The Spots That Won't Form

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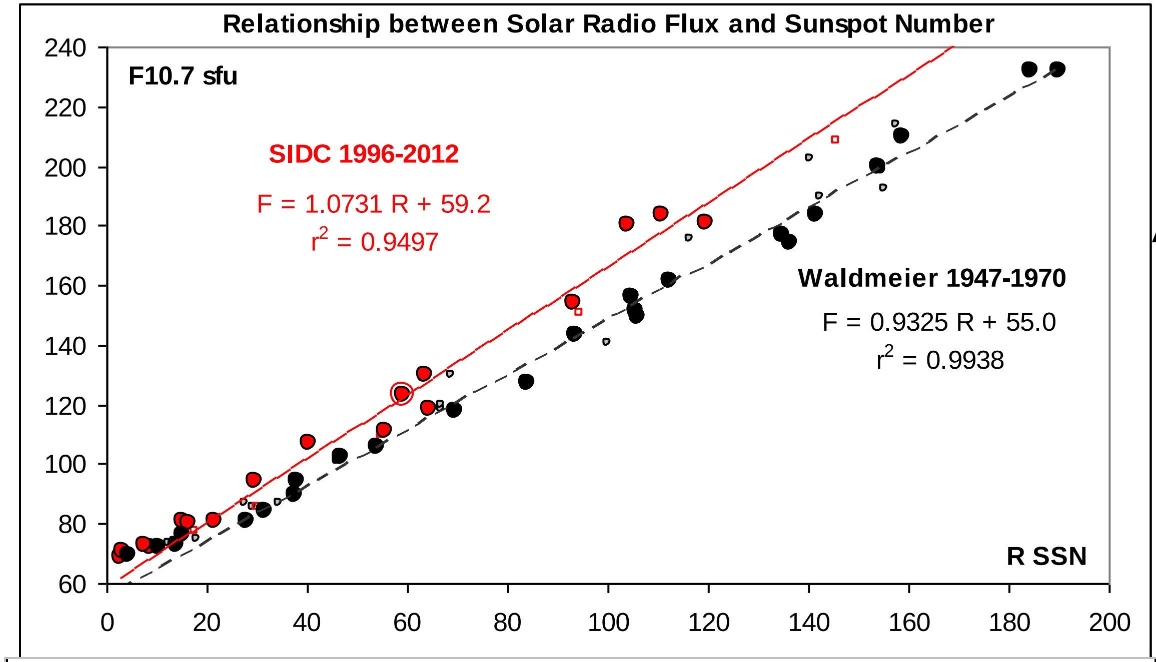
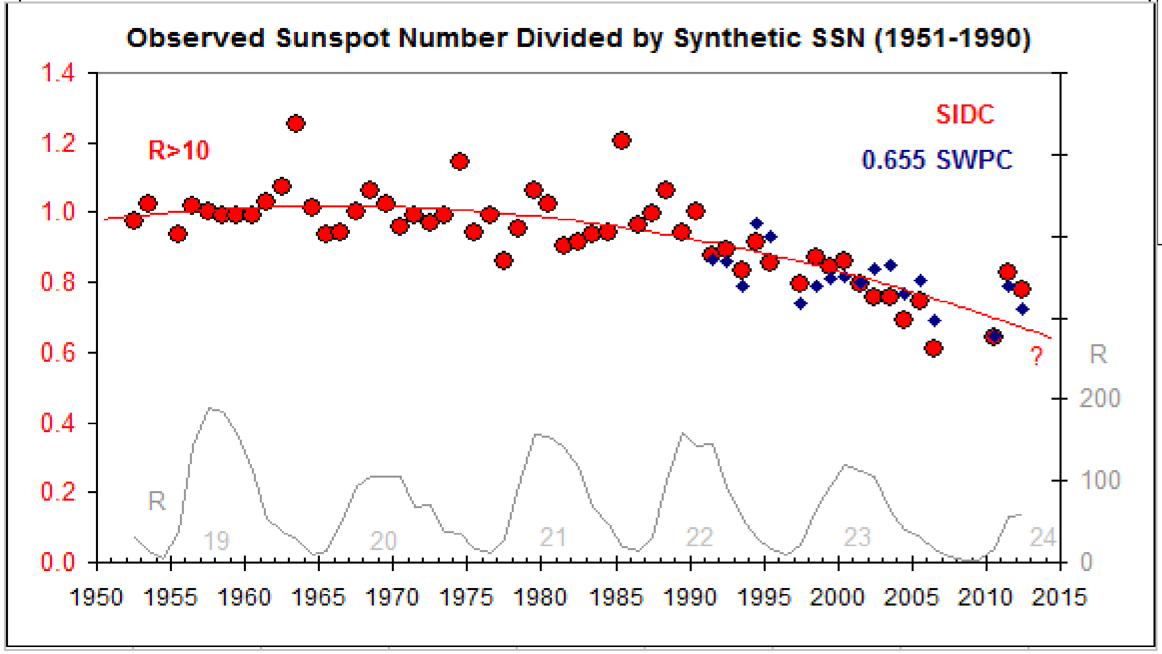
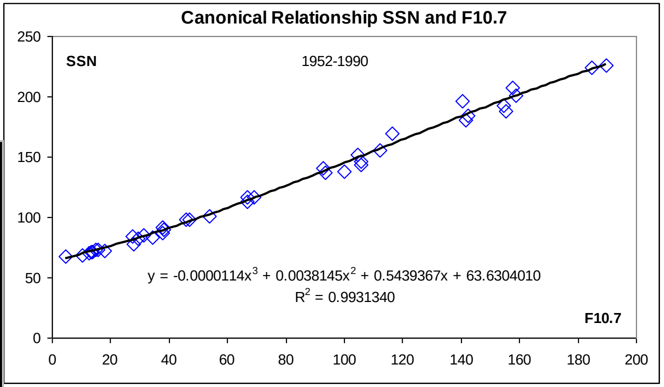
Is the SSN Always a Good Measure of Solar Activity?

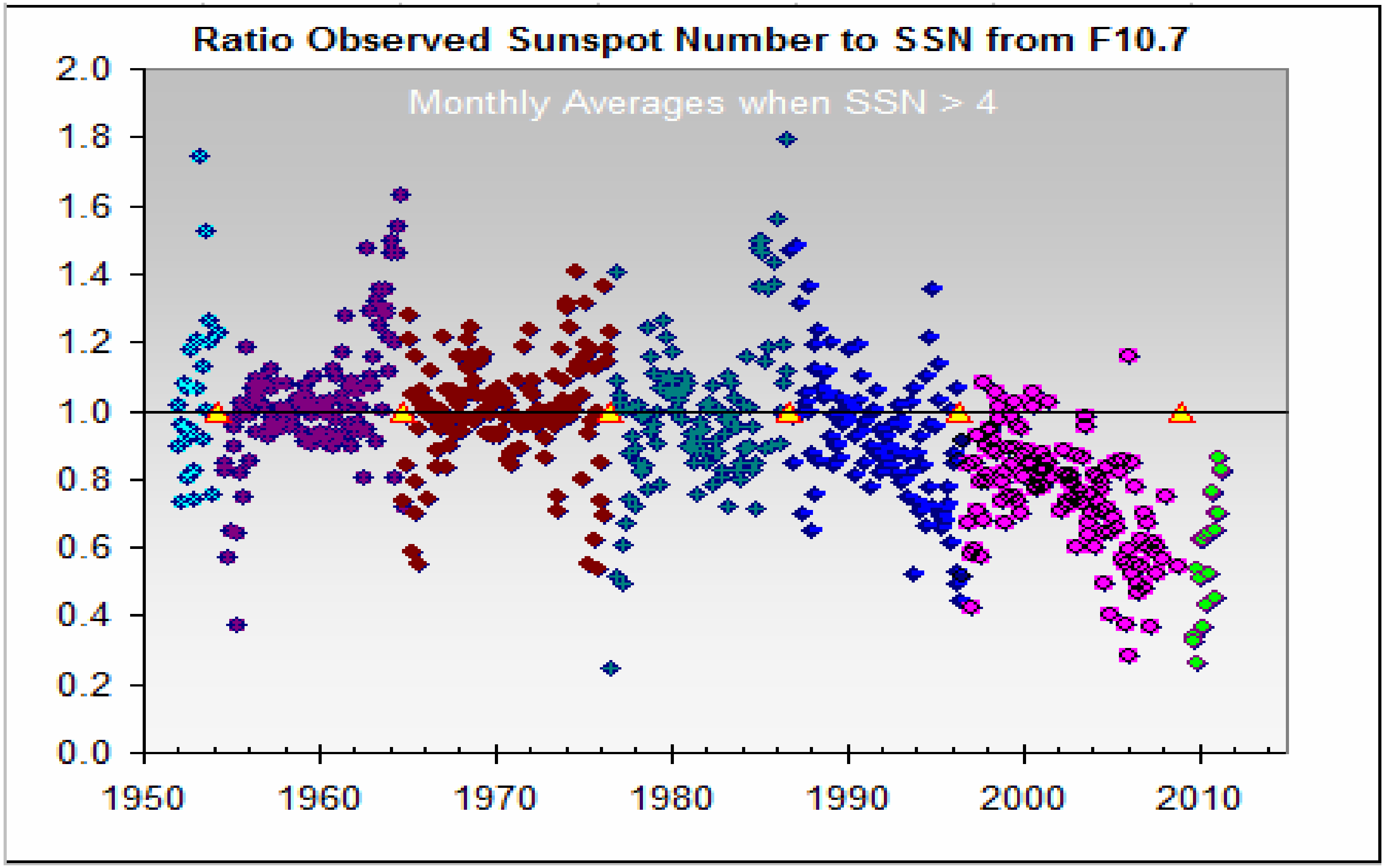


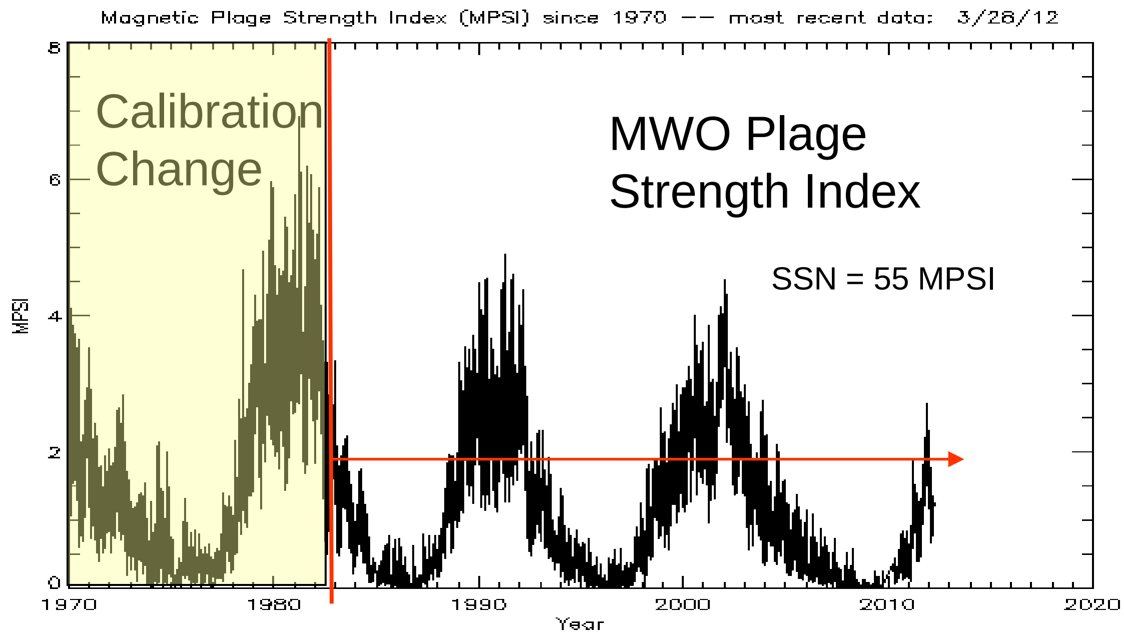




Since ~1990 we record progressively fewer sunspots than expected from observations of F10.7 microwave flux

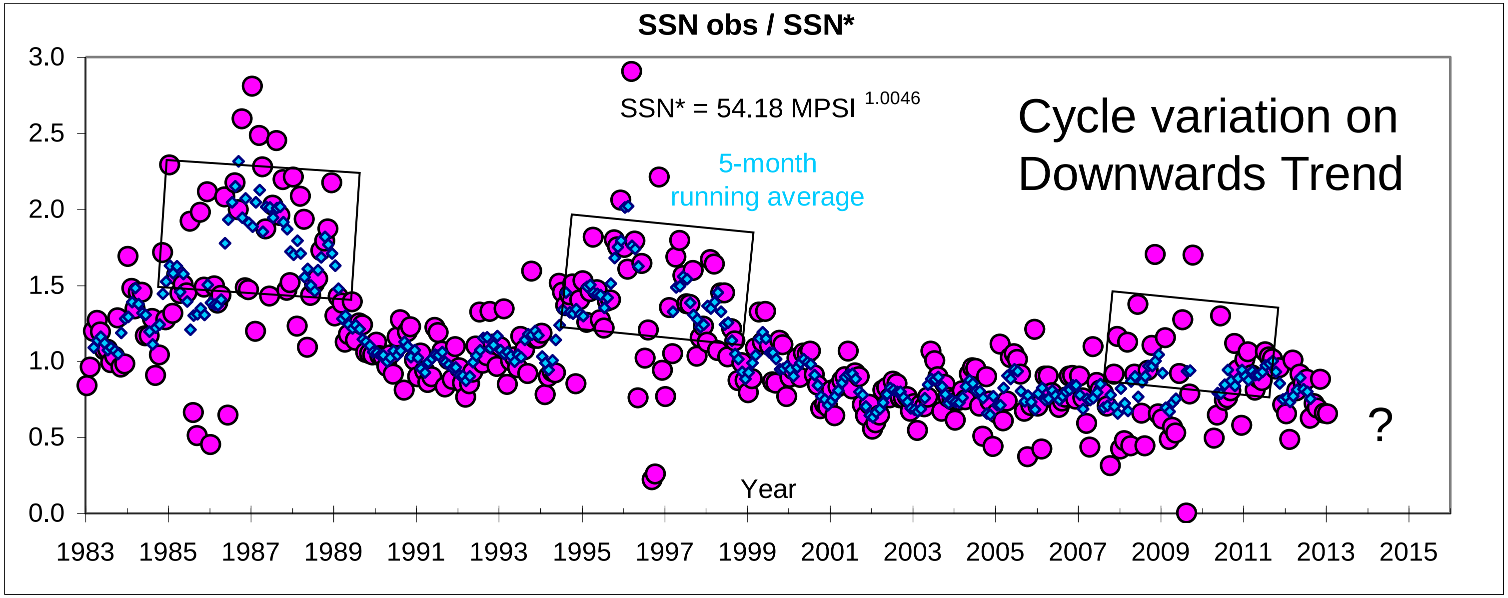
For a given F10.7 flux there are too few sunspots after 2000





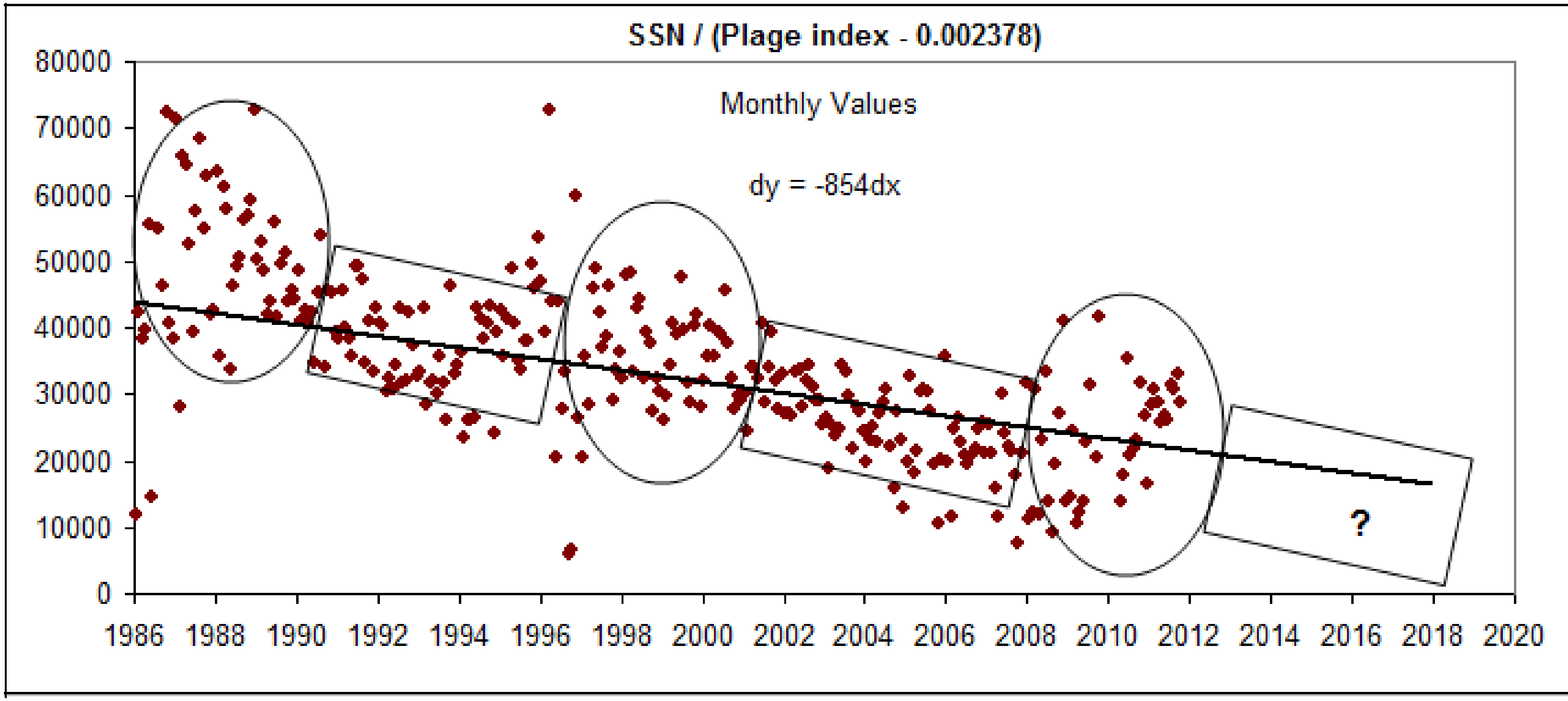
We see fewer sunspots for given MPSI

MPSI is the sum the absolute values of the magnetic field strengths for all pixels where that value is between 10 and 100 gauss. The sum is then divided by the total of number of pixels in the magnetogram.



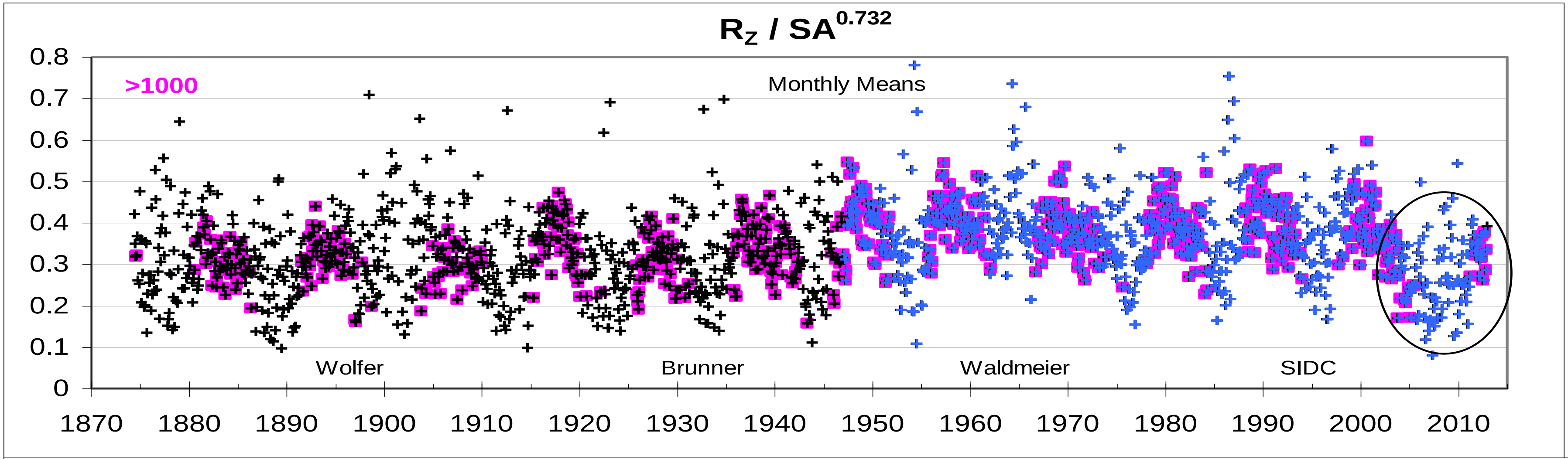
Same result if Ca II or Mg II index is used

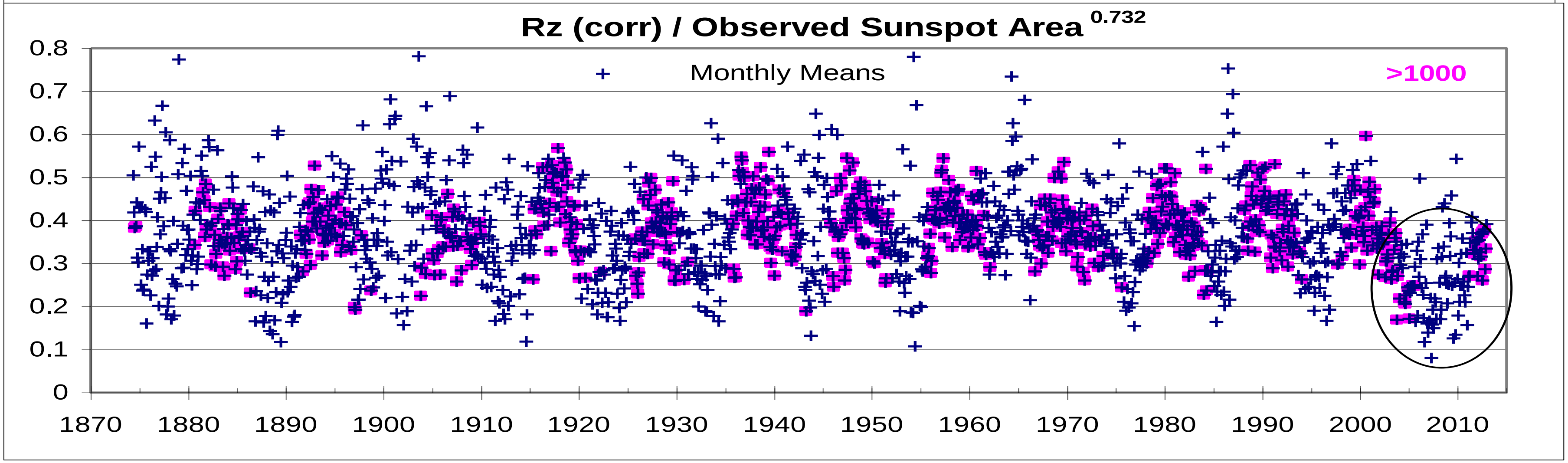
For a given CA II K-line index there are too few sunspots after 2000



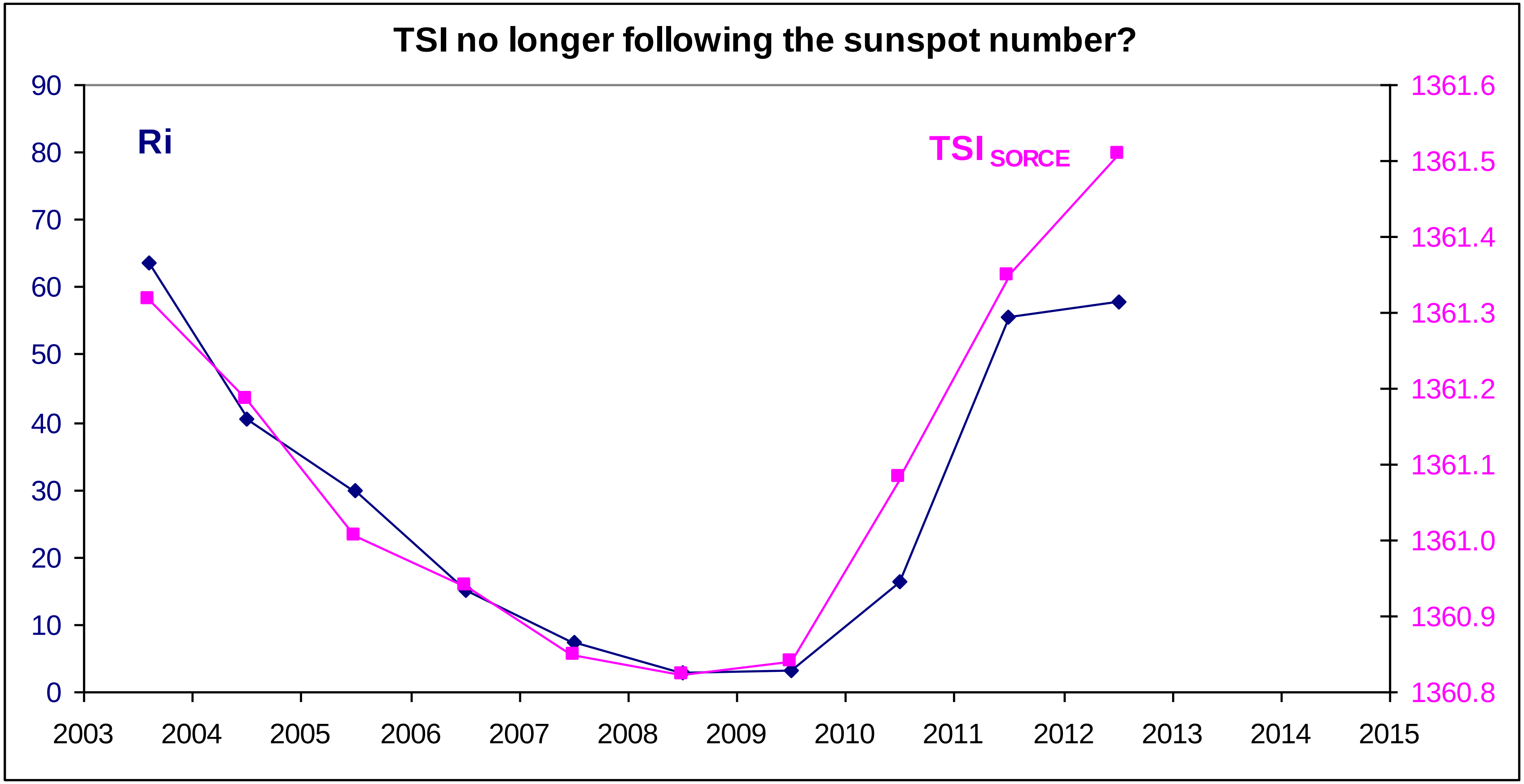
The rising phase seems to be slightly higher than the declining, but the overall trend is a decline of sunspot numbers compared to the CA II emission index.

Sunspots per Area



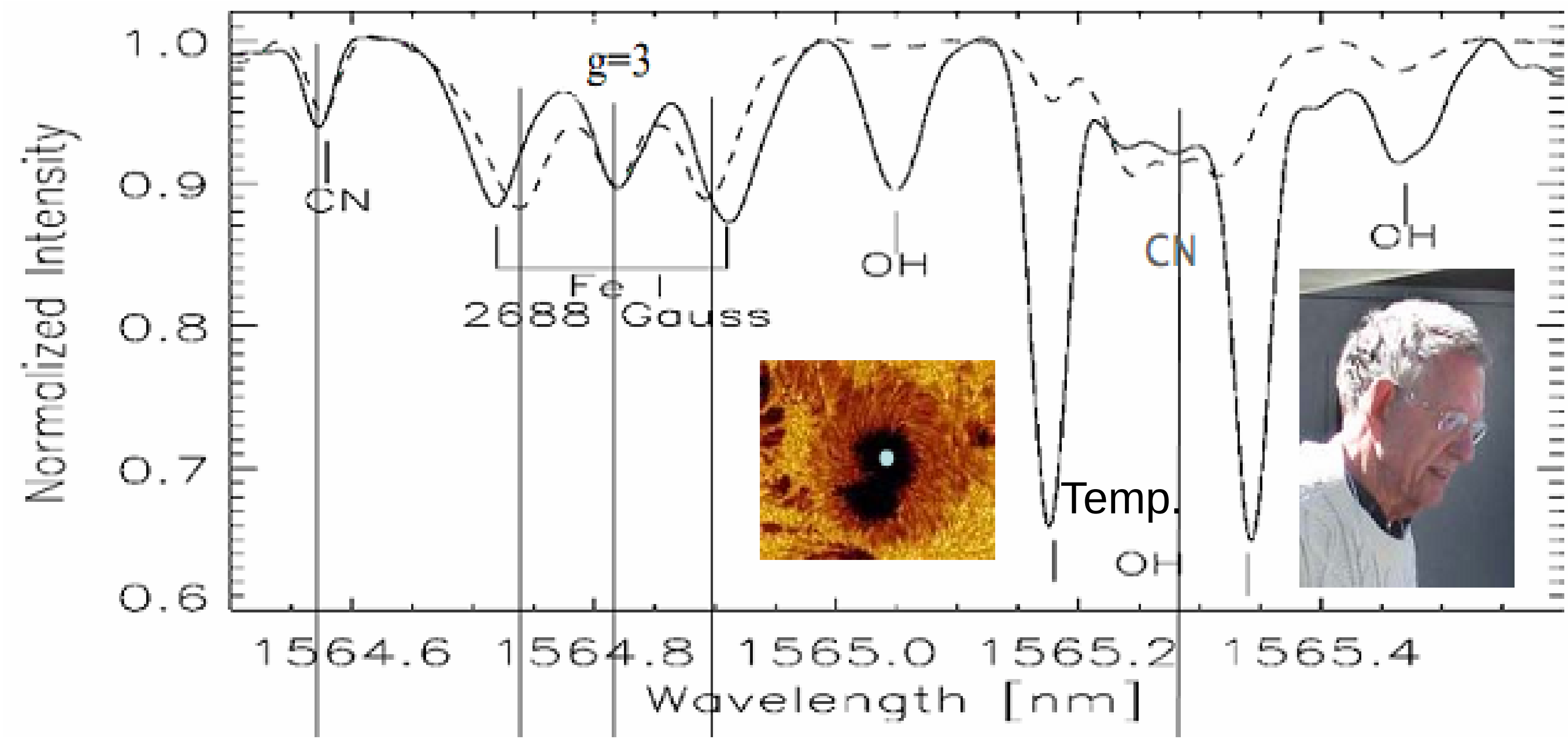


The Sunspot Number is ‘too low’ compared to TSI



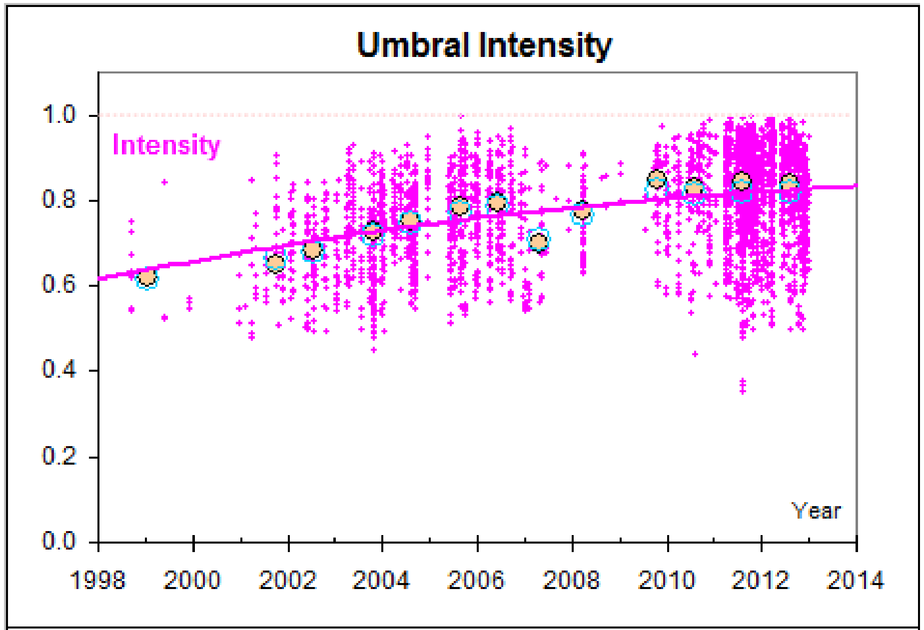
The Total Solar Irradiance used to track the Sunspot Number quite nicely, but with fewer spots compared to faculae, TSI is increasing compared to that expected by the Sunspot Number.

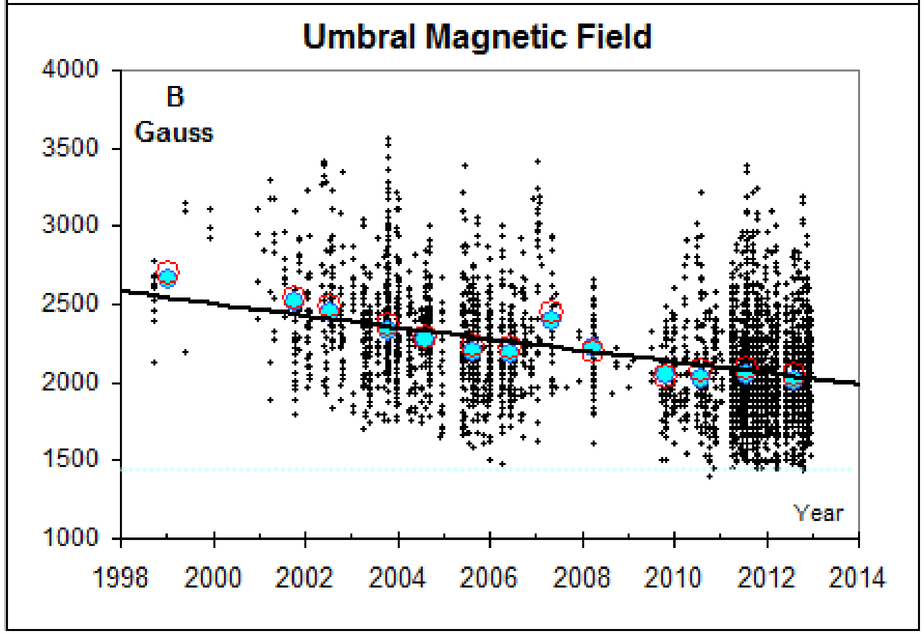
The Livingston & Penn Data

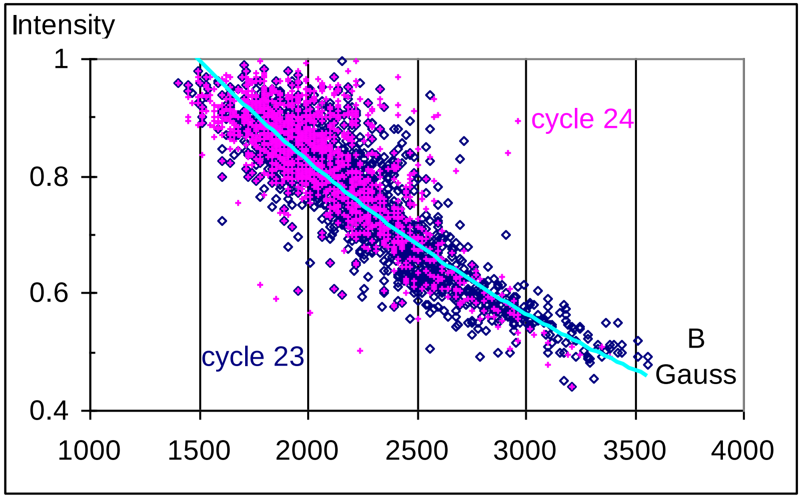


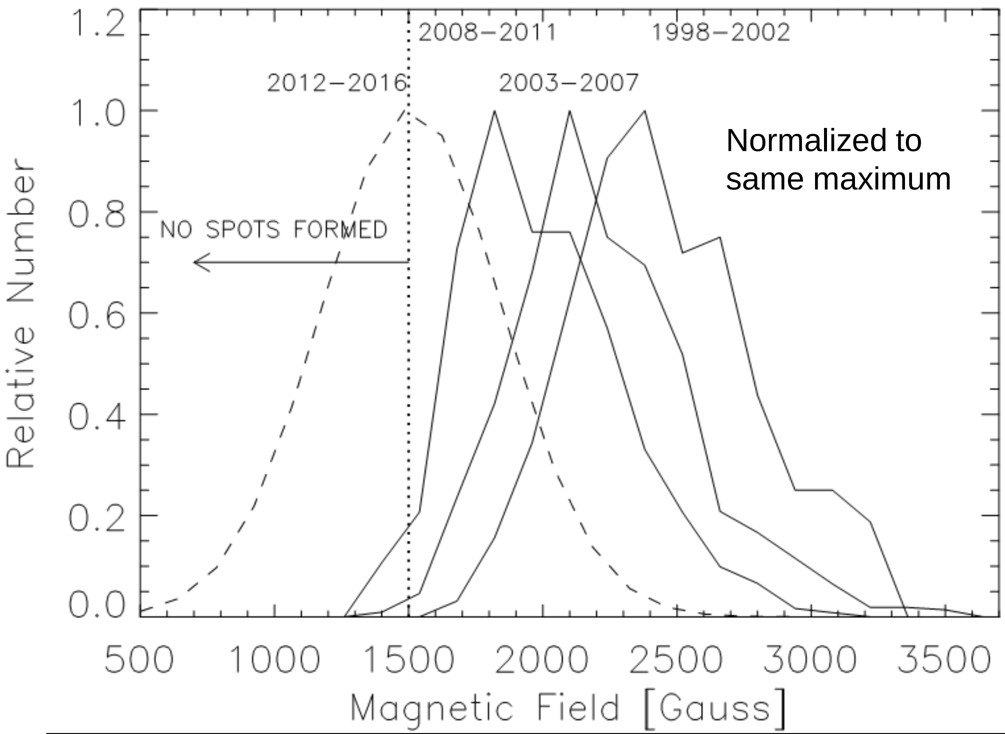
From 1998 through 2012 Livingston and Penn have measured field strength and brightness at the darkest position in umbrae of 3548 spots using the large Zeeman splitting of the infrared Fe 1564.8 nm line..

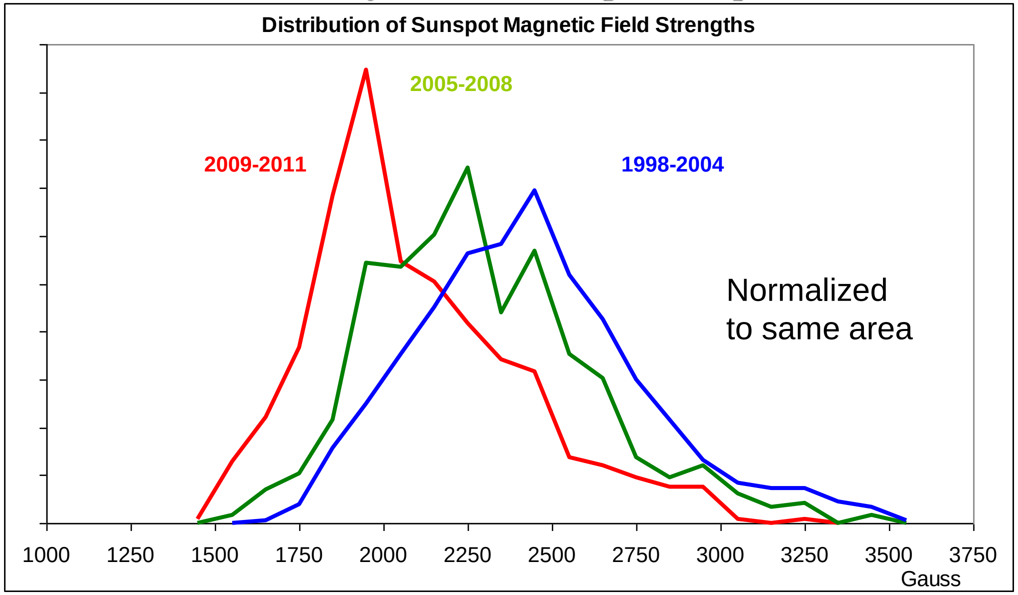
Spot Umbral Intensity [Temperature] and Magnetic Field Changing







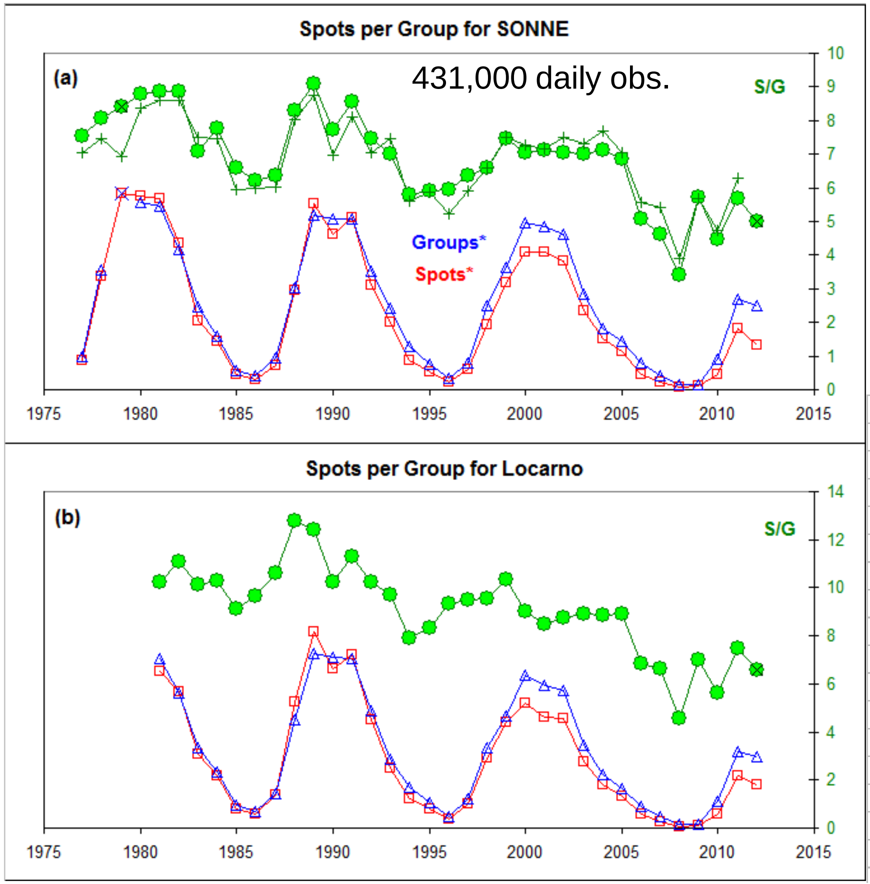


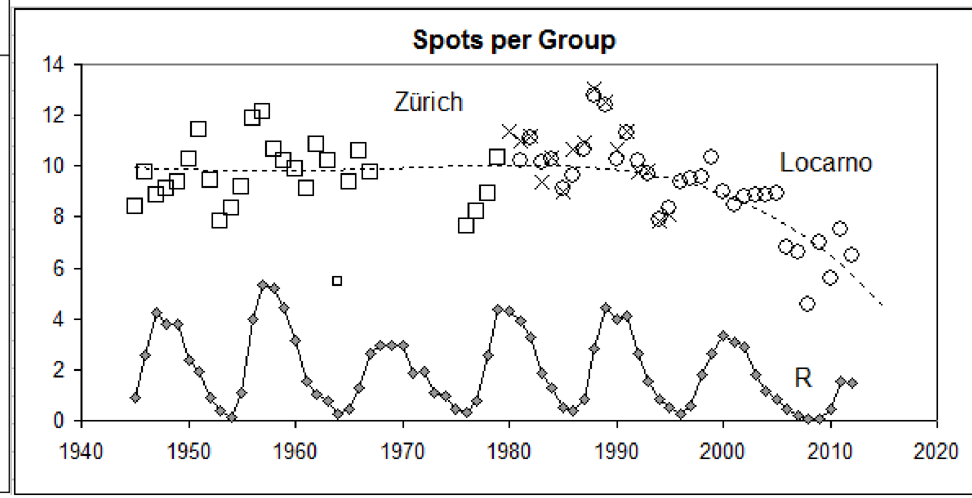


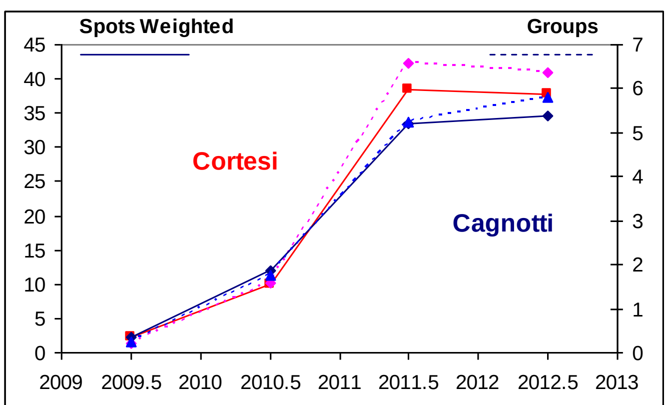
Evolution of Distribution of Magnetic Field Strengths

Sunspots form by assembly of smaller patches of magnetic flux. As more and more magnetic patches fall below 1500 G because of the shift of the distribution, fewer and fewer visible spots will form, as observed

We Observe Fewer Spots per Sunspot Group





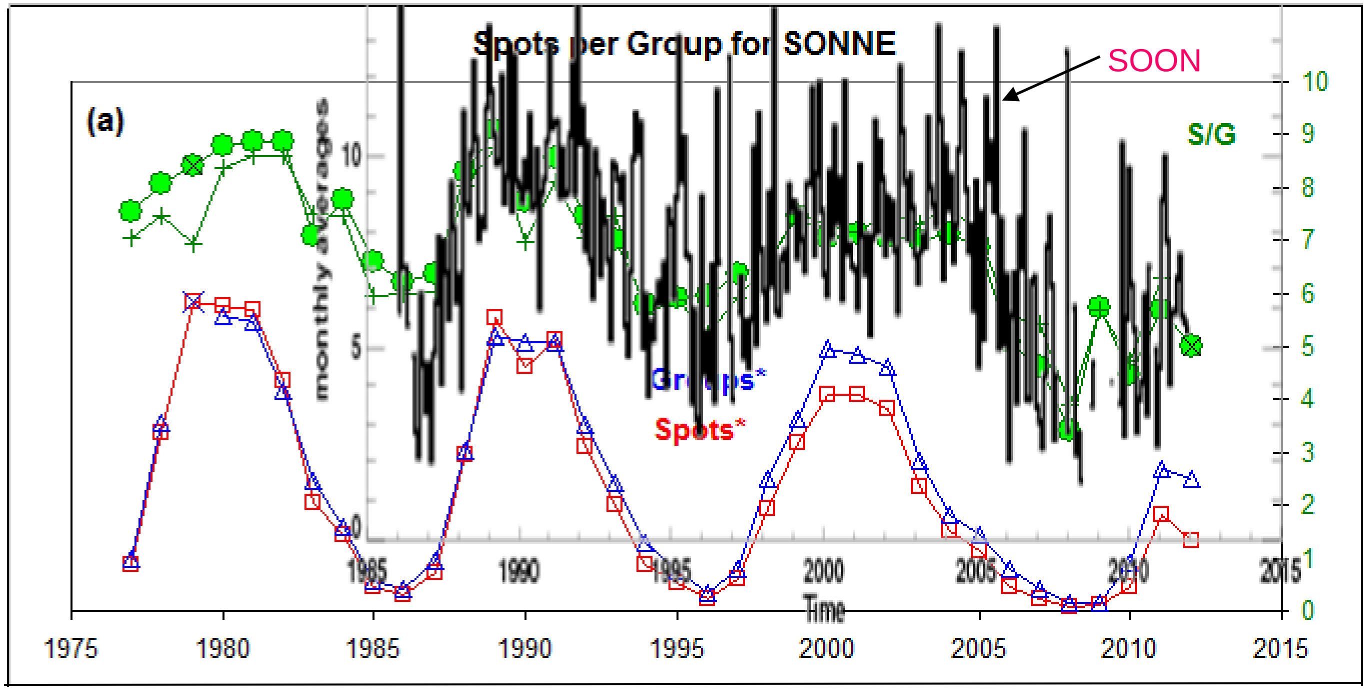


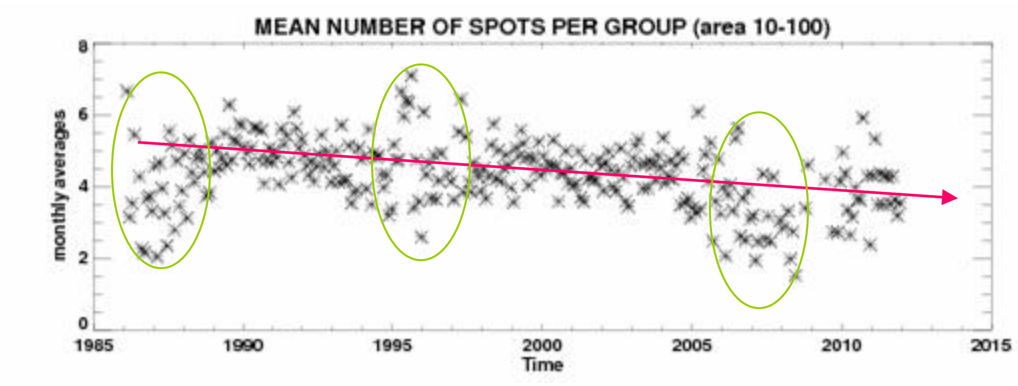
There is a weak solar cycle variation on top of a general downward trend seen by all observers

We are losing the small spots

What could be the cause of that?

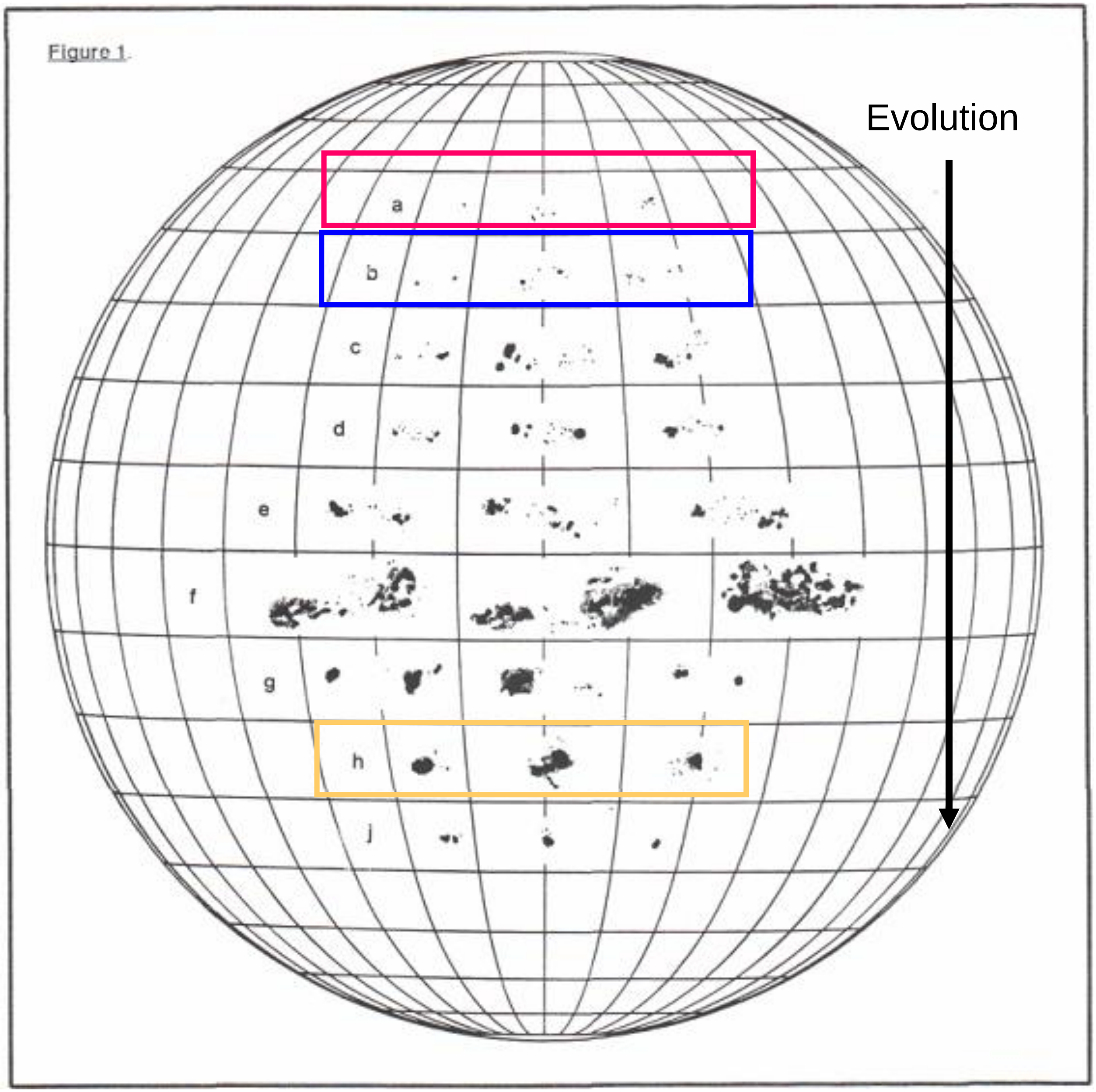
Confirmation Using the SOON Data





Giuliana de Toma reports the number of spots per group recorded by the SOON network. At solar minimum the noise is large (ovals). The result is similar to the decrease seen by the SONNE network. The same decrease is seen in the number of spots per group for very small groups.

The Zürich Classification



a: no penumbra, no bipolar structure

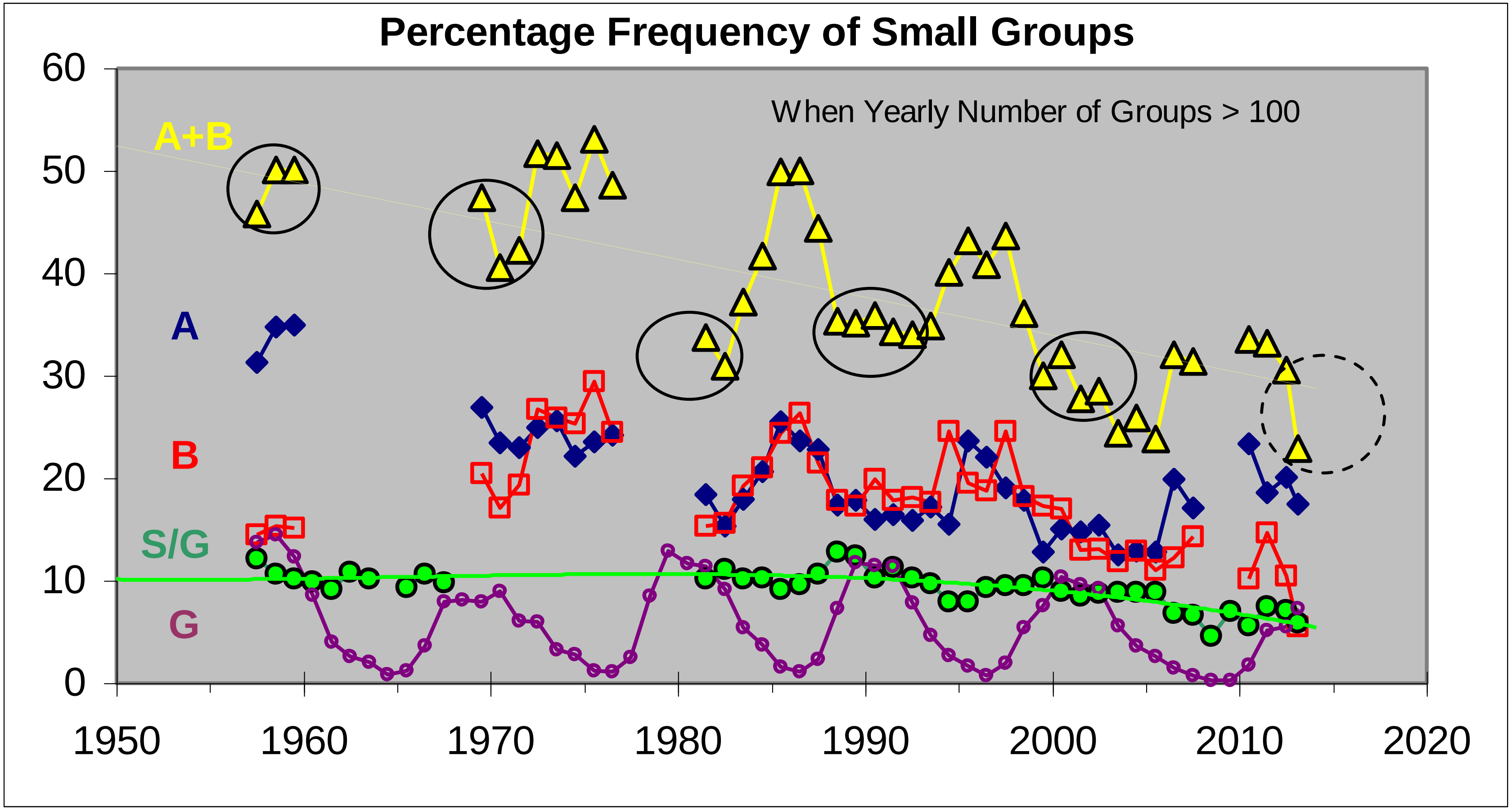
b: no penumbra, but clear bipolar structure

h: with penumbra, but no clear bipolar structure

But **large** spots

Pore: A feature in the photosphere, 1 to 3 arc seconds in extent, usually not much darker than the dark spaces between photospheric granules. It is distinguished from a sunspot by its short lifetime, 10 to 100 minutes.

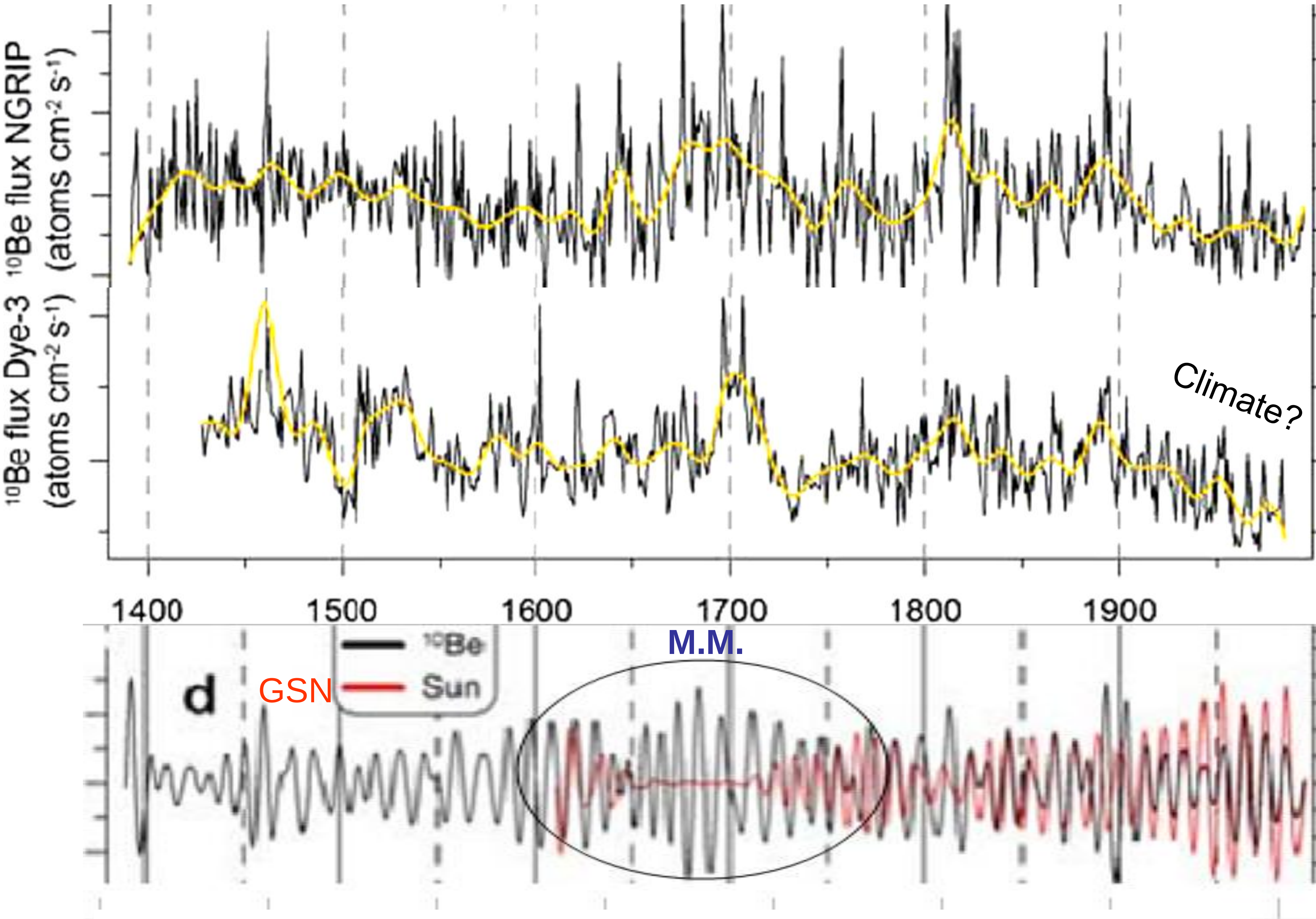
Declining Occurrence of Small Spot Groups [Zürich Class A and B]



Data from Waldmeier, McIntosh, and Locarno

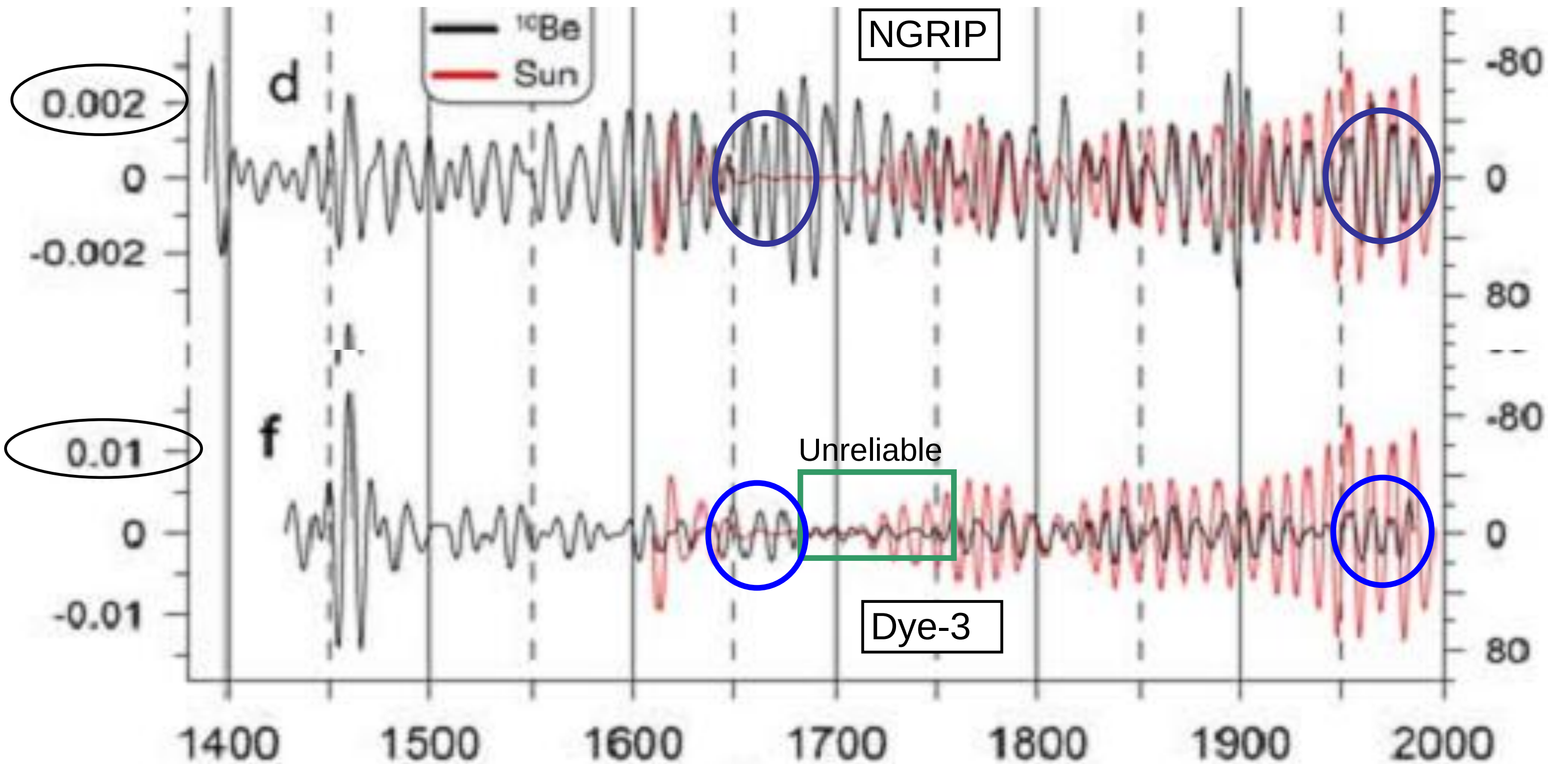
New Solar Activity ‘Regime’

- Can we use the statistical properties of past solar cycles to say something about future cycles?
- If the Maunder Minimum was qualitatively different the answer seems to be ‘No’
- If the Sun is now entering a qualitatively new regime the same conclusion may hold
- ‘Rear guard’ struggle to deny such a possibility seems to miss a chance for exciting new solar physics



Cosmic Ray Proxy [Berggren et al.]

NGRIP is better than Dye-3



Note scale difference by factor of 5. Dye-3 has problems between 1680-1770.

The Figures show the Flux of the 10Be atoms, not the Concentration.

The Problem with Dye-3

In Dye-3, differences between concentration and flux exist mainly around 1490–1530 AD and partly during **1680–1770** AD. In order to investigate how these periods and differences correspond to solar activity, we compare NGRIP and Dye-3 concentration and flux with frequencies found in the sunspot number record (Figure 2). We note that NGRIP 10Be concentration and flux both have a negative relationship to solar activity, although there are occasional leads and lags before 1820 AD and during 1880–1910 AD in both 10Be parameters relative to the solar data. In Dye-3, there are phase differences until around 1780 AD, after which 10Be is well synchronized with the sunspots. This indicates that there is either some dating uncertainty in the older part of the cores, where Dye-3 dating was established by a different method than in the newer part, or there was a slower response in the 10Be deposition to changes in solar activity. It should be stressed that the good agreement between NGRIP and Dye-3 fluxes suggest that remaining dating inaccuracies are small. In the period around 1800 AD when NGRIP 10Be is slightly out of phase with the sunspot cycle, Dye-3 concentration is in phase, underlining the importance of having data from at least two high resolution cores for an accurate solar activity reconstruction. In addition, **we reconfirm earlier findings [Beer et al., 1998] of a cyclically active sun during [grand] solar minima; a clear Schwabe cycle is present in both cores during the Maunder minimum**, especially so in NGRIP.

‘Burning Prairie’ => Magnetism

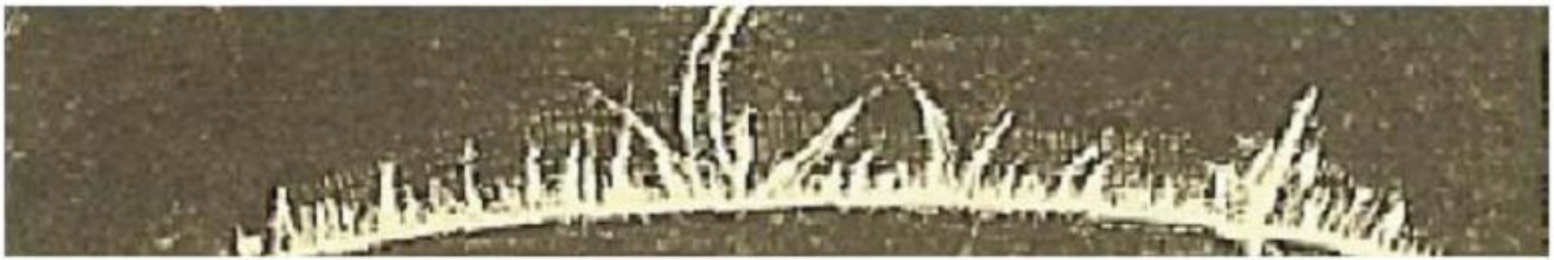


Figure 1 An early drawing of the “burning prairie” appearance of the Sun’s limb made by C.A. Young, on 25 July 1872. All but the few longest individual radial structures are spicules.

It is now well known (see, *e.g.*, the overview in Foukal, 2004) that the spicule jets move upward along magnetic field lines rooted in the photosphere outside of sunspots. Thus the observation of the red flash produced by the spicules requires the presence of widespread solar magnetic fields. Historical records of solar eclipse observations provide the first known report of the red flash, observed by Stannyan at Bern, Switzerland, during the eclipse of 1706 (Young, 1883). The second observation, at the 1715 eclipse in England, was made by, among others, Edmund Halley – the Astronomer Royal. These first observations of the red flash imply that a significant level of solar magnetism must have existed even when very few spots were observed, during the latter part of the Maunder Minimum.

Foukal & Eddy, Solar Phys. 2007, *245*, 247-249

My Working Hypothesis

- The Maunder Minimum was not a serious deficit of magnetic flux, but
- A lessening of the efficiency of the process that compacts magnetic fields into visible spots
- This may now be happening again
- If so, there is new solar physics to be learned, let us not shy away from that!