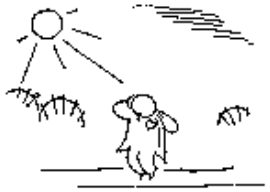
“Does the Sun Vary Enough?”

Leif Svalgaard
Stanford University, CA, USA
leif@leif.org
http://www.leif.org/research

Eddy symposium, Oct. 22, 2010

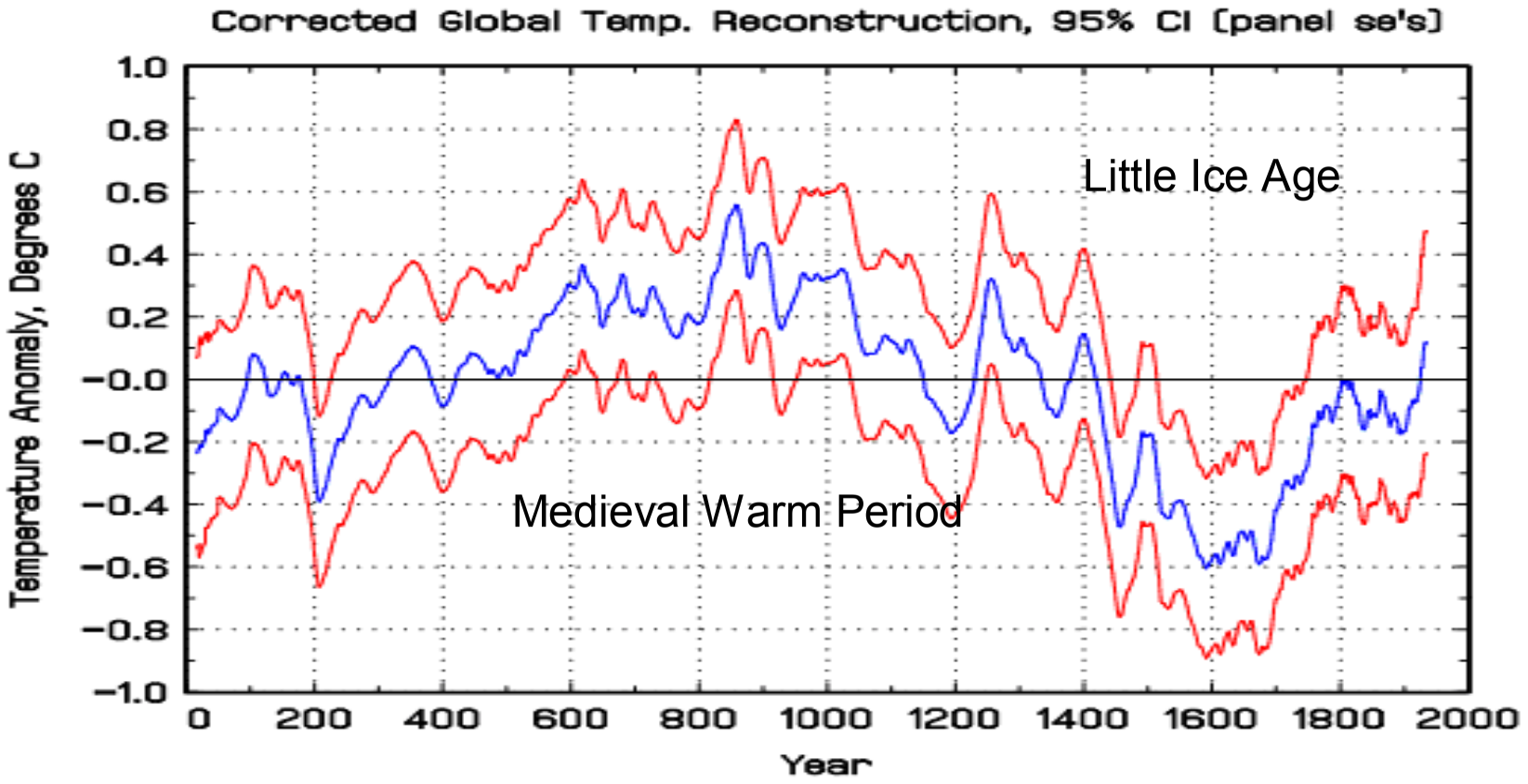
Was the Little Ice Age Global?

Sun that gives all things birth
Shine on everything on earth!
If that's too much to demand
Shine at least on this our land
If even that's too much for thee
Shine at any rate on me

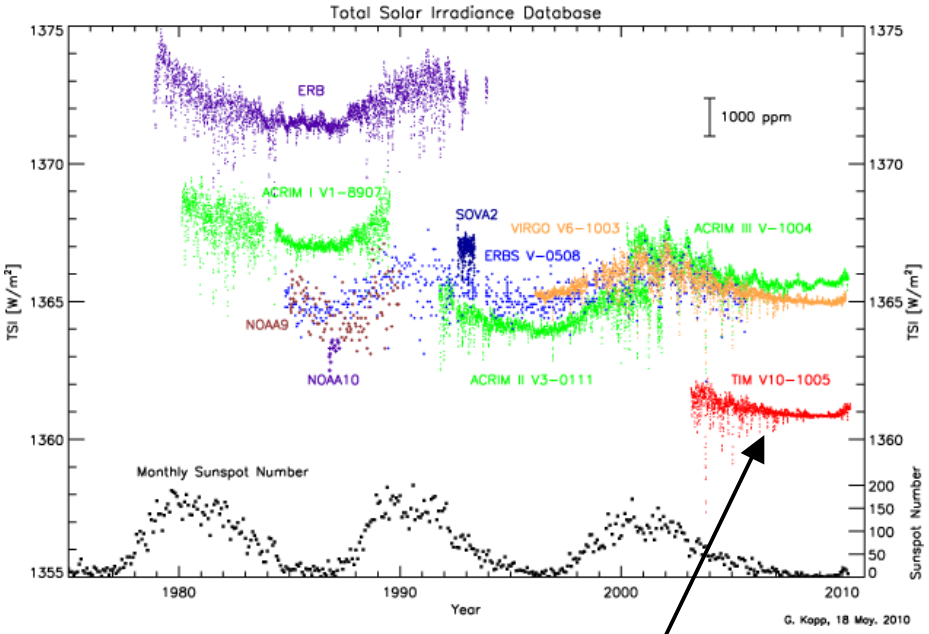


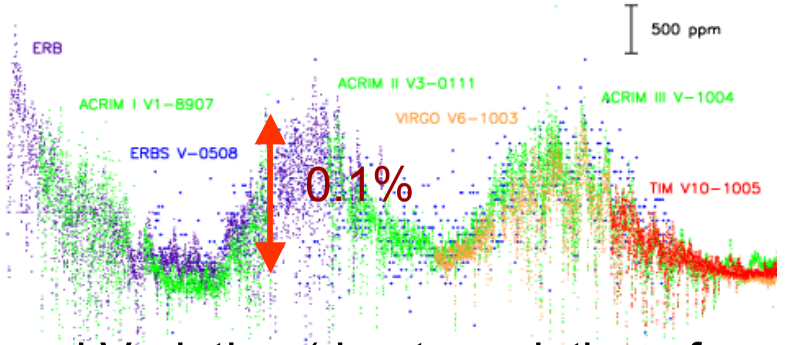
Piet Hein (Danish Poet, 1905-1996)

Craig Loehle: Global Temperature Reconstruction [non-tree ring]. Range ~1ºC

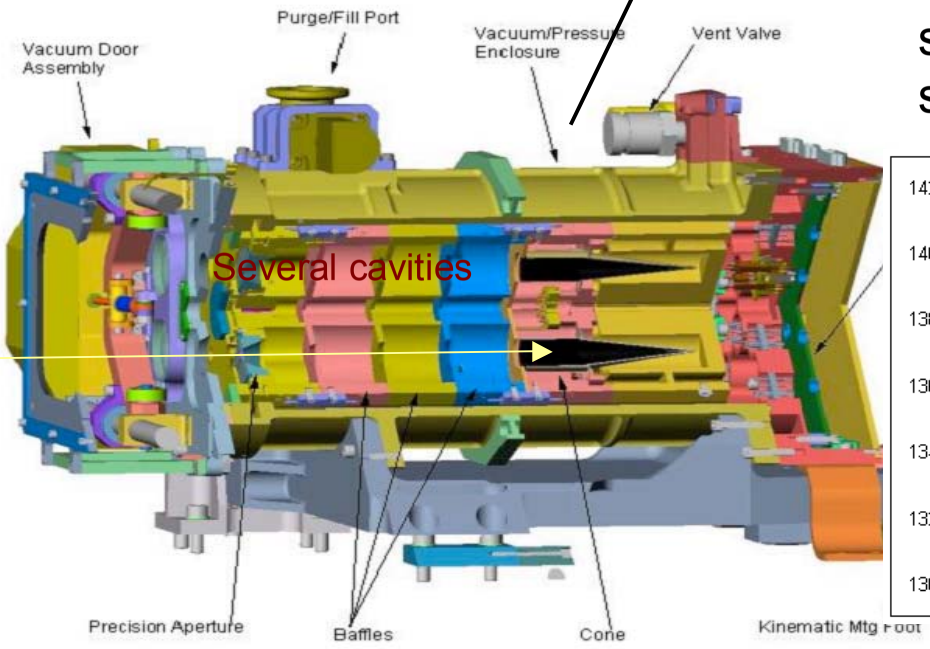


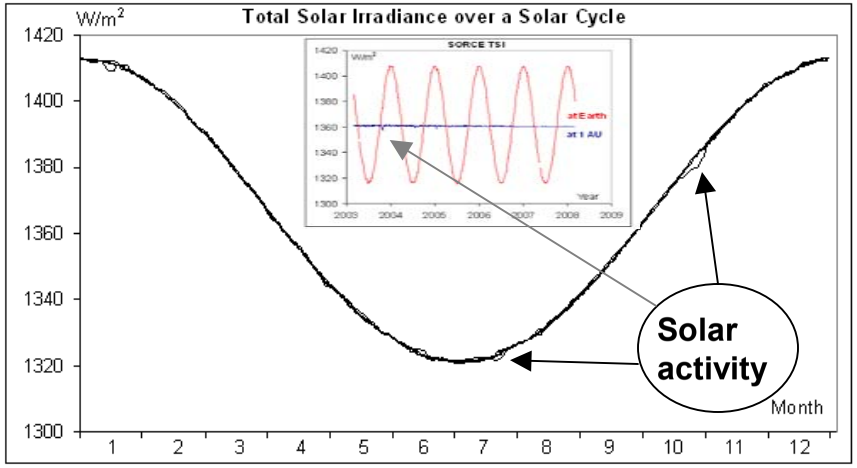
Measurement of TSI by spacecraft



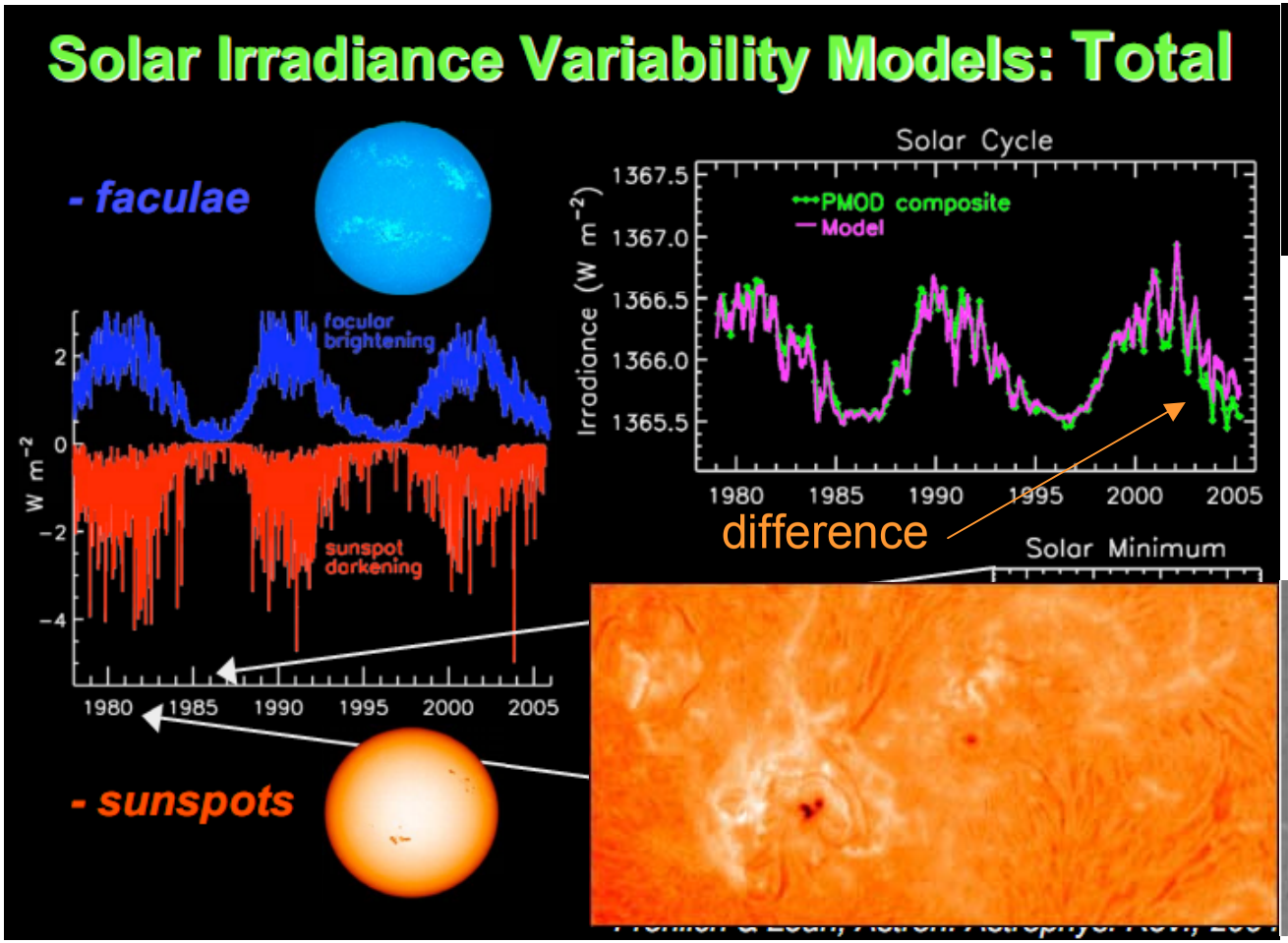


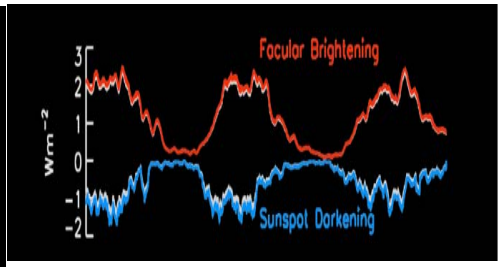
Annual Variation (due to variation of solar distance) is 70 times larger than solar cycle variation:



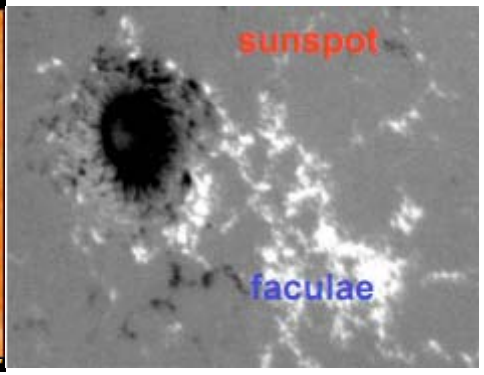


TSI is the combined effect of sunspot dimming and facular brightening (2x)



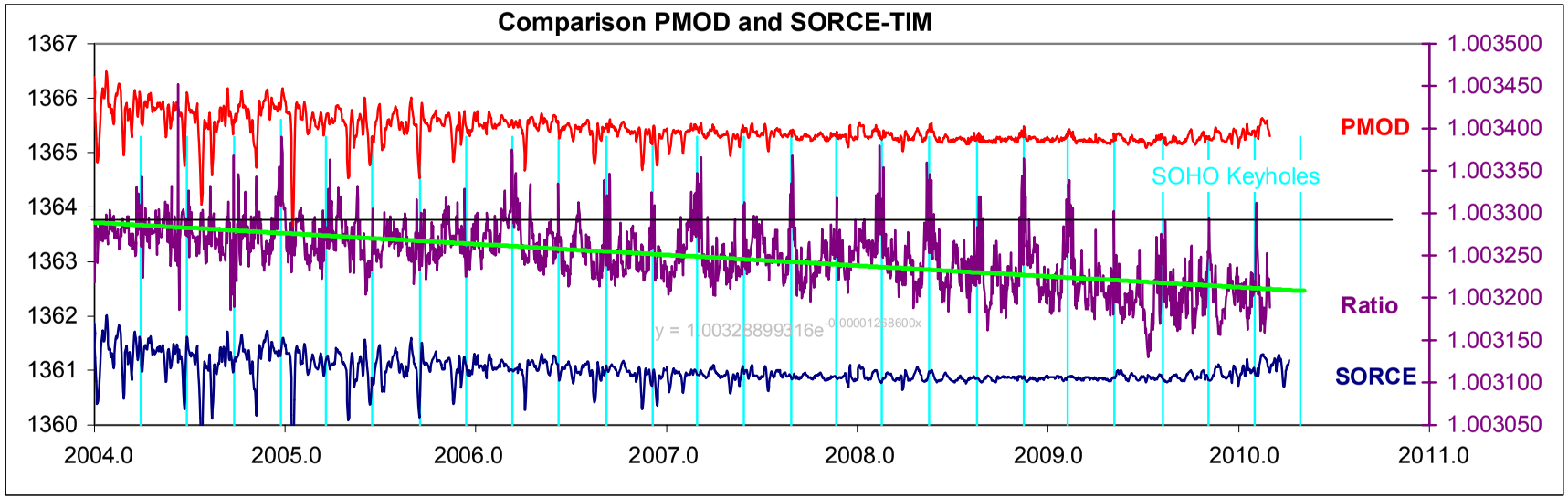


Faculae are areas with significant magnetic fields near sunspots



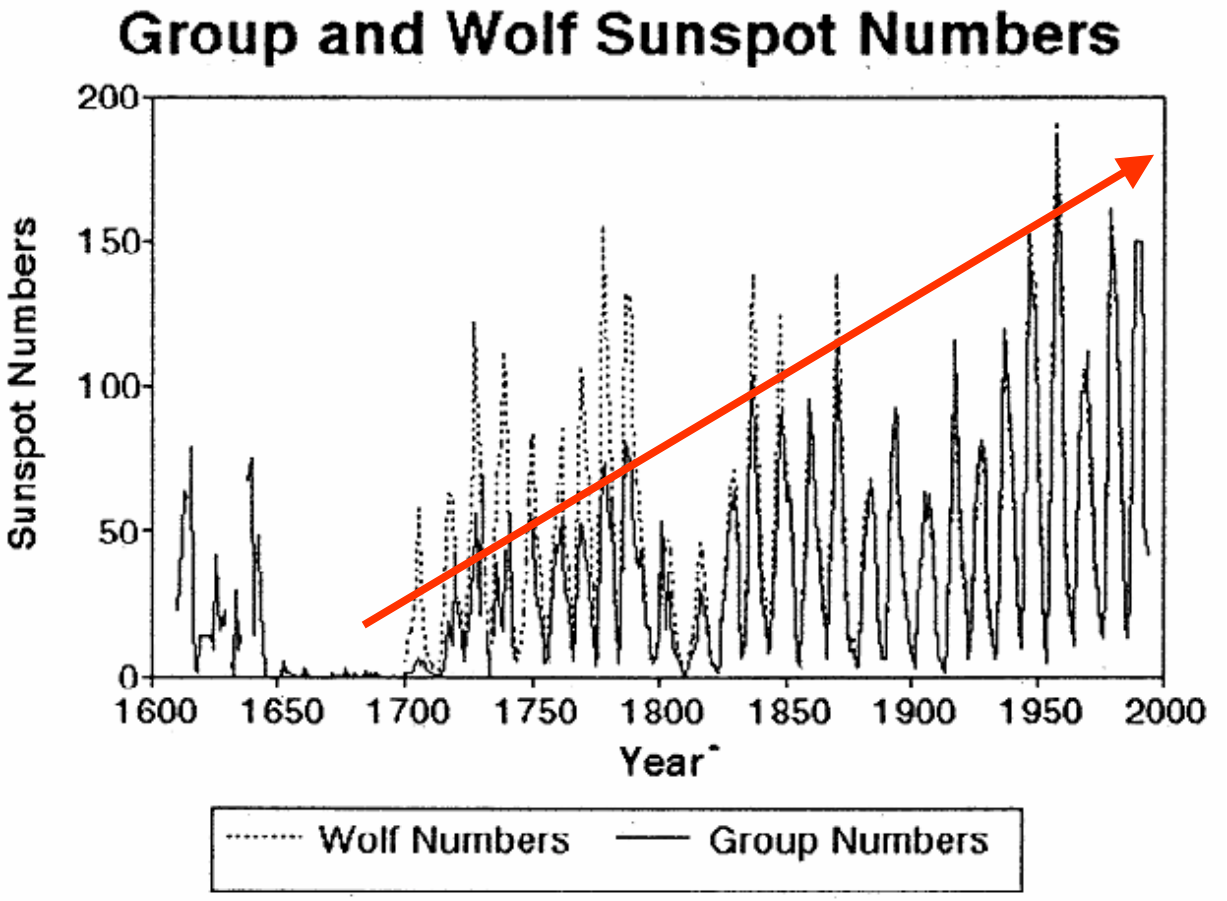
Degradation of Active Cavity Instruments due to Harsh Space Environment

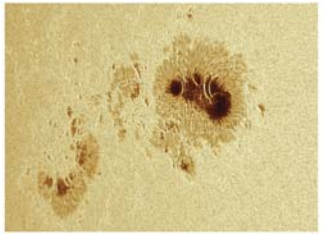
In an ideal world the ratio [or difference] between PMOD TSI (SOHO at L1) and SORCE TIM TSI (LEO) should be constant. This is not the case. The ratio PMOD/SORCE is slowly decreasing exponentially:



Sometime in 2003 the azimuth drive of the high gain antenna (on SOHO) got stuck. The operations people were able to move to a position which was ok for most of the halo orbit (±30 degrees seen from Earth). As the antenna is locked at one azimuthal angle, SOHO is turned around its solar axis by 180 deg for the East or West legs of the orbit, respectively. So in this context, the 'keyhole' is when low emission in the antenna pattern close to extremes of the halo orbit are encountered. The different orientation of the spacecraft may have thermal effects.

Reconstructions of TSI often use the Sunspot Number [going back 400 years]

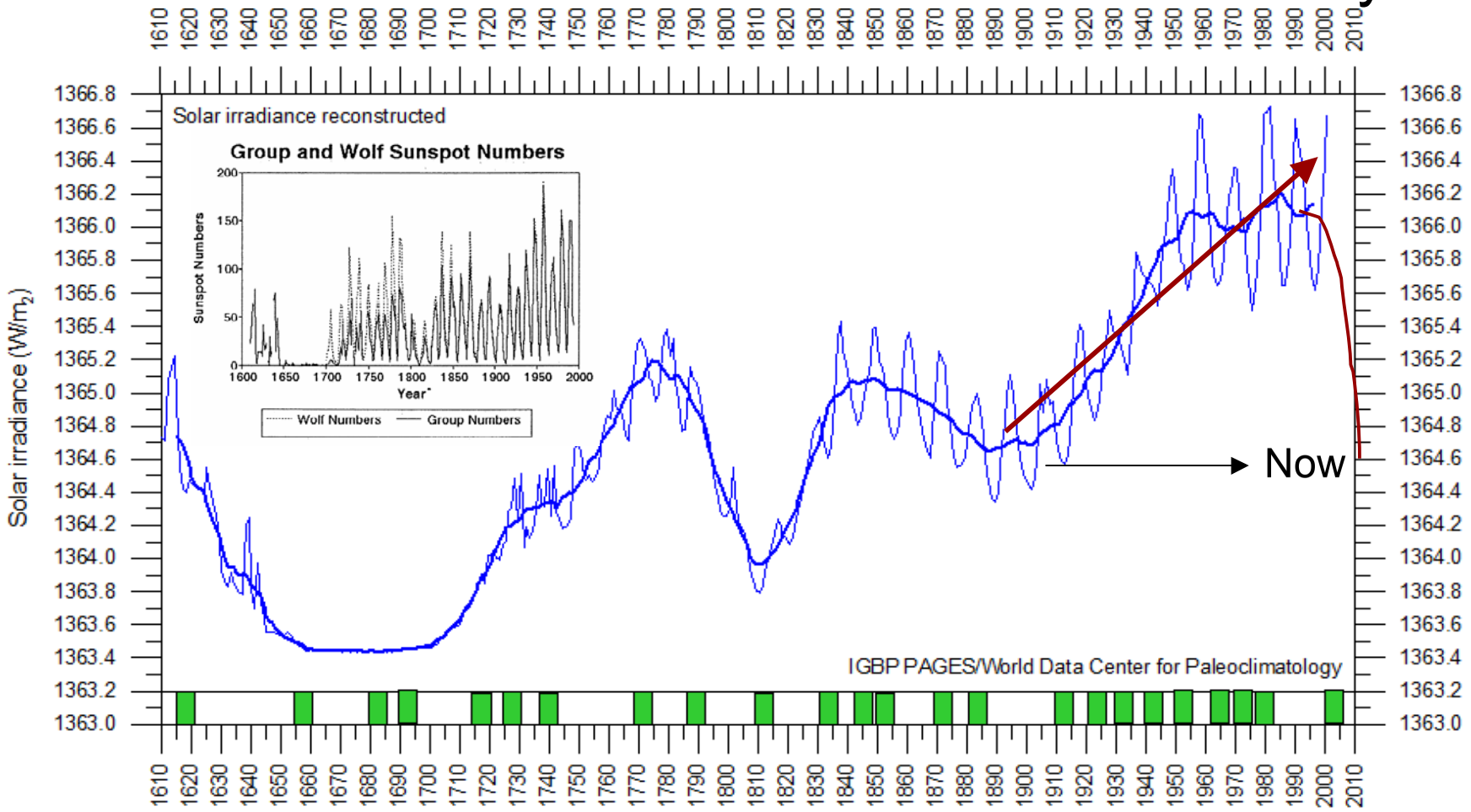




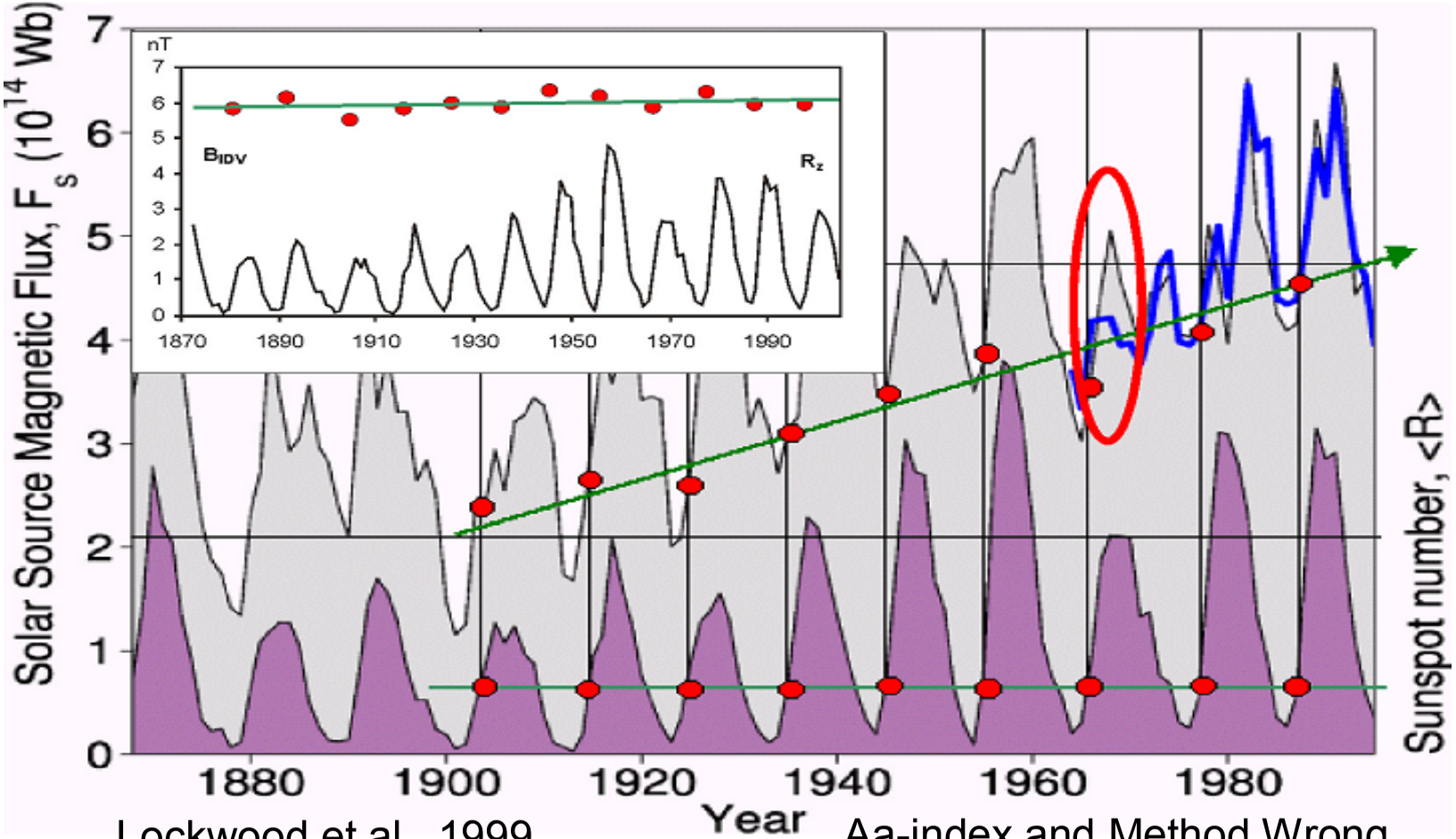
Different series of sunspot numbers are in use, according to what fits your pet theory the best

Early Reconstructions

$$TSI \sim TSI_0 + a \cdot SSN + b \cdot \langle SSN \rangle_{11yr}$$



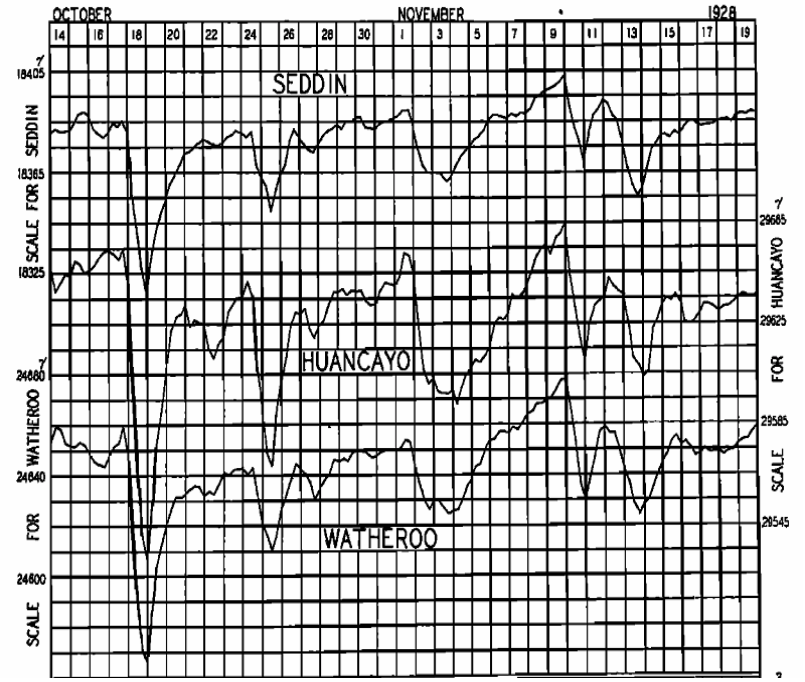
Solar Magnetic Field ⇨ Heliospheric Magnetic Field ⇨ Geomagnetic Activity: Centennial Secular Increase ?🚫

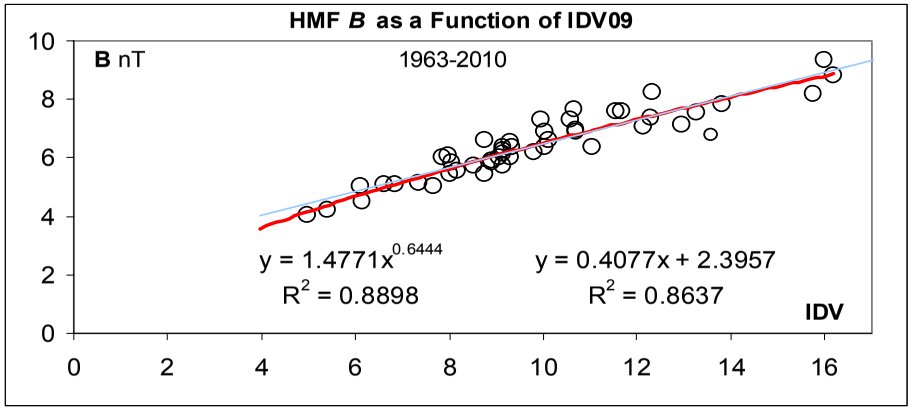


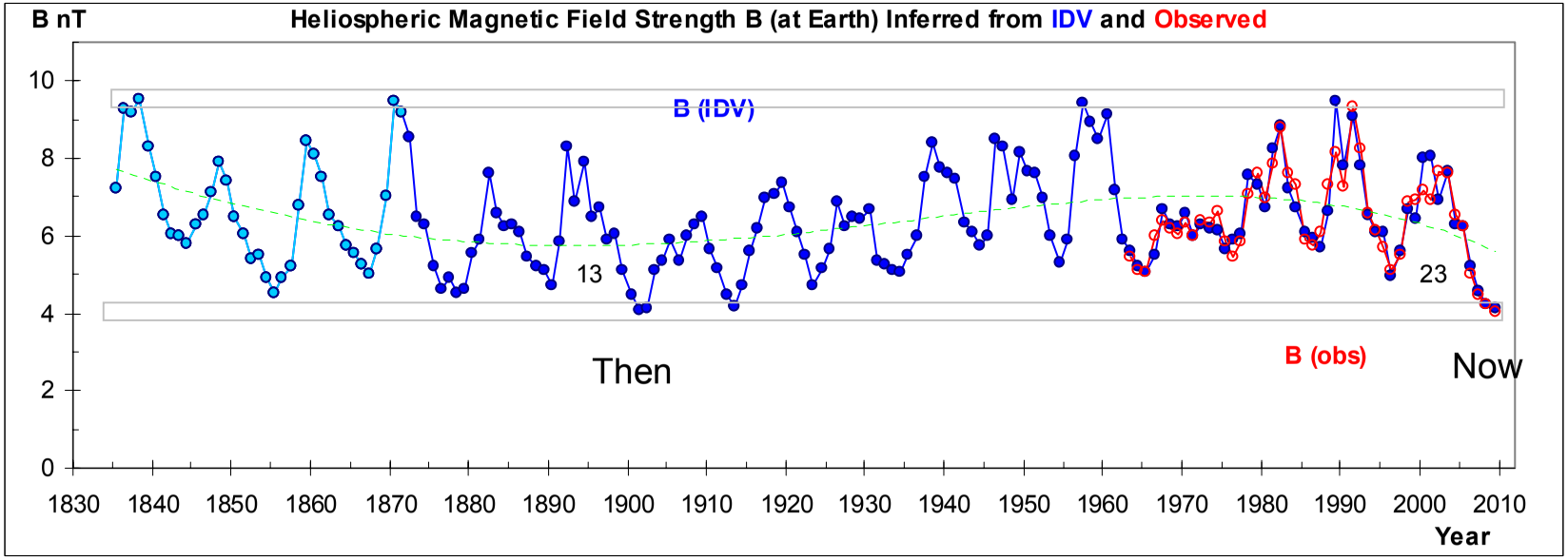
Lockwood et al., 1999

Aa-index and Method Wrong

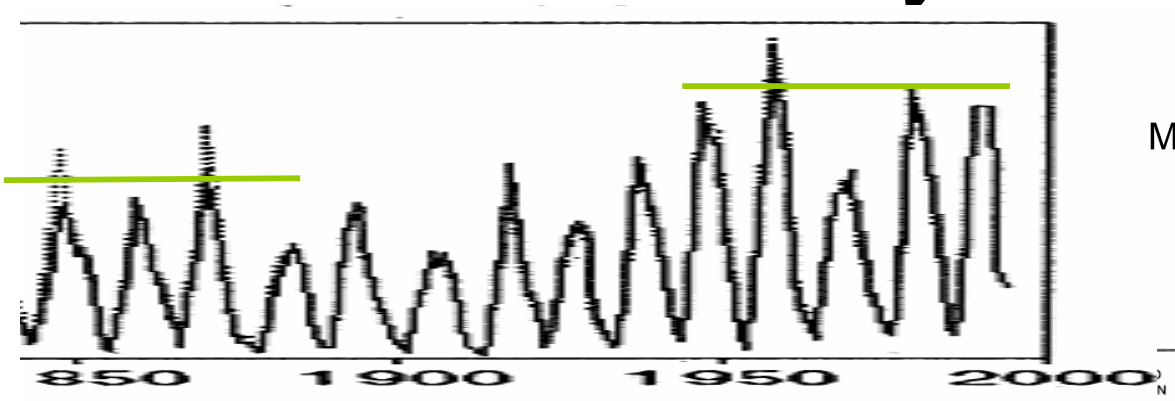
HMF from Geomagnetism

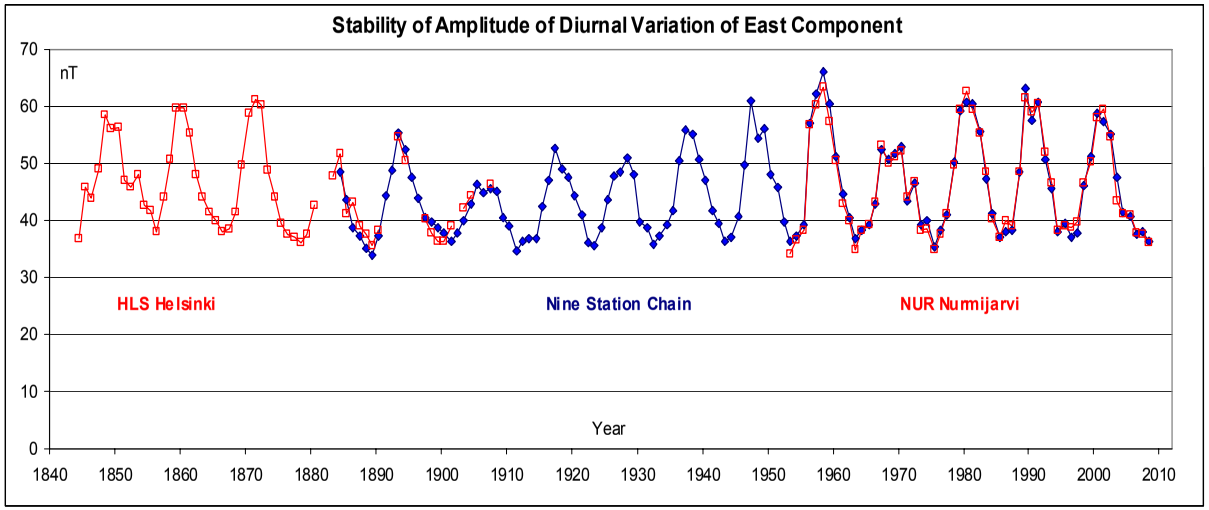


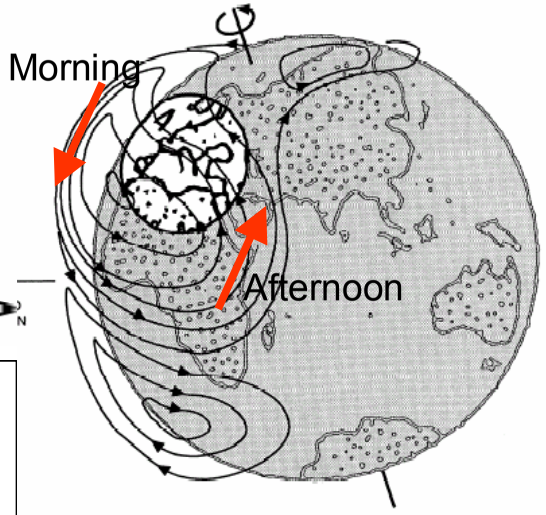




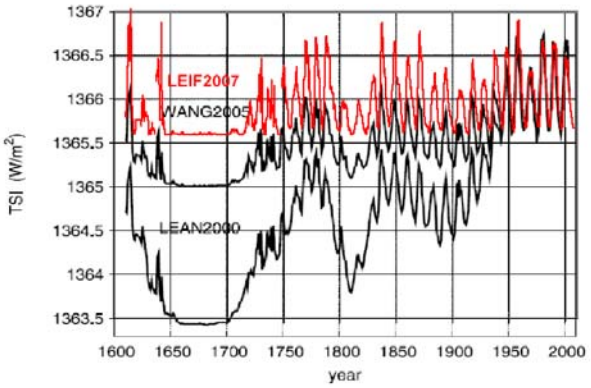
Historical Sunspot Number Records Probably Not Correct



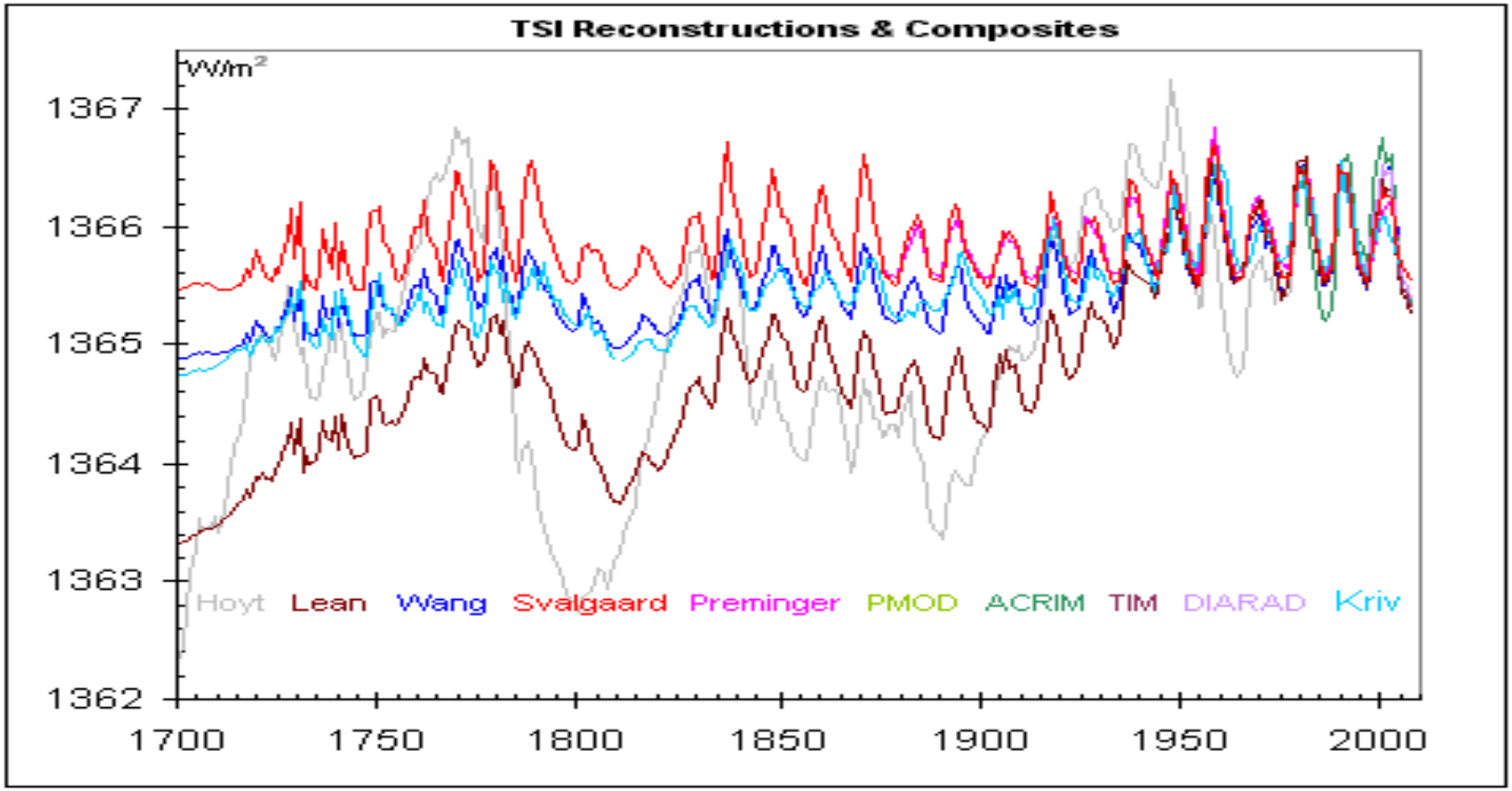


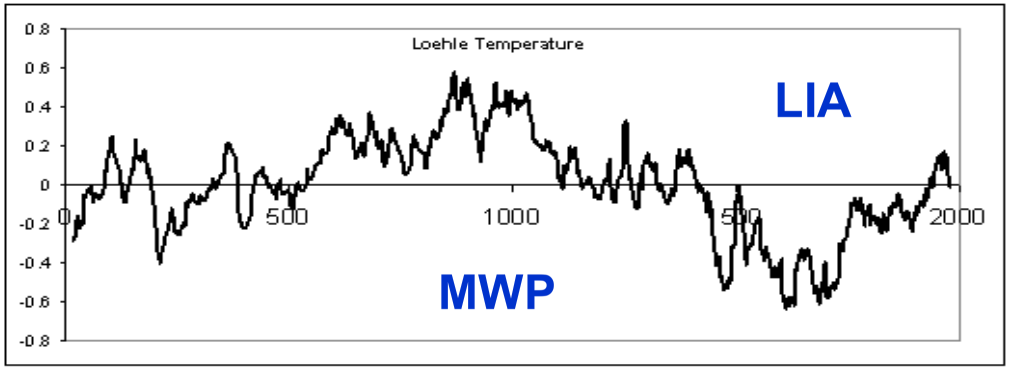


Current System in Ionosphere Created by UV Radiation Produces Diurnal Magnetic Effect at the Surface (1722)

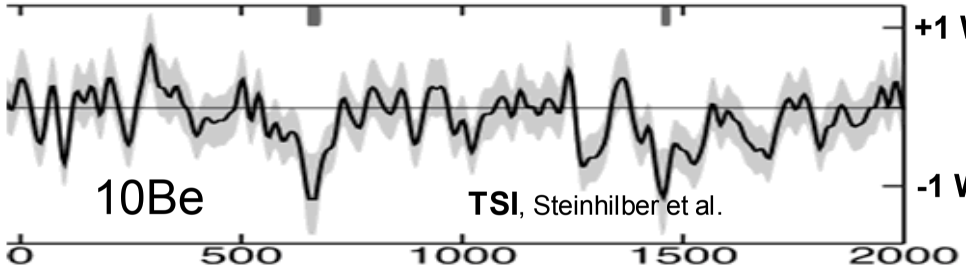


So, Reconstructions of TSI are converging towards having no 'background'

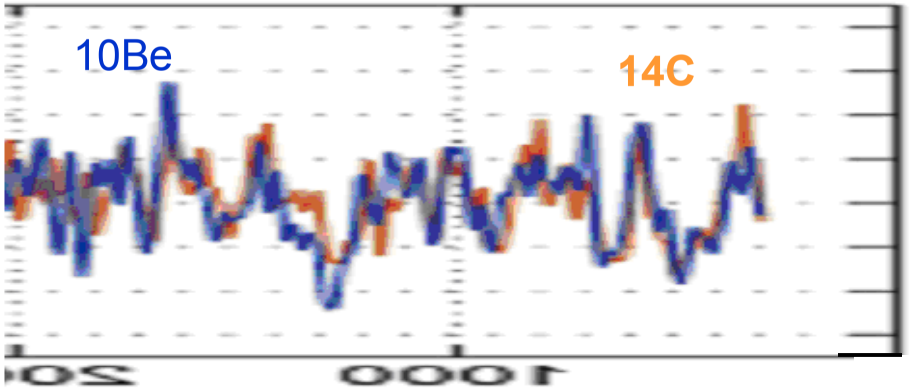




Global Temp.



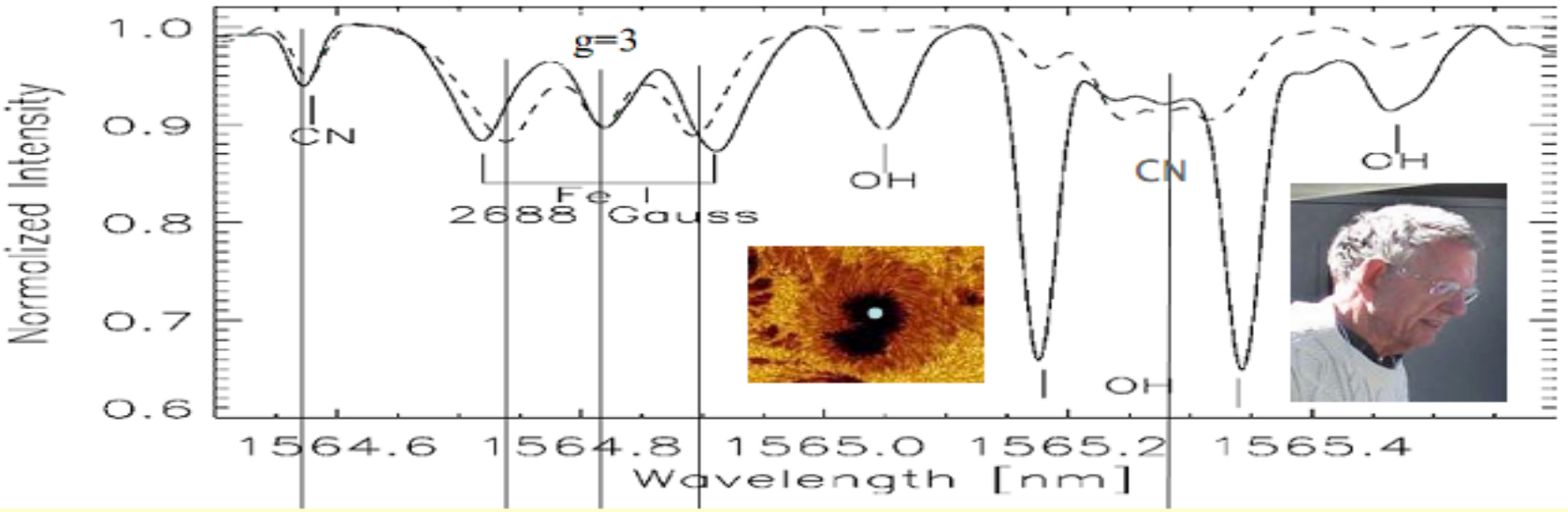
Solar Output, TSI



^{10}Be and ^{14}C-based reconstructions are largely in agreement

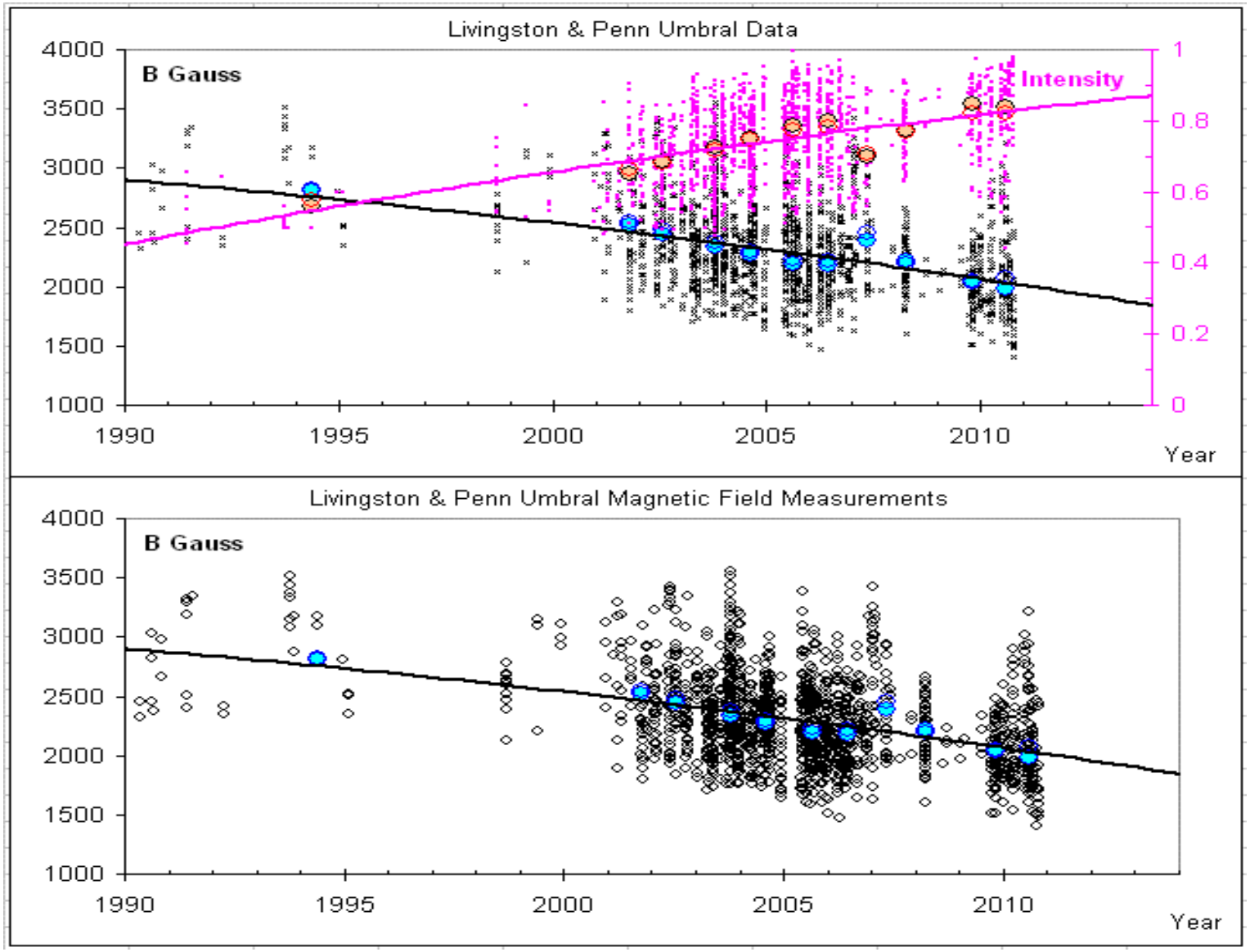
Why Were There No Sunspots During the Maunder Minimum?

The Fe I line at 1564.8 nm has a very large and easily measured Zeeman splitting. The Hydroxyl radical OH is very temperature sensitive and the lines weaken severely at higher temperatures.



Courtesy Bill Livingston

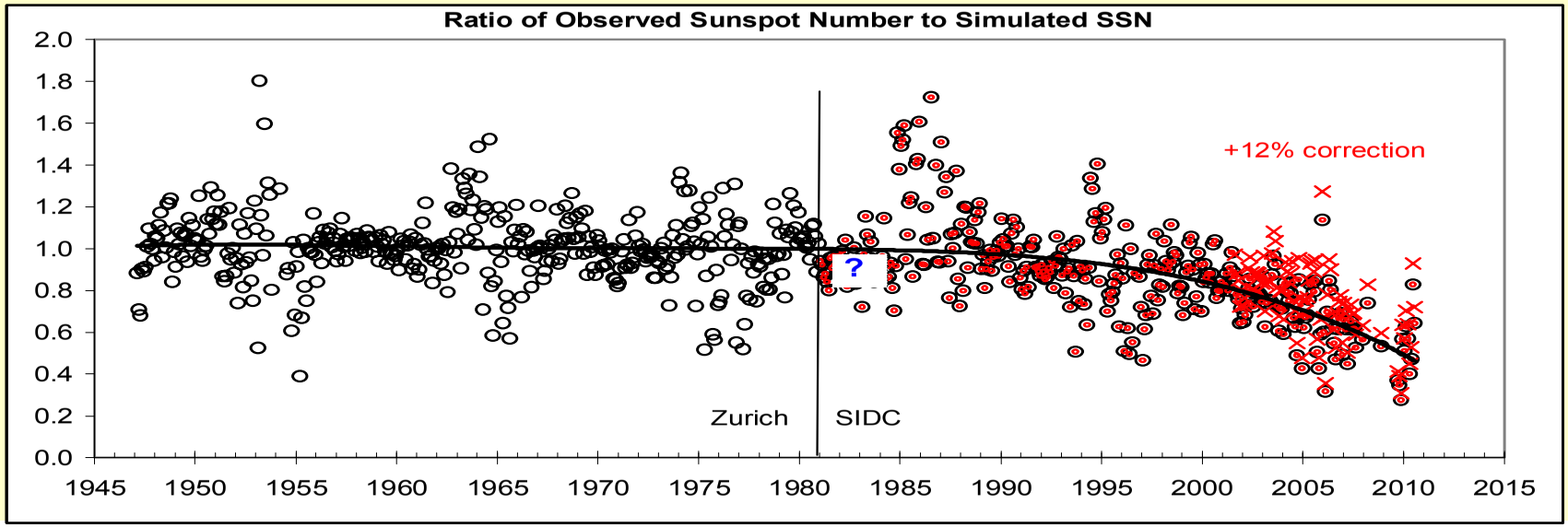
Magnetic Field is decreasing. Intensity is increasing => less contrast



The F10.7 cm Microwave Flux Also Shows that Lately Sunspots are Harder to See

Comparing Ratios

The ratio between observed and fitted Sunspot Numbers should be one [avoiding cases where R is too small – and still we have large noise near solar minima – marked by small *m*'s on the graph]. The change in SSN observers from Zurich to Brussels might introduce a small offset (less than 5%), but cannot account for the decrease during solar cycle 23



Wild Speculation

Was the Maunder Minimum Just an Example of a Strong L&P Effect?

Cosmic Ray proxies show that during both the Maunder Minimum and the Spörer Minimum, the modulation of cosmic rays proceeded almost as 'usual'. So the Heliosphere was not too different then from now, and perhaps the spots were there but just much harder to see because of low contrast because of B ≈ 1500 G.