strong fields, although not completely

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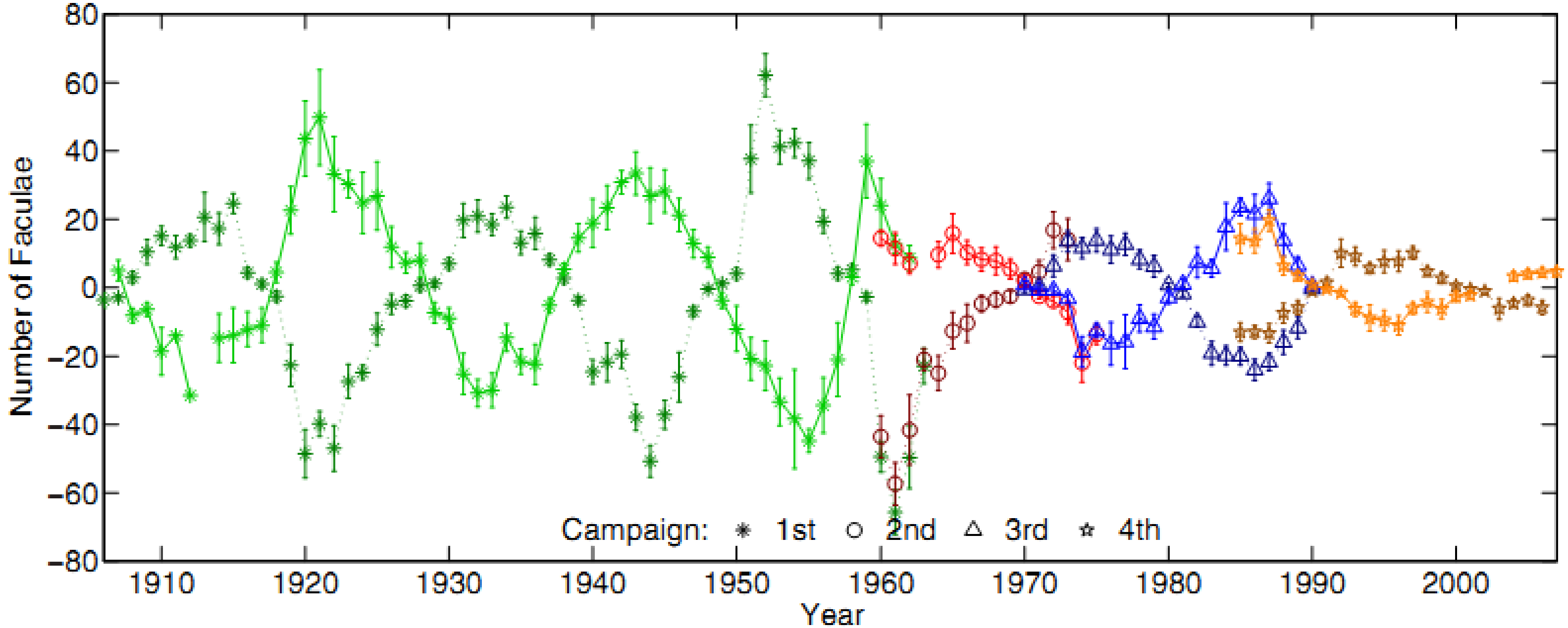
Faculae at the poles of the Sun revisited: infrared observations

J. Blanco Rodríguez and F. Kneer

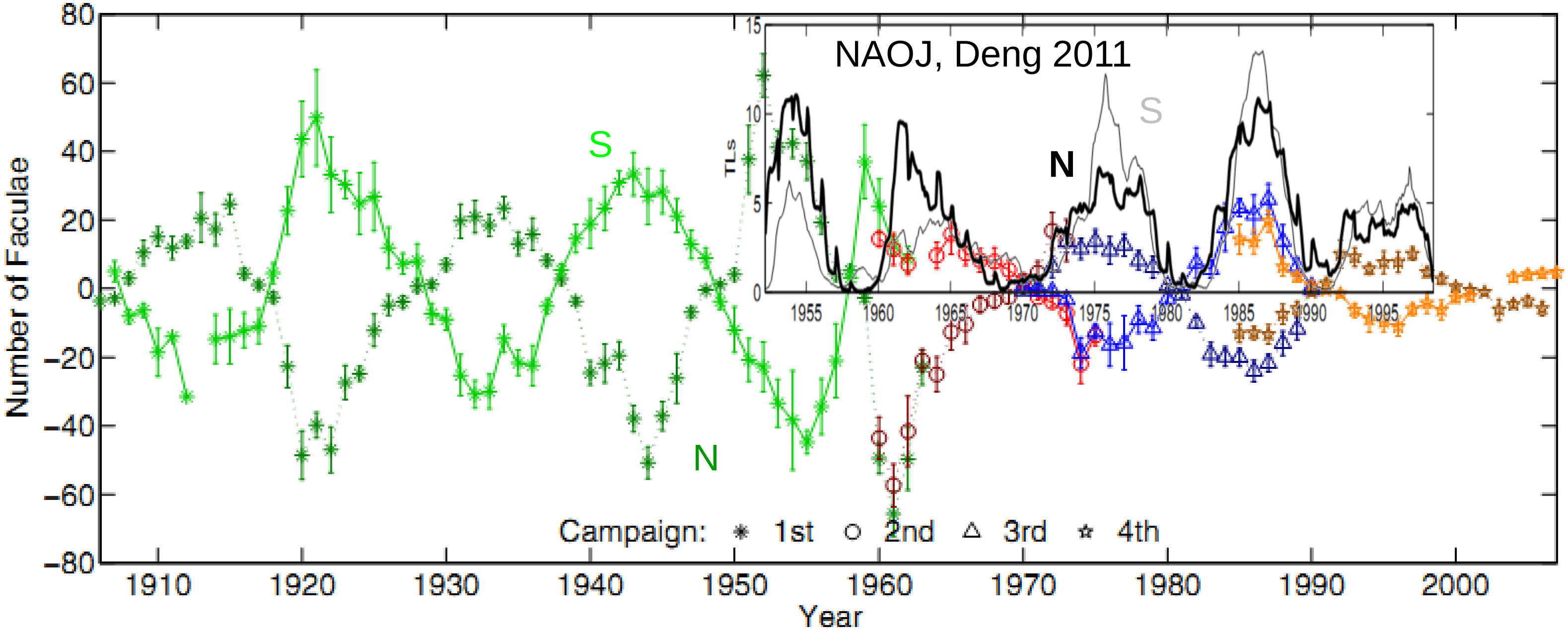
Neil Sheeley's Faculae Counts



Raw MWO facular measurements. Each campaign is marked with a different color and marker: greenish asterisk (1st), reddish circle (2nd), bluish triangle (3rd), and orangish star (4th). Measurements for the north (south) pole are shown using a dark dashed (light solid) line. After each minima the sign is reversed to match the polarity of each magnetic cycle.

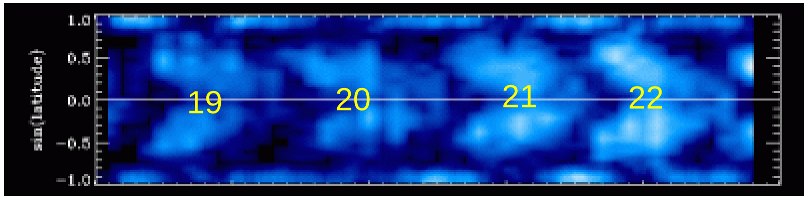
Plates were selected from times when the poles were close to maximum visibility, then marked and randomized, and finally the polar faculae were counted in four campaigns

Compared to Other Faculae Counts

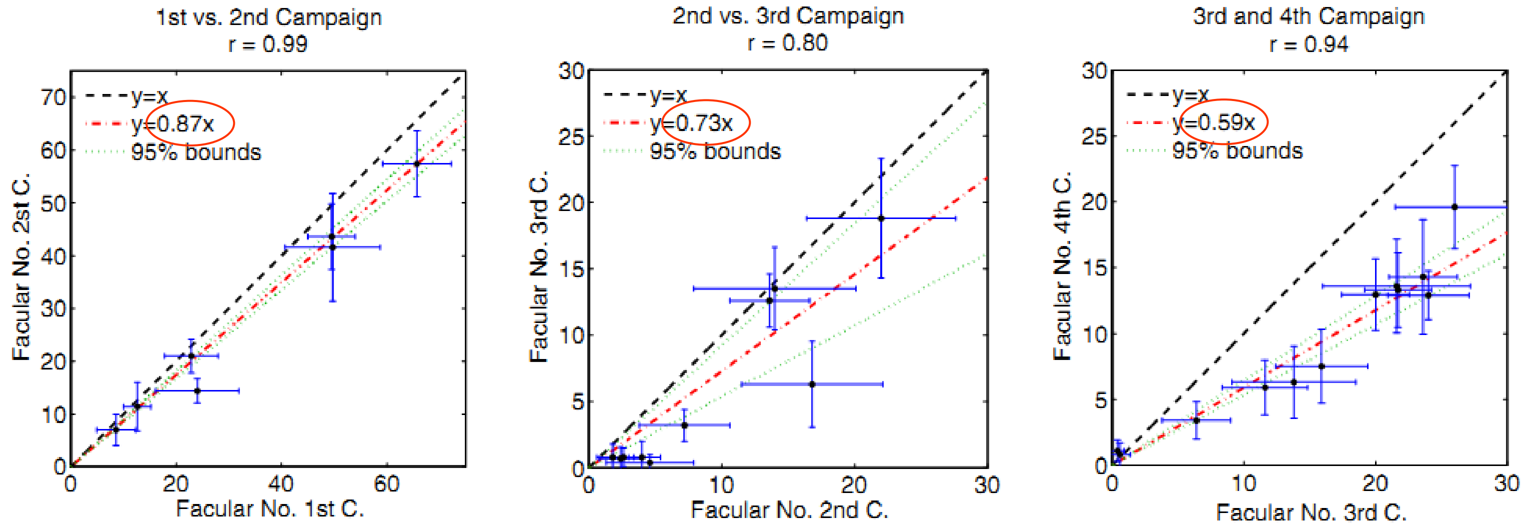


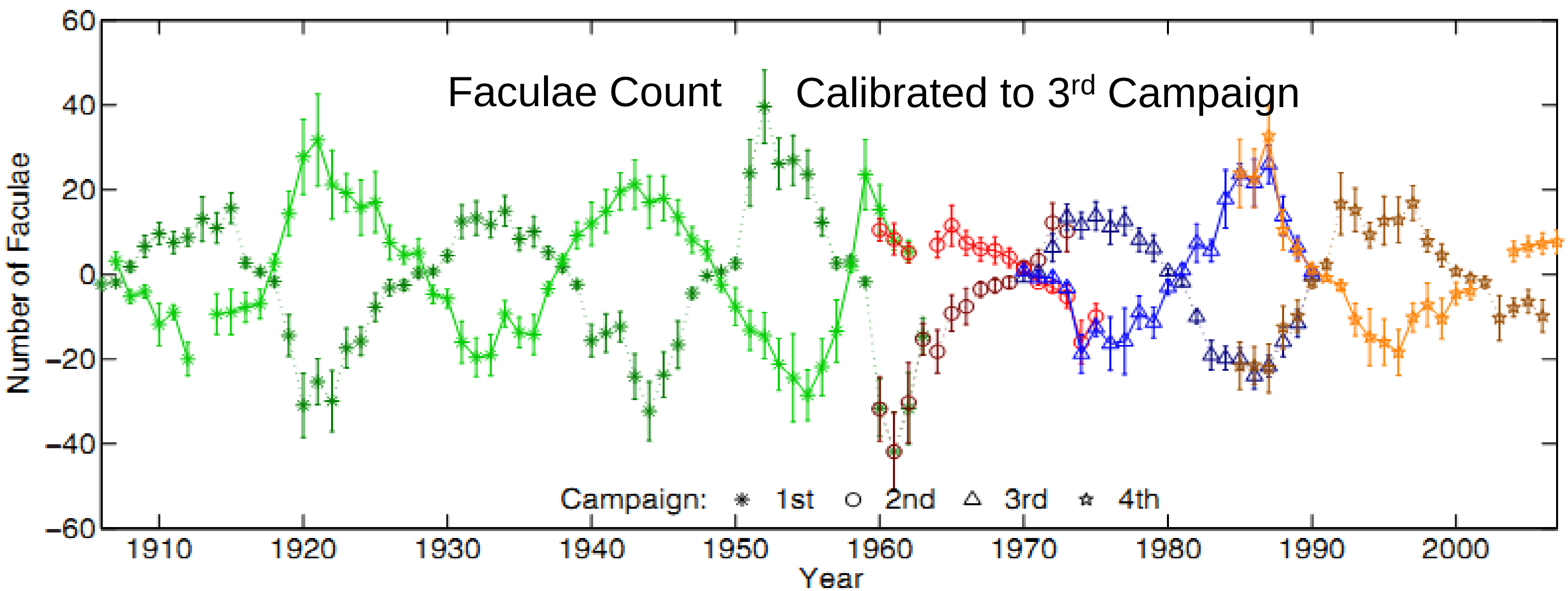
NAOJapan has a database with polar faculae counts since 1951 [Deng et al. 2011]. Note the large 'spikes' in the two datasets. Sometimes they agree, sometimes not. Also, note the possible decreasing trend in the faculae count. The trend is likely to be a calibration issue. As the campaigns overlap we can make cross-calibrations.

Supersynoptic chart of the Japanese observations



Cross-Calibration of Campaigns





The 1961 ‘Spike’ is Visible in MWO Magnetogram as well

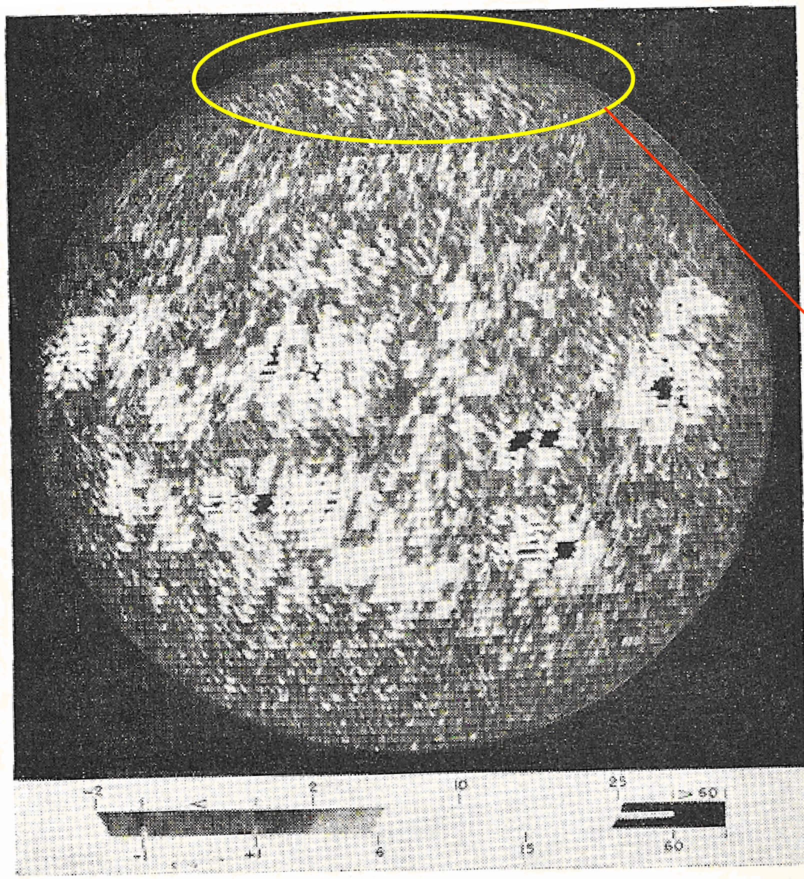
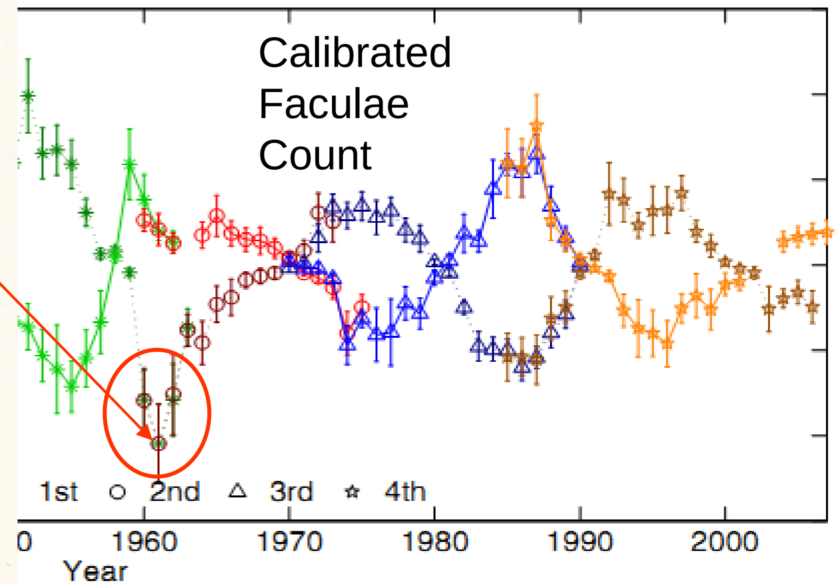
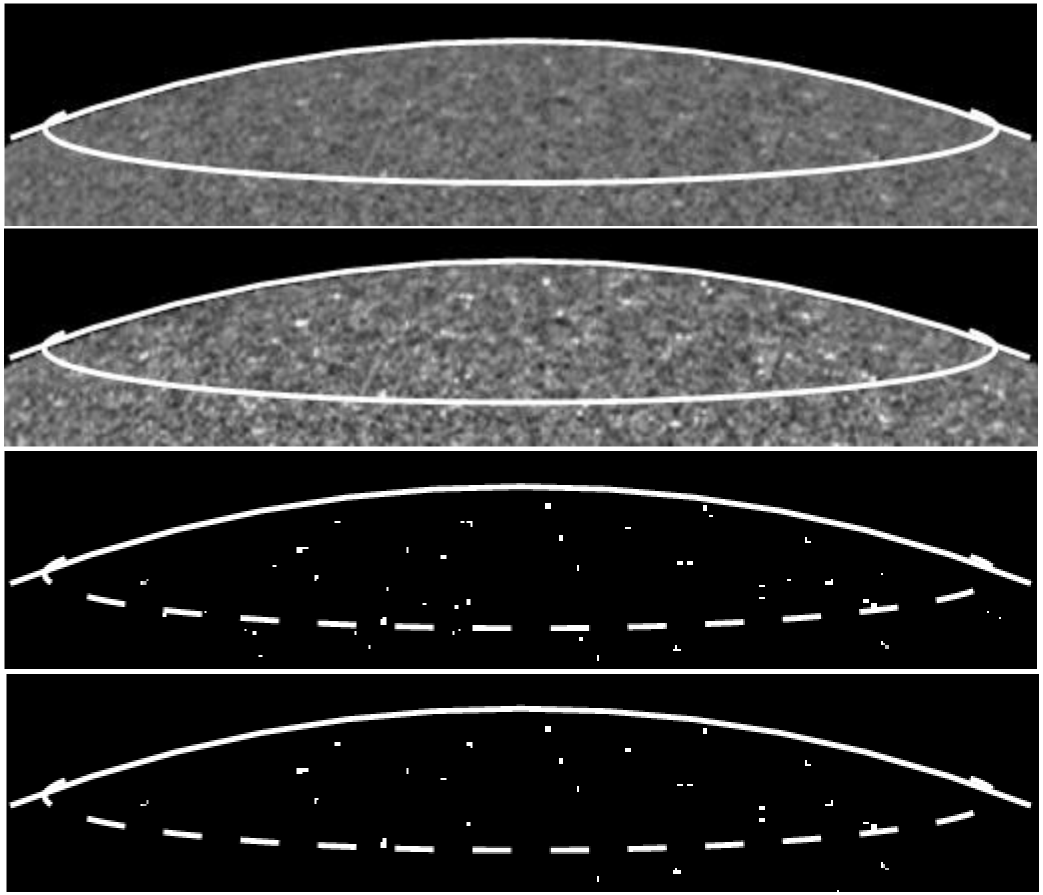


Fig. 1—The Solar Magnetogram for 21 July 1961. North is above and east is right. A faint field can be seen near the north pole.



So, the spikes are likely real, but short-lived. What role do they play, if any?

Use MDI Magnetograms to Identify and Count Polar Faculae



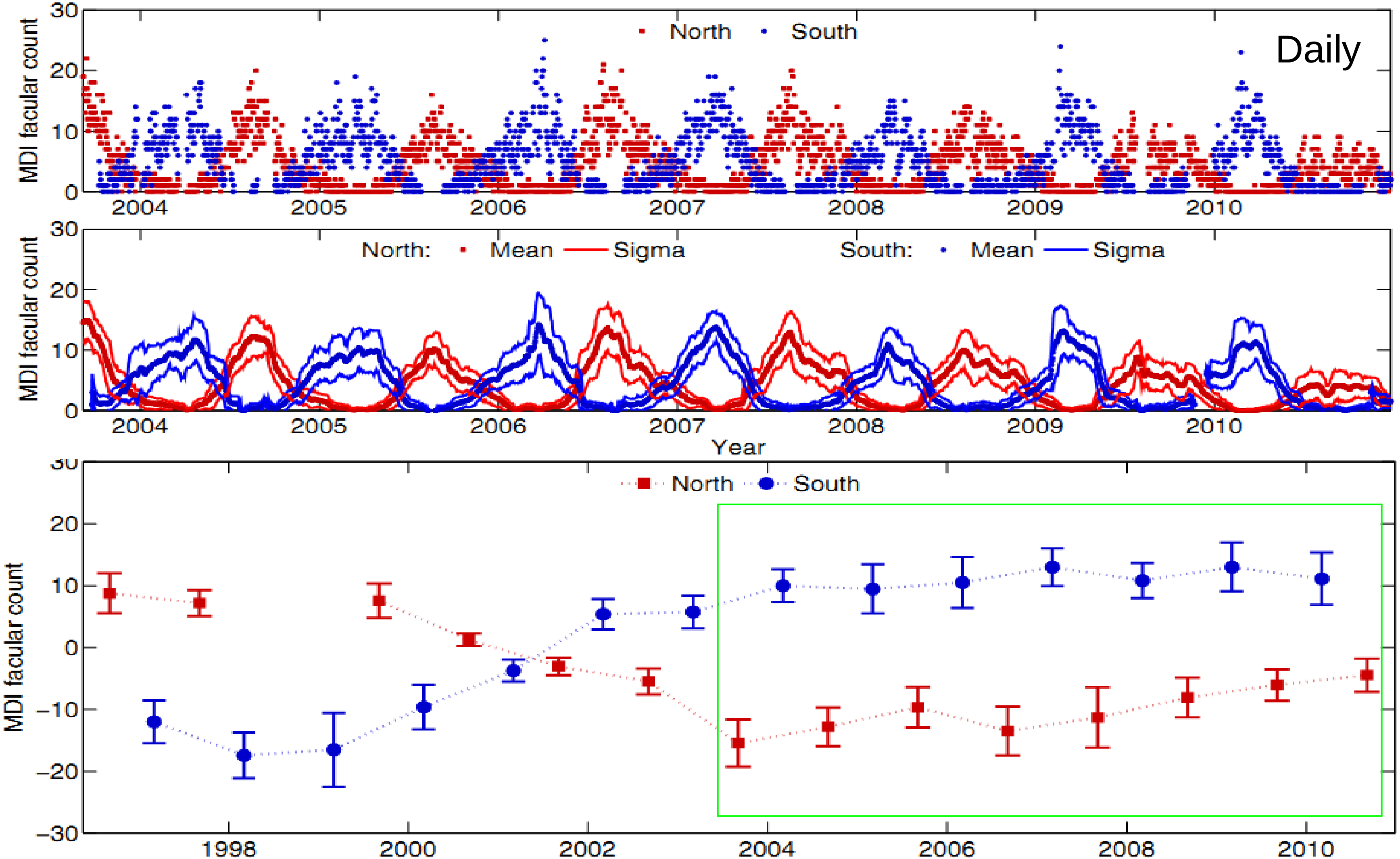
1: Perform ‘gamma scaling’ of the image to enhance contrast using the expression f (x) = 100 x^{γ} where γ = 15 is the enhancement exponent

2: Mask pixels above a certain image intensity threshold (160.0)

3. Remove single facular pixels in order to distinguish facular regions from small and bright intergranular regions

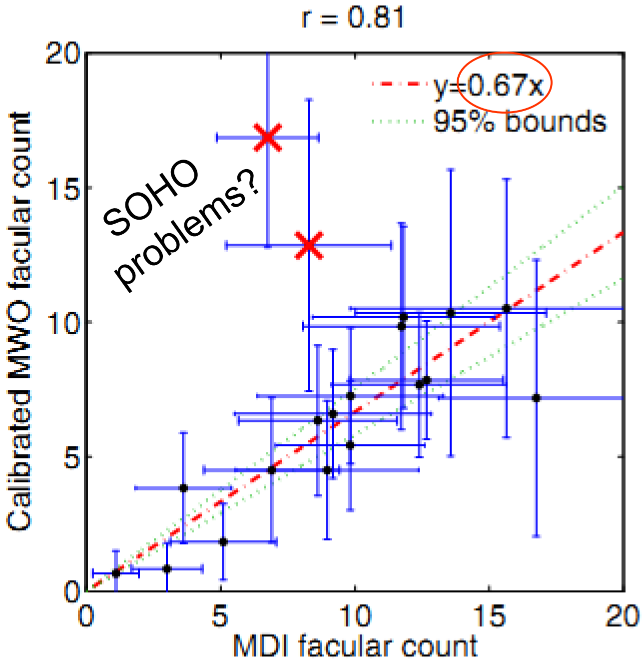
4. Count each isolated facula, fully automatically, independently of the amount of pixels it contains. After removing overexposed, overcorrected, and incomplete images, we obtain a daily data series of facular count to which we apply a month-long running mean

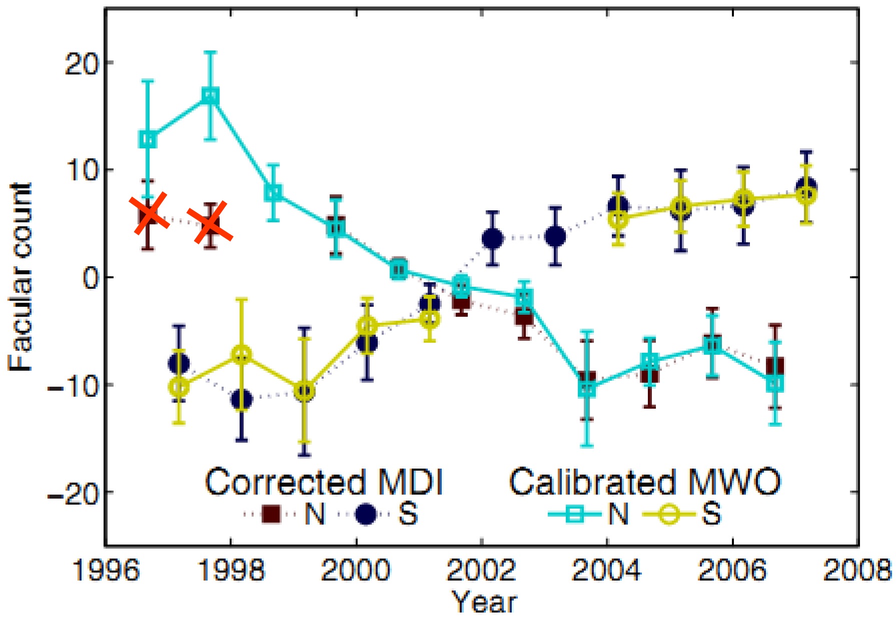
Resulting MDI Facular Counts



Selecting counts near 4 March and 4 Sept. signing with polarity

Calibrating to MWO Facular Count

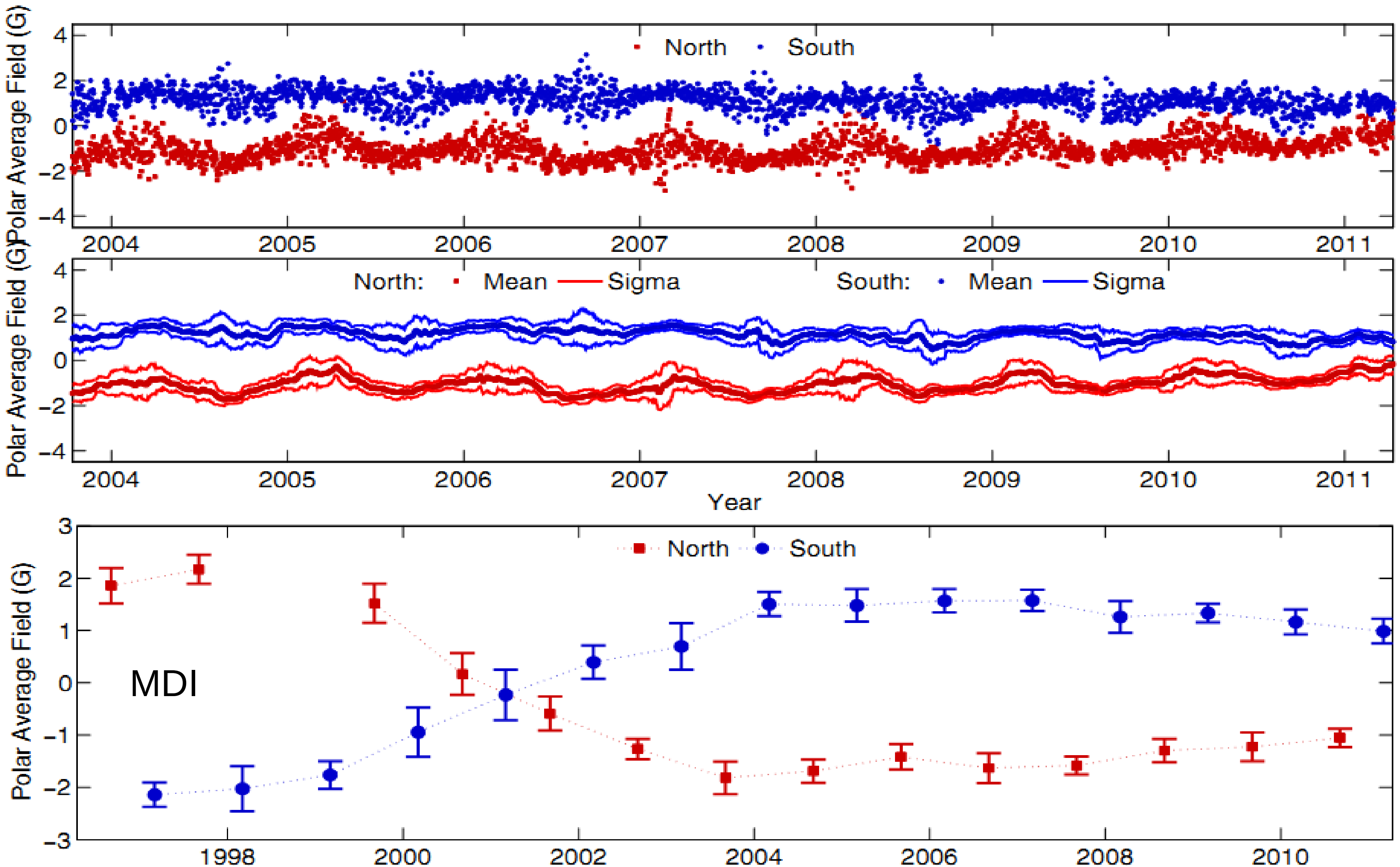




The MDI faculae count is brought onto the MWO [Sheeley!] scale by multiplying by 0.67. The two outliers in 1996 and 1997 are ascribed to problems associated with the SOHO mishaps at that time.

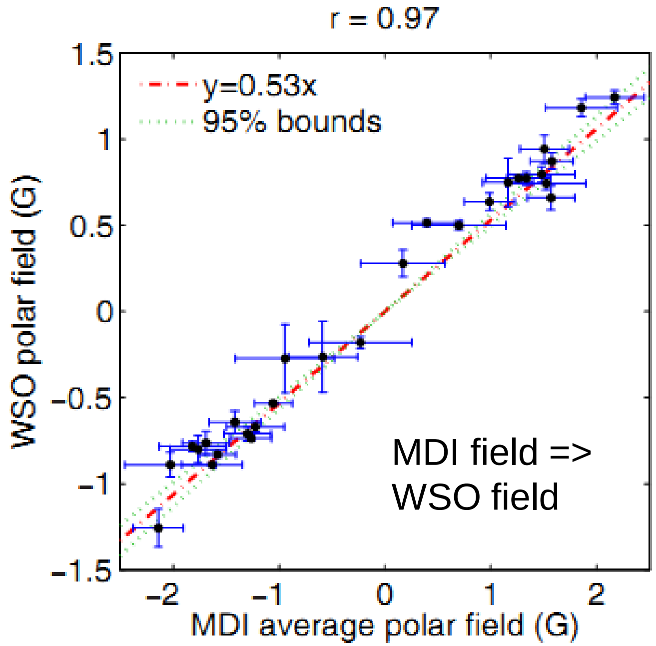
Determining MDI Polar Magnetic Field

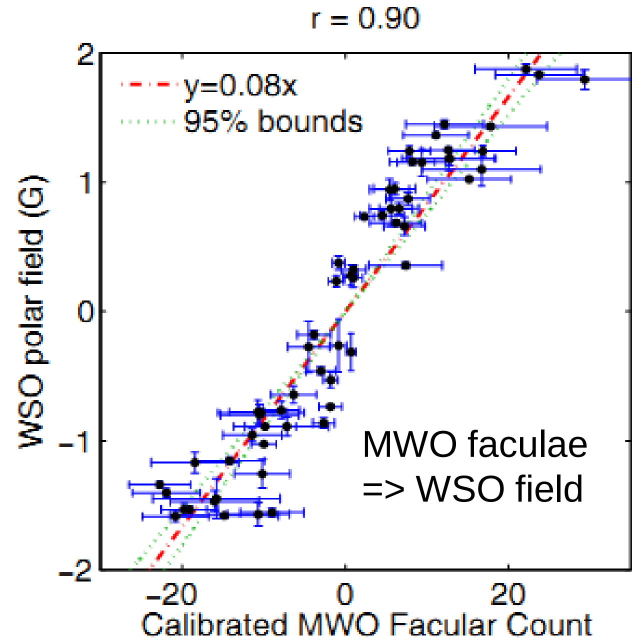
(From LOS, Assuming Vertical Field and using Field for each Facular Pixel)

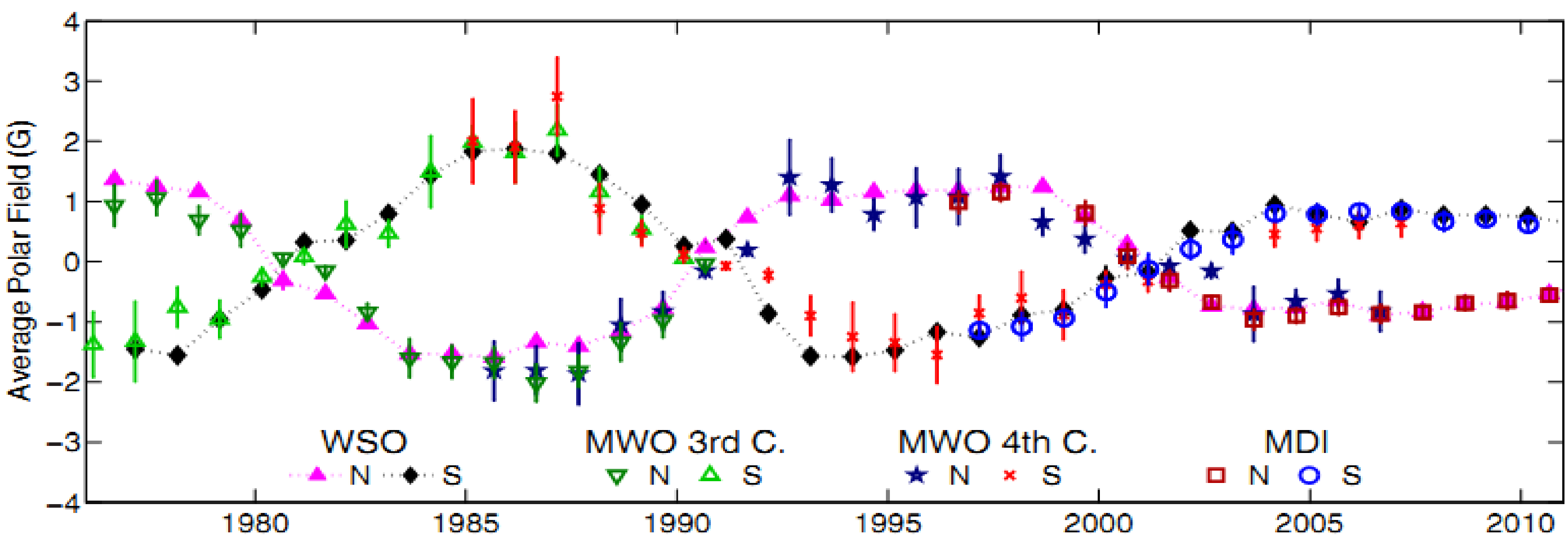


Selecting counts near 4 March and 4 Sept.

Bringing it all onto the WSO Field Scale



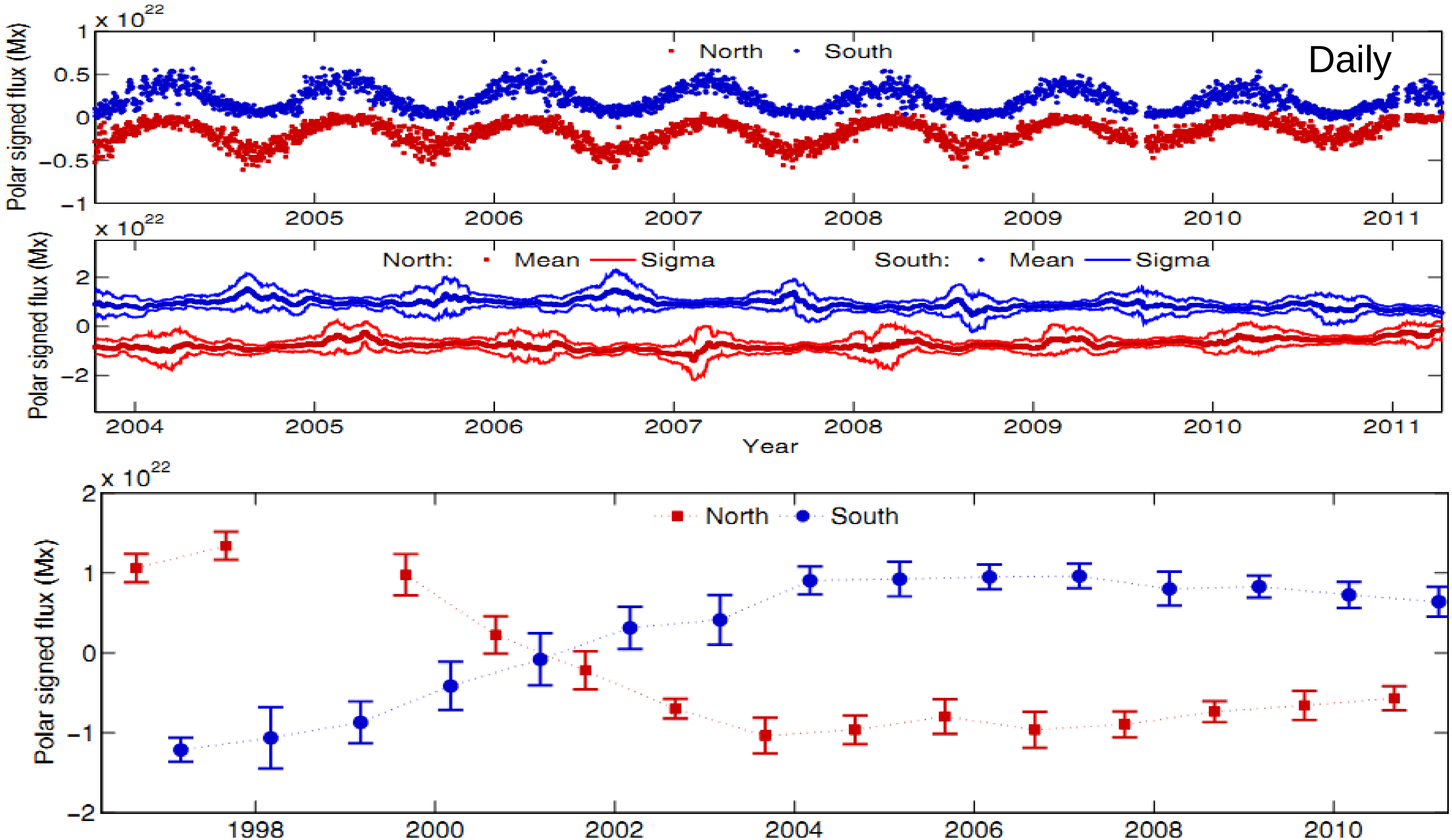




This is nice for Consistency Check, but is not what we really want

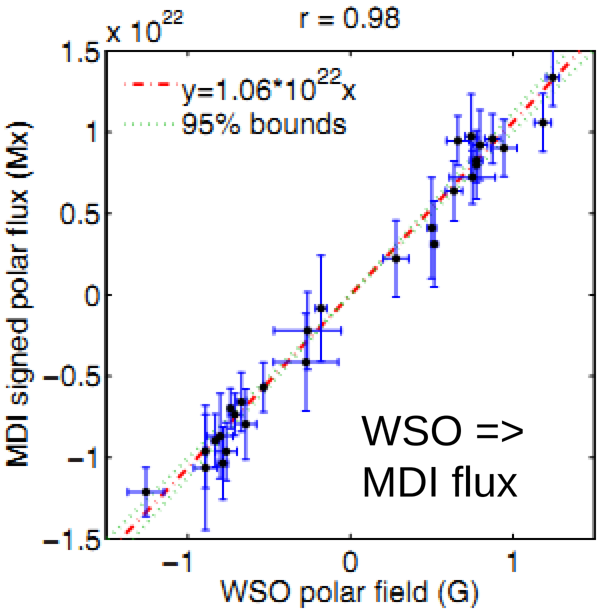
Total MDI Flux for Polar Faculae

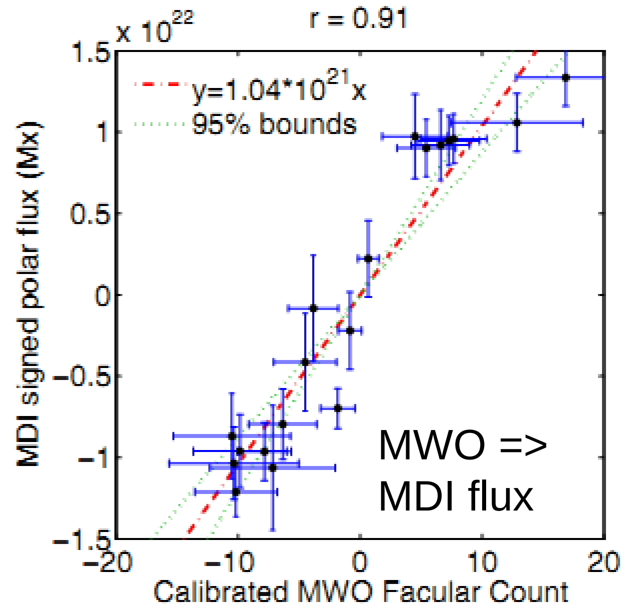
(corrected for foreshortening and axis tilt [2nd panel])



This is what we are after. BTW, HMF flux is ~5 times larger…

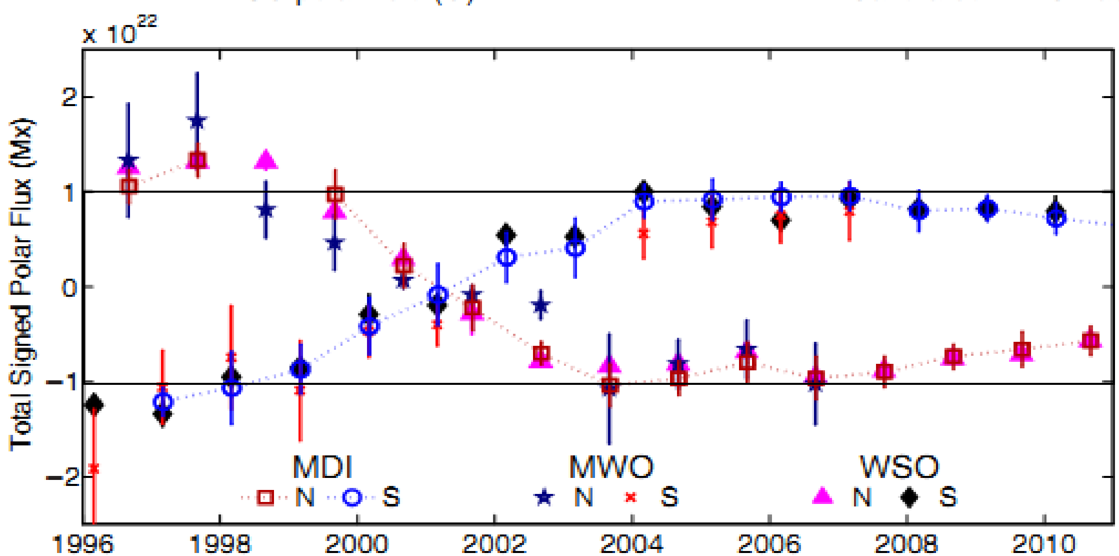
Converting to Polar Cap Magnetic flux





1 [WSO] Gauss equals 10 MWO polar faculae and 10^{22} [MDI] Mx or 10^{14} Wb

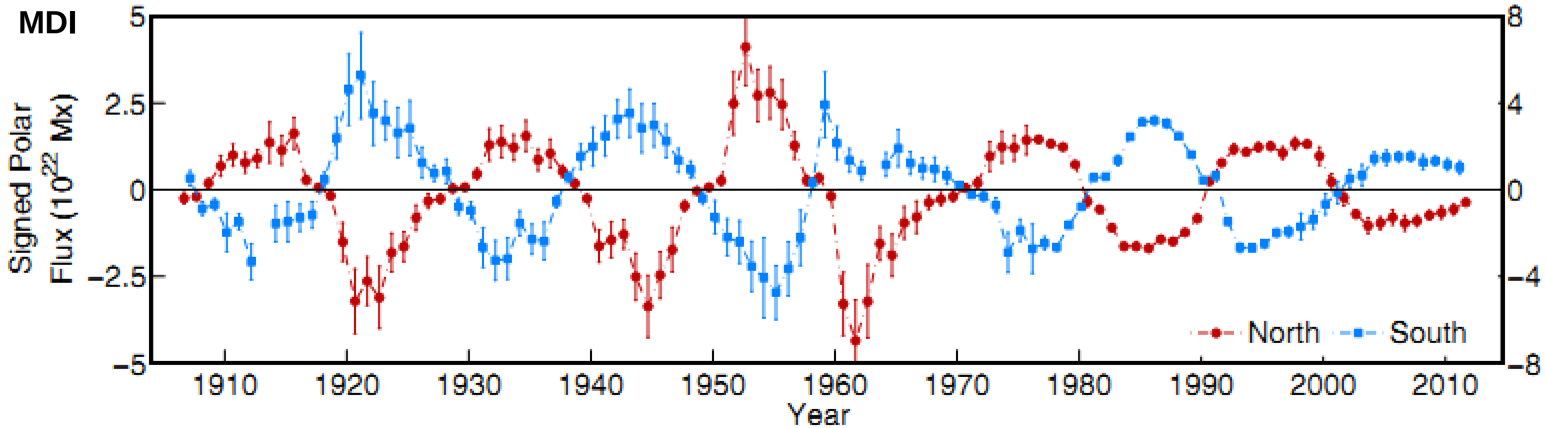
I qualify with the observatory name, because we actually don't know what the values are in real units



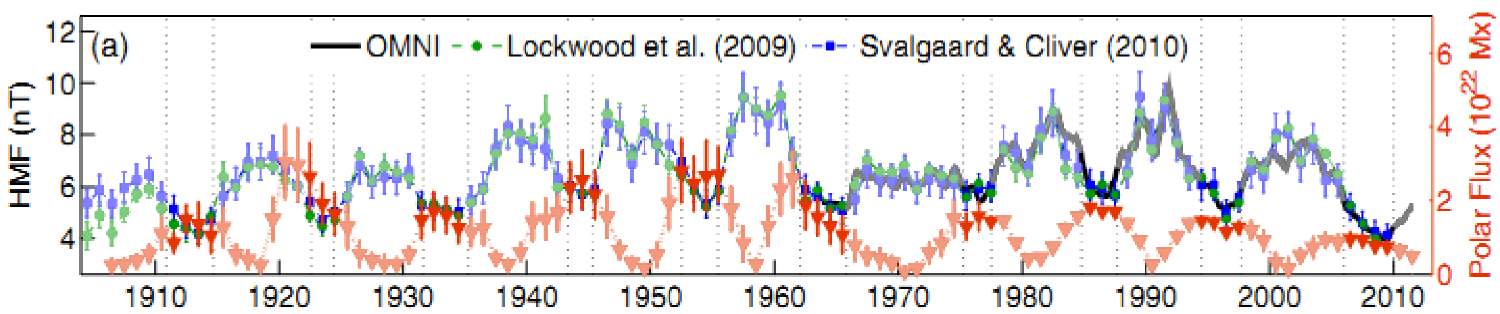
The 'final' result for the total Open Flux per hemisphere is then $1*10^{14}$ Wb [MDI] which is 4 times smaller than that measured in situ by spacecraft near the Earth

Comparison with Heliospheric Open Flux

(at Minimum Coming mostly from the Polar Caps)



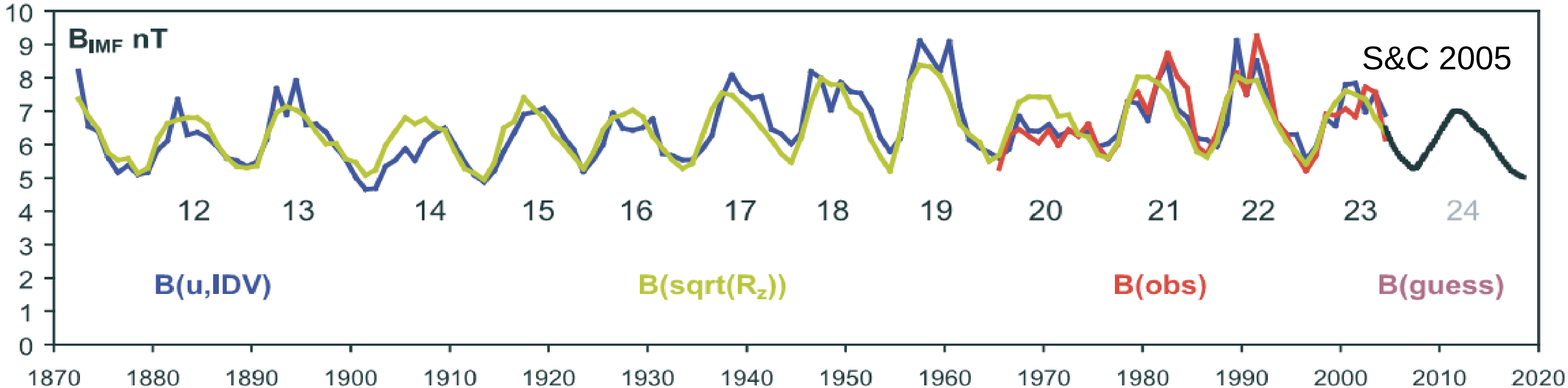
1 G [WSO] = 0.625•10^{22} Mx [MDI]



The red [orange] points show the total [unsigned] open flux from both hemispheres divided by two to simulate the flux from one hemisphere. The blue and green points show the HMF strength at Earth determined independently by Lockwood et al. and by Svalgaard & Cliver using geomagnetic records. The black curve shows HMF observed by spacecraft. Note the good correspondence at solar minima.

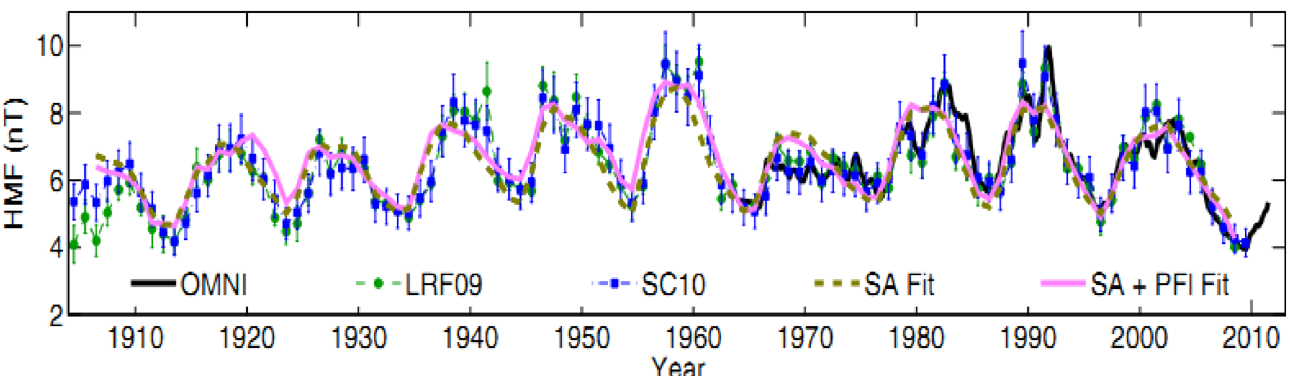
Influence of Solar Activity

The HMF has two components: the open flux from the polar caps and the flux [mixed open and closed] from solar activity [CMEs, Active Regions, etc]. If these active regions emerge at random longitudes, their net equatorial dipole moment will scale as the square root of their number or area [Wang et al. 2005] which would add to the HMF. We confirmed that back in 2005:



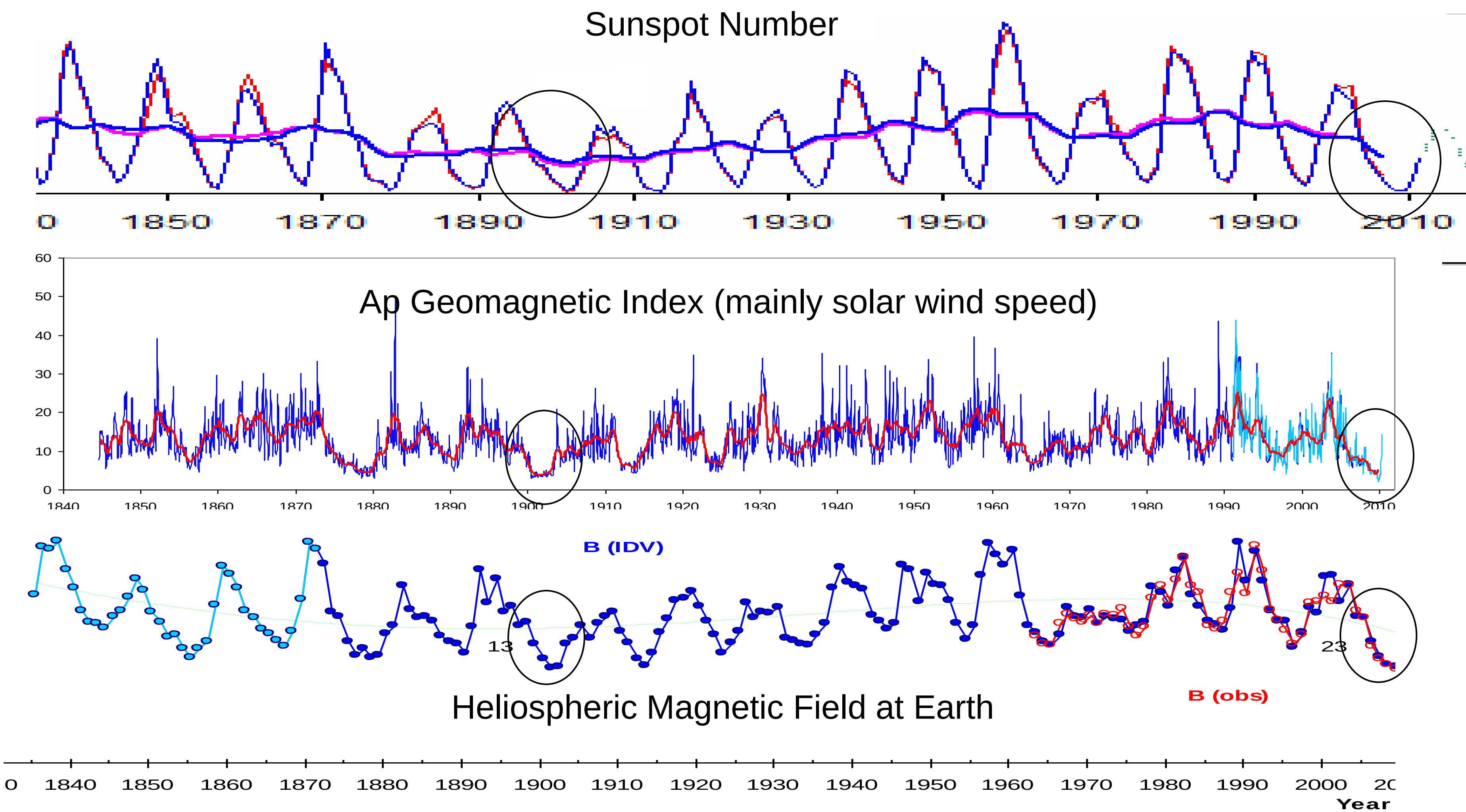
Our three Js had the same brilliant idea:

$$\mathrm{HMF} = a_0 + a_1\sqrt{\mathrm{SA}} + a_2\mathrm{PF}$$



With the same satisfying result

We are Beginning to get a Good Grip on HMF *B* Back in Time



Activity now is similar to what it was a century ago