

Has the Sun's Output Really Changed Significantly Since the Little Ice Age?

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Tromsø, Norway, May 27, 2010

Was the Little Ice Age Global?

Sun that gives all things birth

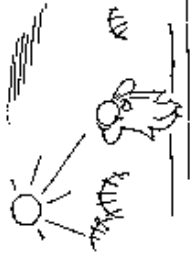
Shine on everything on earth!

If that's too much to demand

Shine at least on this our land

If even that's too much for thee

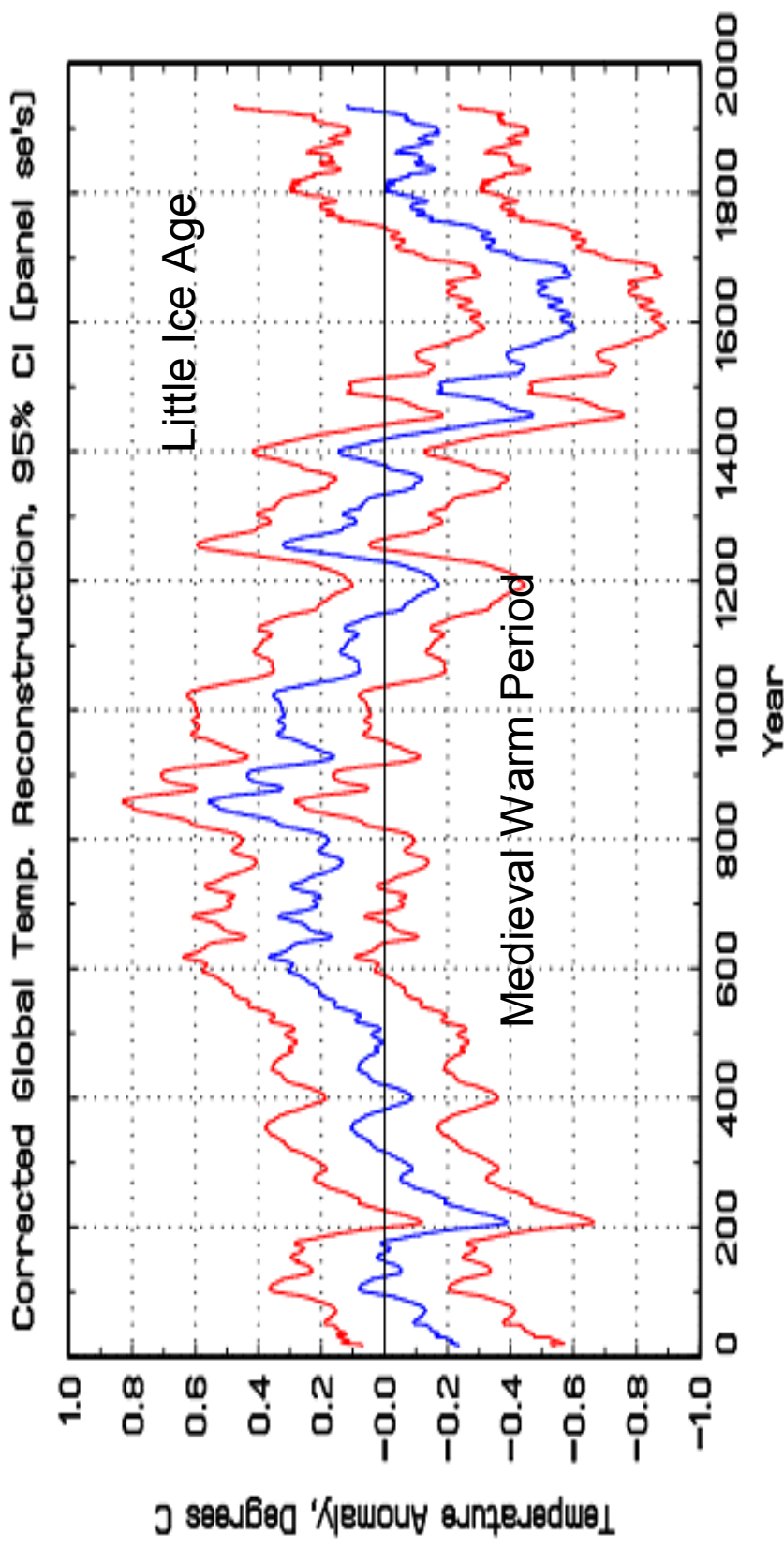
Shine at any rate on me



[Piet Hein](#) (Danish Poet, 1905-1996)

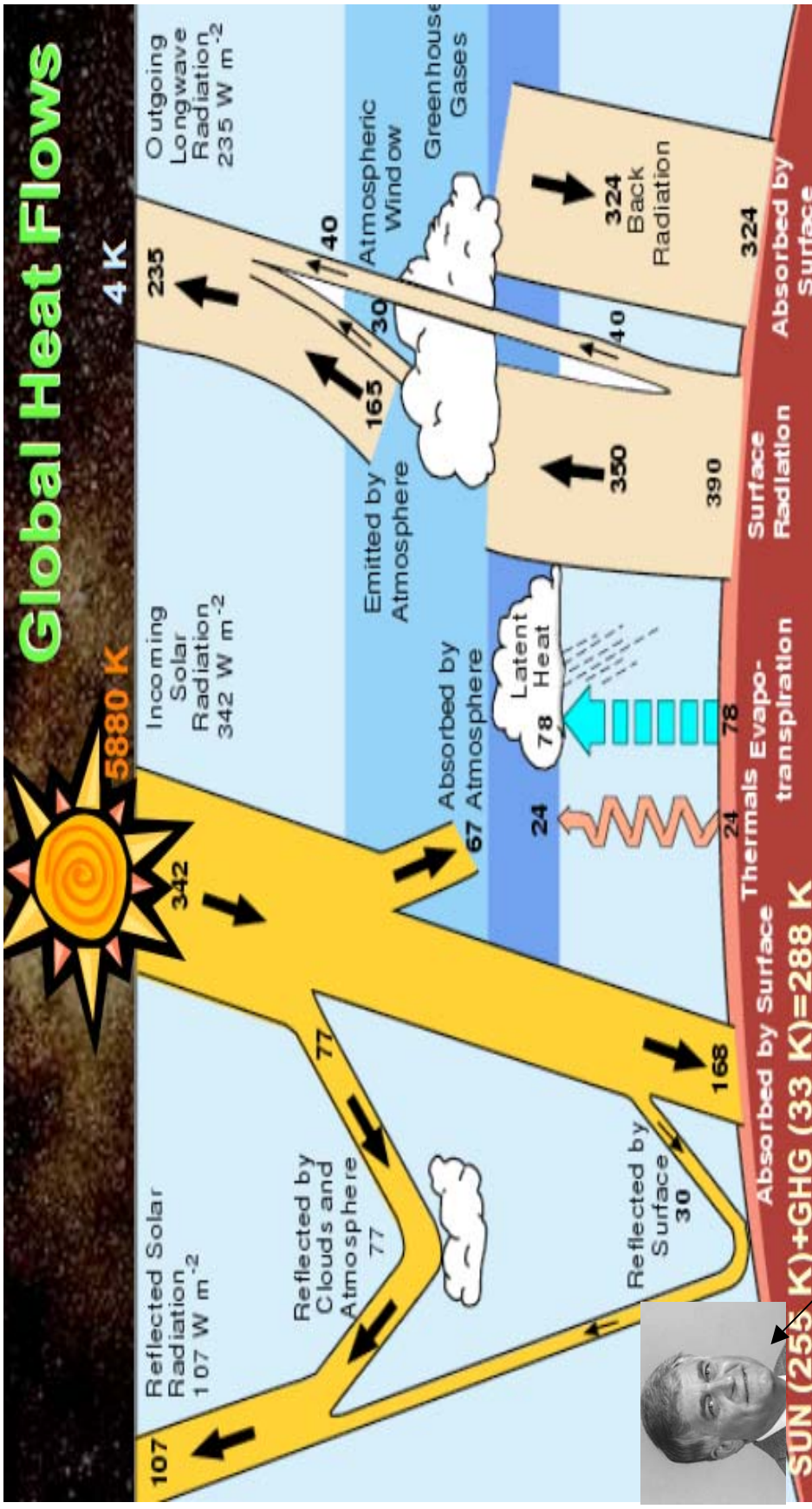
Craig Loehle: Global Temperature Reconstruction [non-tree ring].

Range $\sim 1^\circ\text{C}$



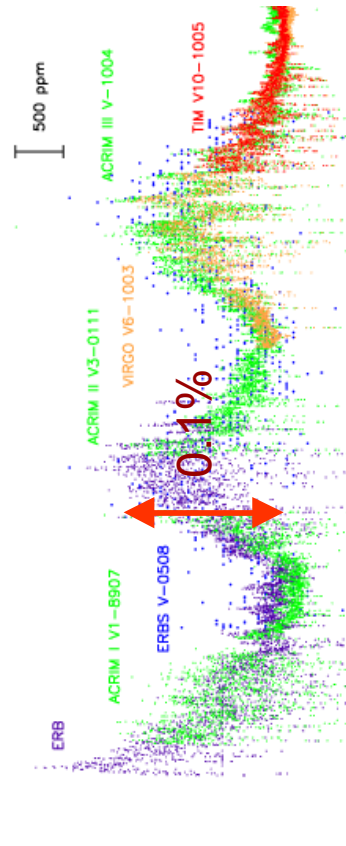
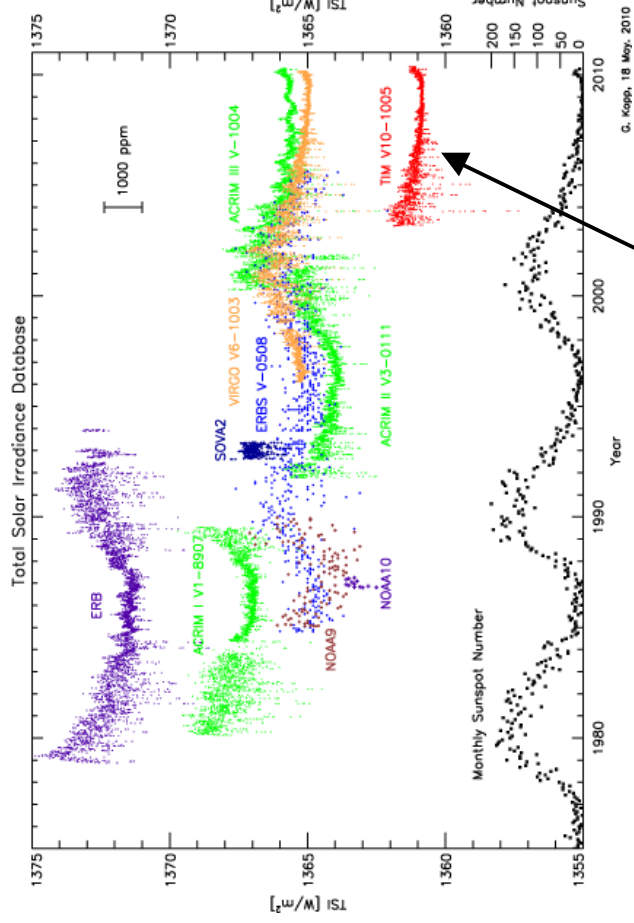
Total Solar Irradiance, TSI \rightarrow Global Heat Flow

$$dT/T = \frac{1}{4} dS/S; dS/S = 1\% \rightarrow dT = 0.25\%T \sim 1^\circ\text{C}$$

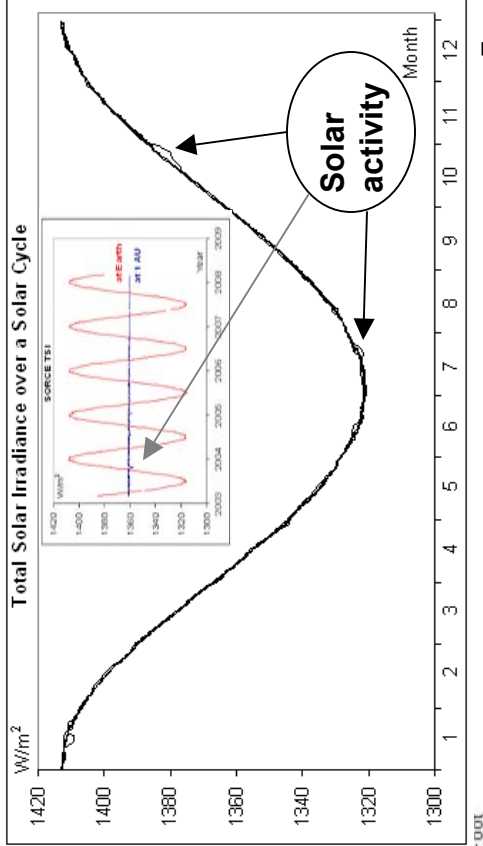
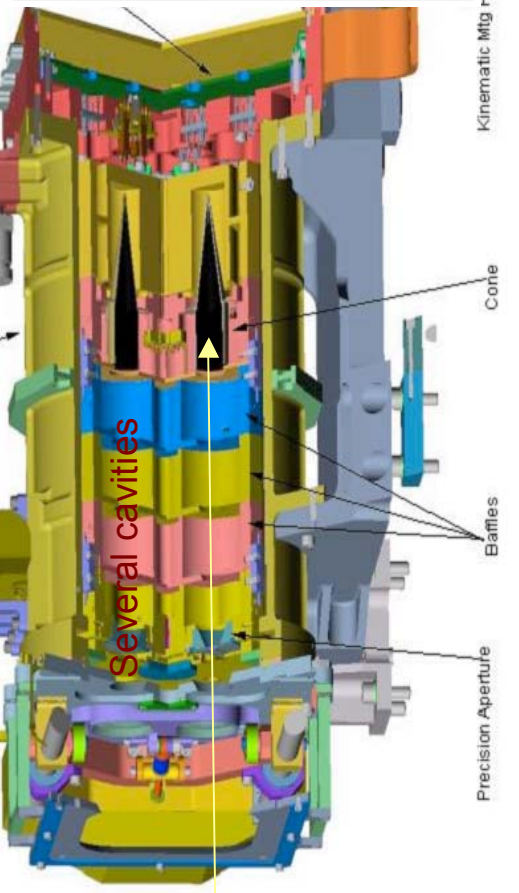


When Jack Eddy Proposed a Connection Between the Maunder Minimum and the LIA it was thought that dS/S of 1% was a possible variation (Abbot)

Measurement of TSI by spacecraft

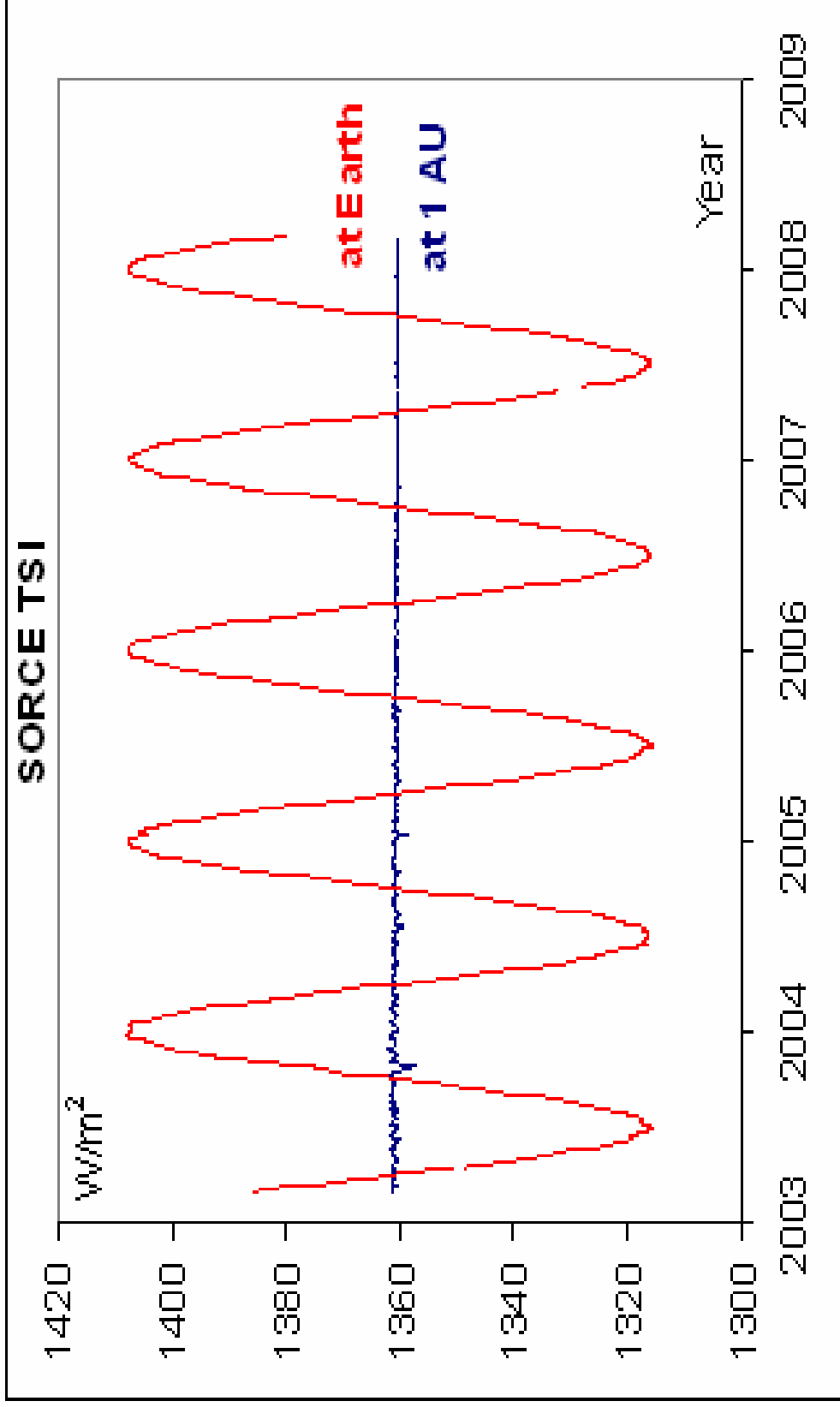


Annual Variation (due to variation of solar distance) is 70 times larger than solar cycle variation:

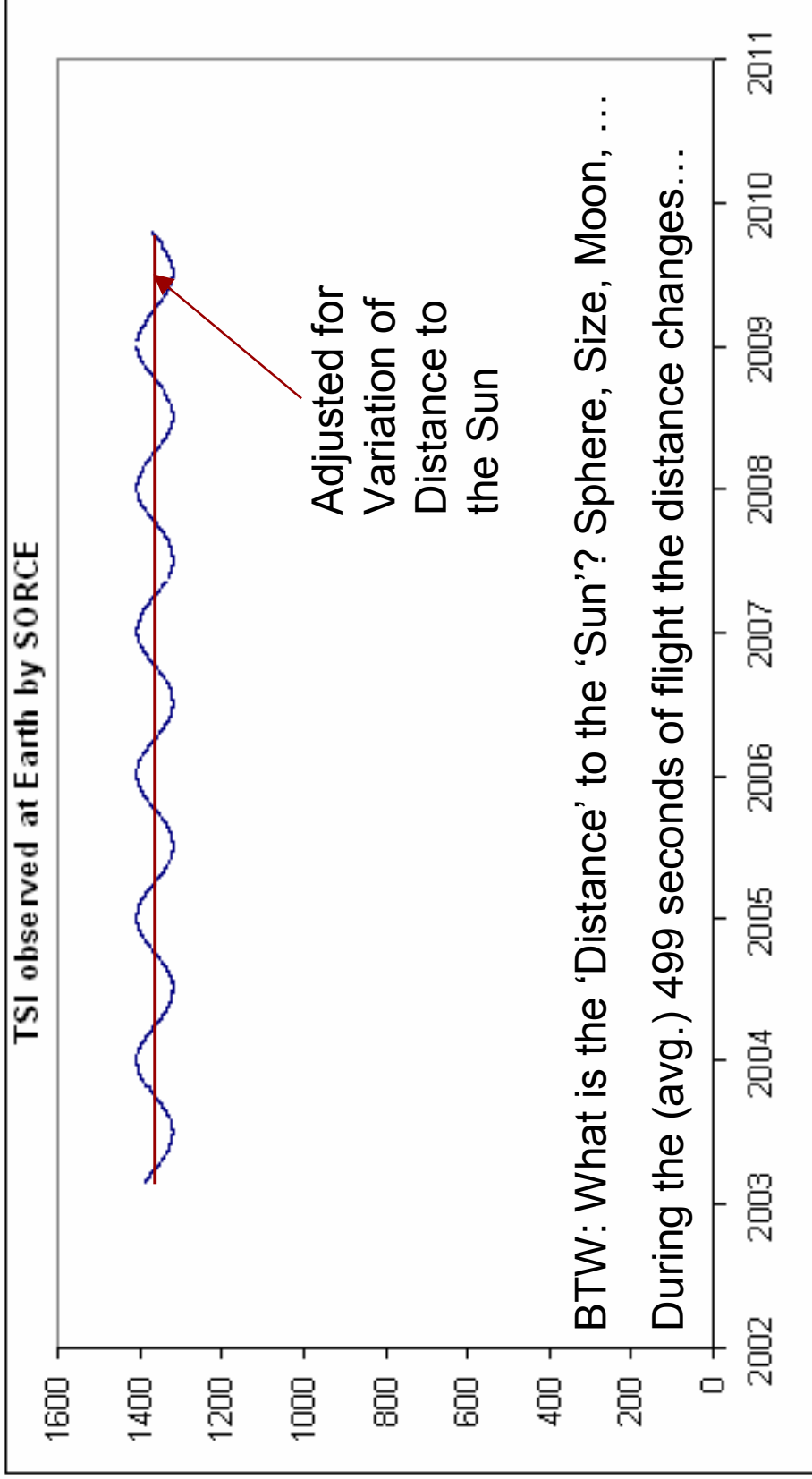


G. Kopp, 18 May, 2010

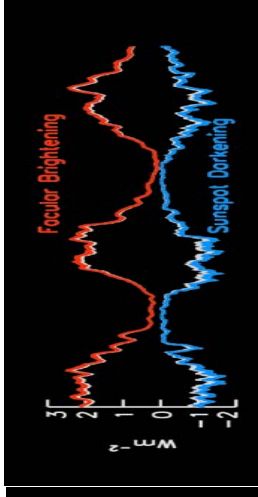
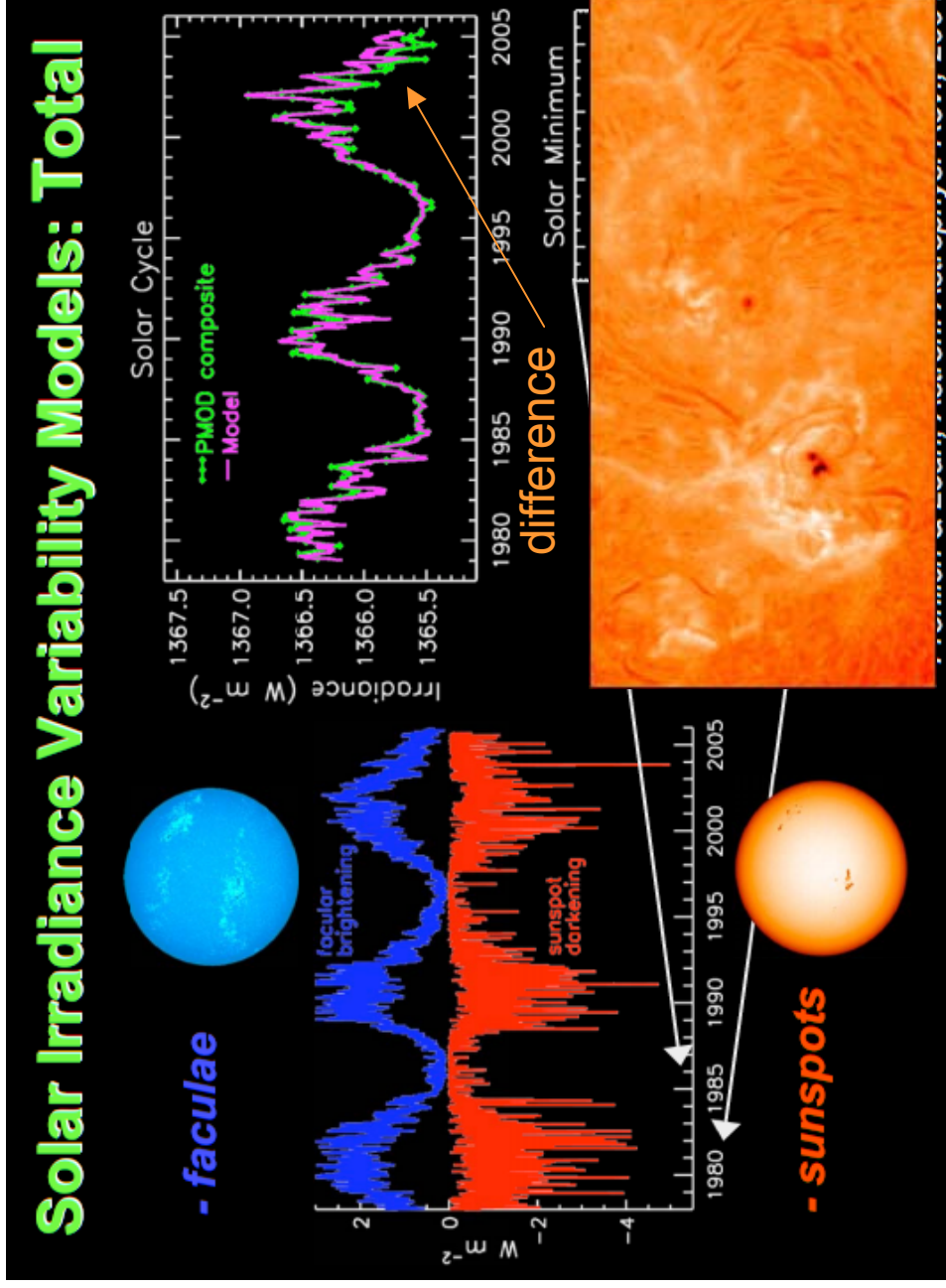
Putting TSI variations in Perspective



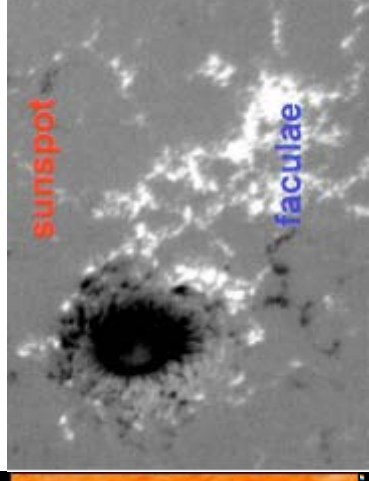
The 'Solar Constant'



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

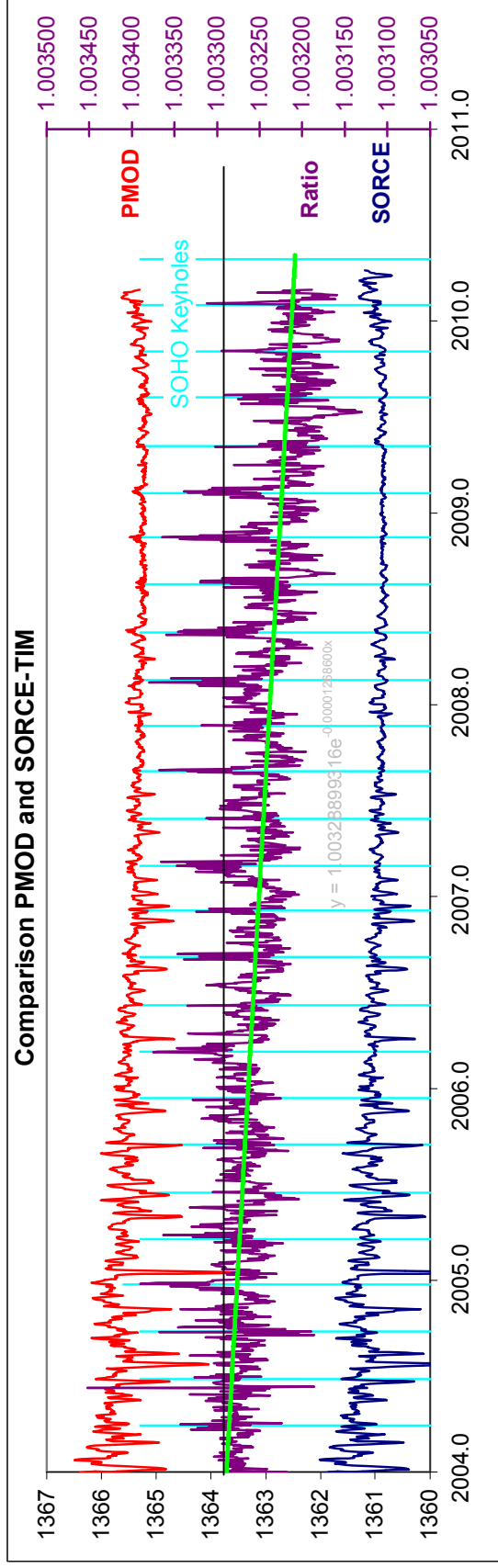


Faculae are areas with significant magnetic fields near sunspots



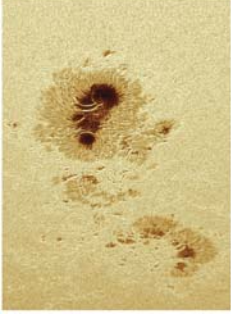
Degradation of Active Cavity Instrument due to Harsh Space Environment

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:

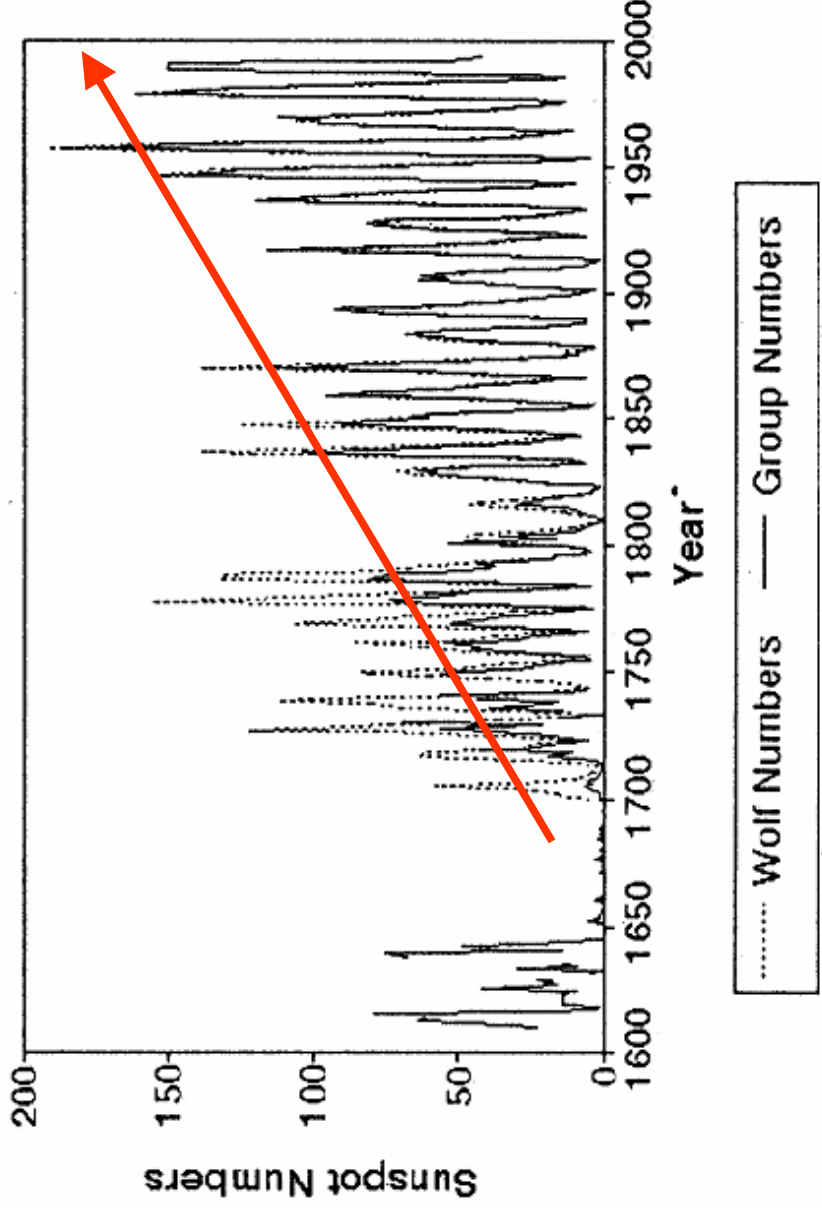


Sometime in 2003 the azimuth drive of the high gain antenna (on SOHO) got stuck. The operations people were able to move to a position which was ok for most of the halo orbit (± 30 degrees seen from Earth). As the antenna is locked at one azimuthal angle, SOHO is turned around its solar axis by 180 deg 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]



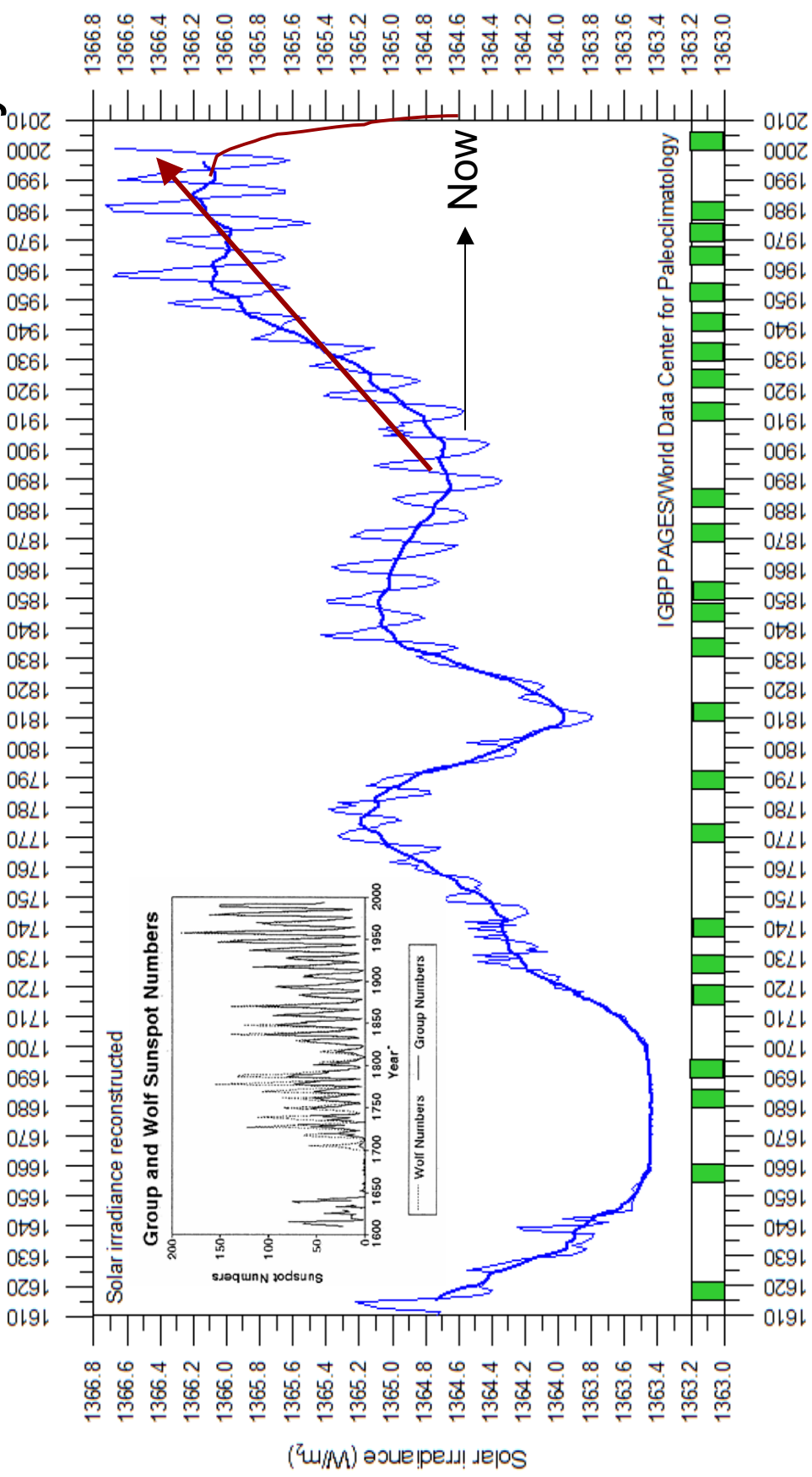
Group and Wolf Sunspot Numbers



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

Early Reconstructions

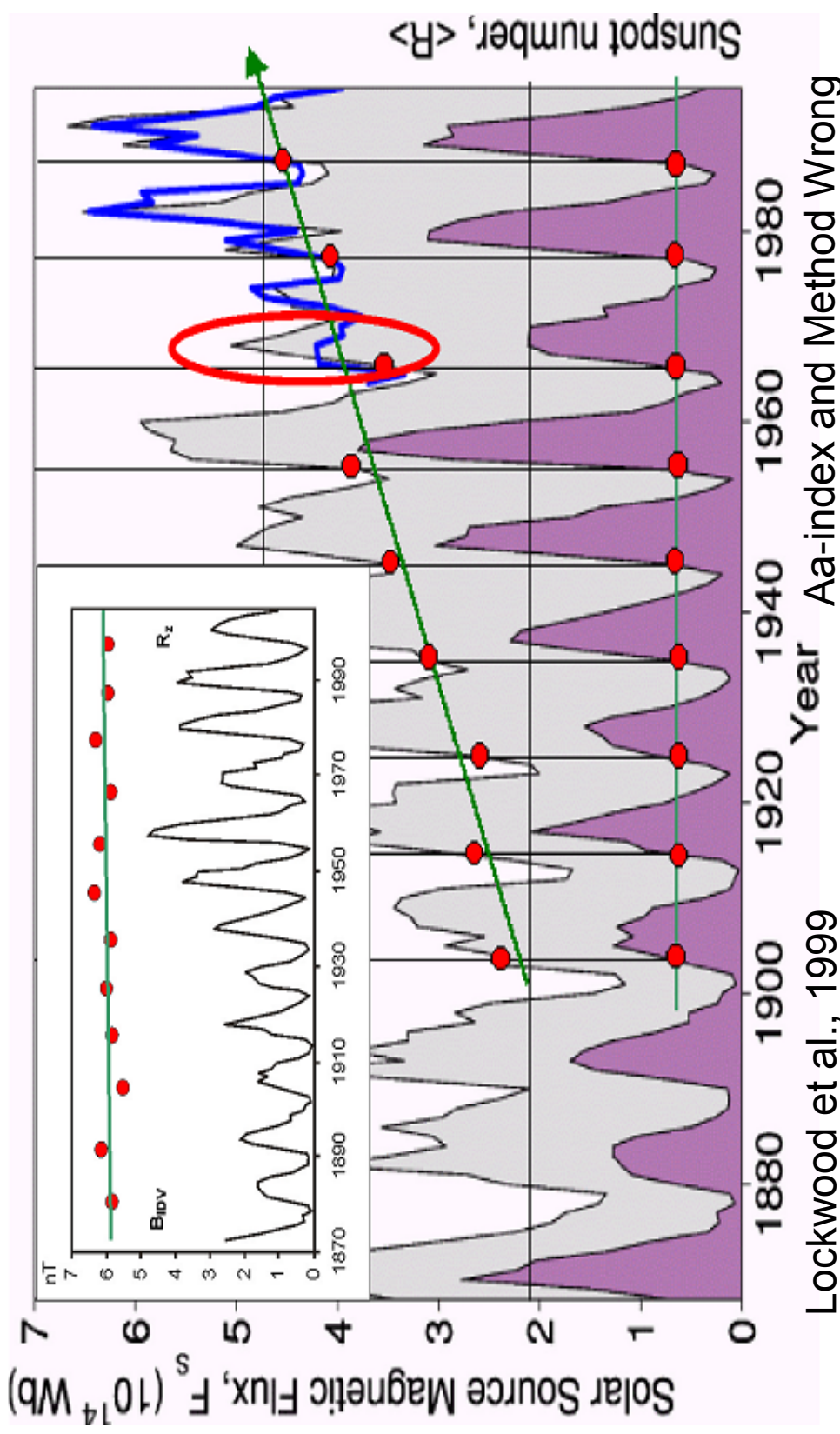
$$TSI \sim TSI_0 + a \cdot SSN + b \cdot <SSN>_{11yr}$$



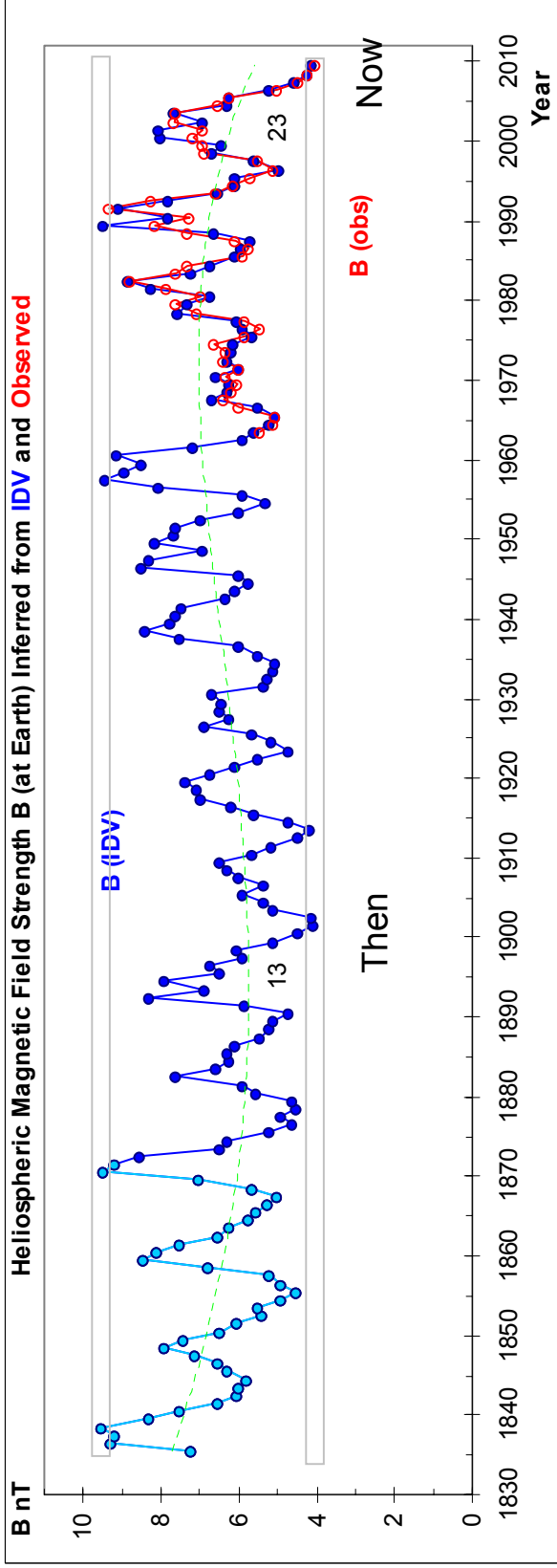
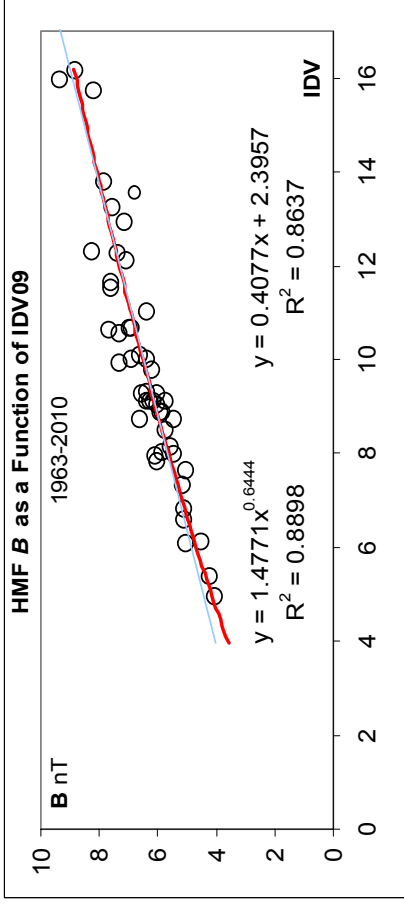
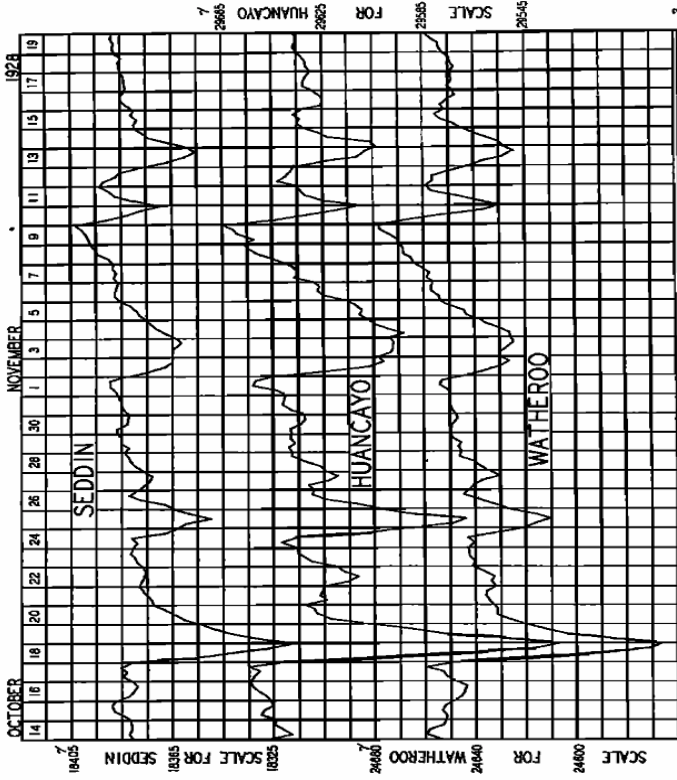
Solar Magnetic Field \rightarrow Heliospheric Magnetic

Field \rightarrow Geomagnetic Activity:

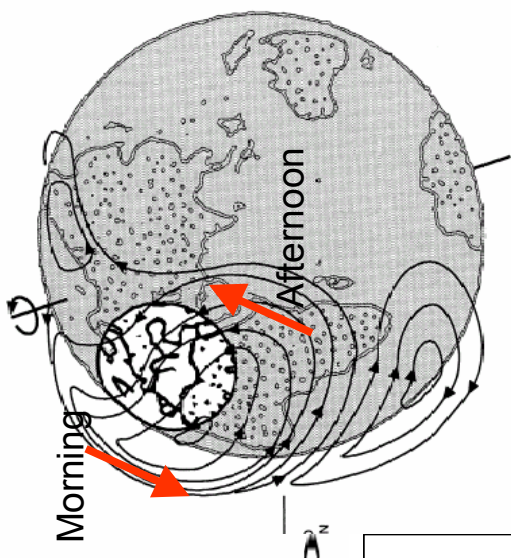
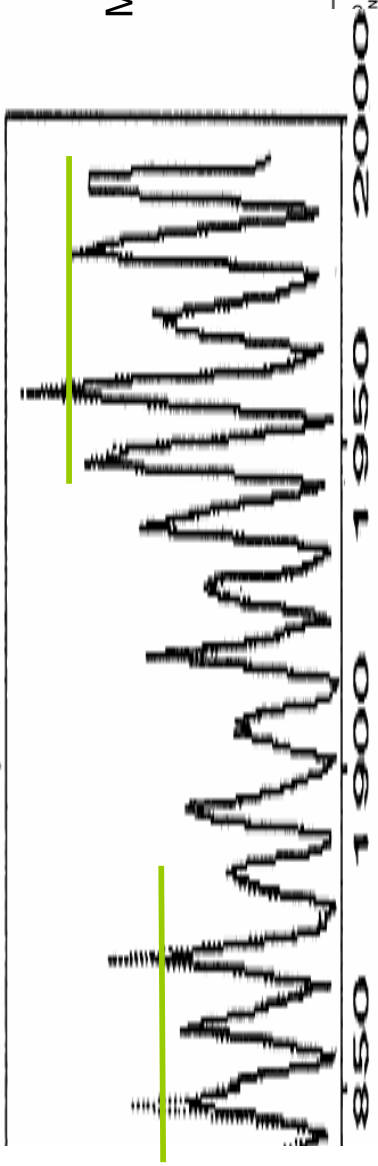
Centennial Secular Increase ? \propto



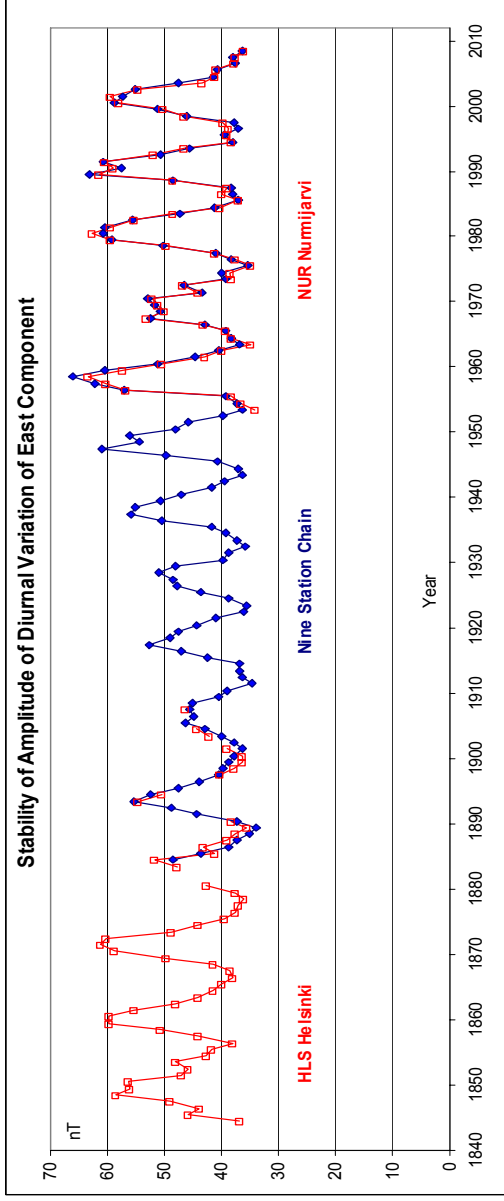
HMF from Geomagnetism



Historical Sunspot Number Records Probably **Not** Correct

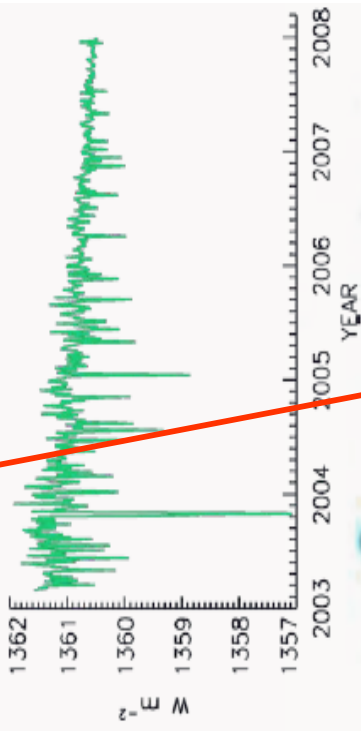
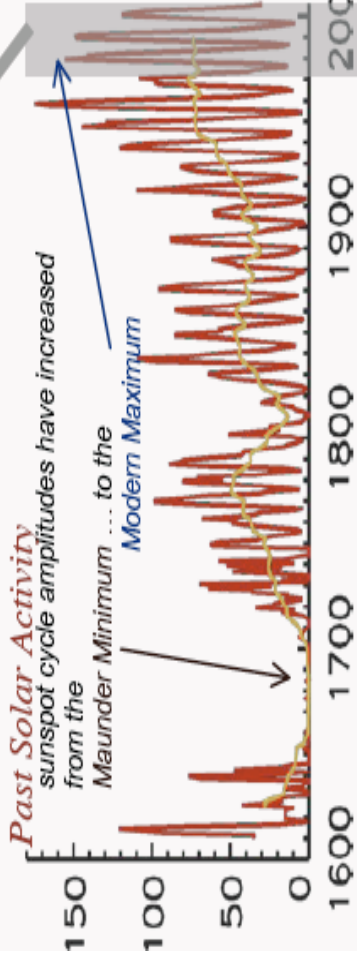
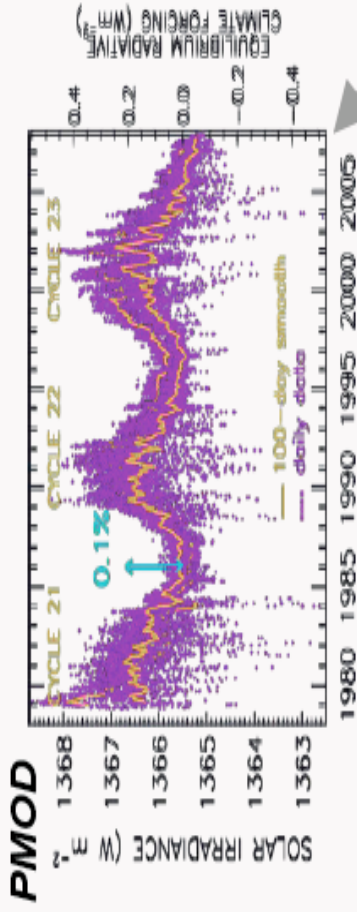


Current System in
Ionosphere Created
by UV Radiation
Produces Diurnal
Magnetic Effect at
the Surface (1722)



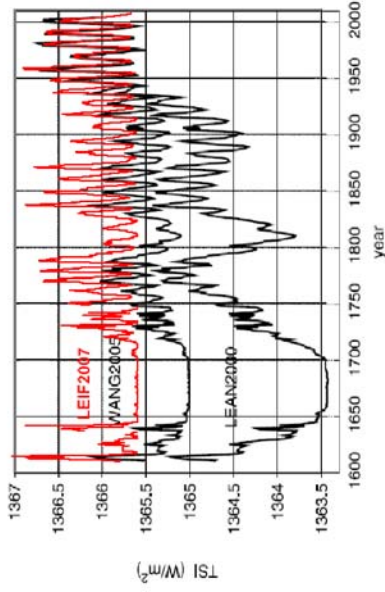
Even the Scientists that Advocated the Large Variation of TSI are Doubting that now

SORCE/TIM Continues a 28-year Record of Total Solar Irradiance

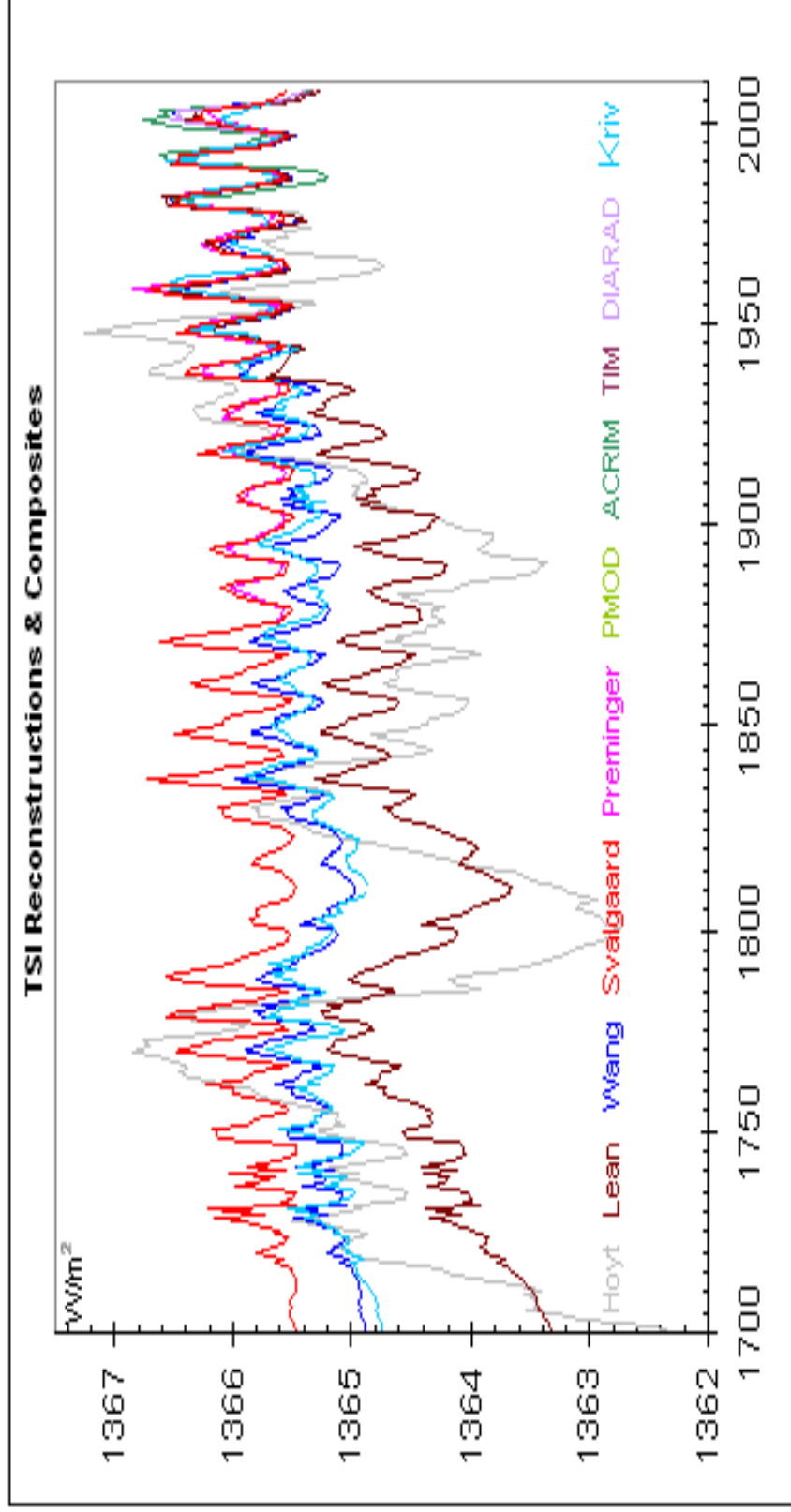


5-min oscillation ~ 0.003%
 27-day solar rotation ~ 0.2%
 11-year solar cycle ~ 0.1%
 longer-term variations not yet detectable -
 do they occur?

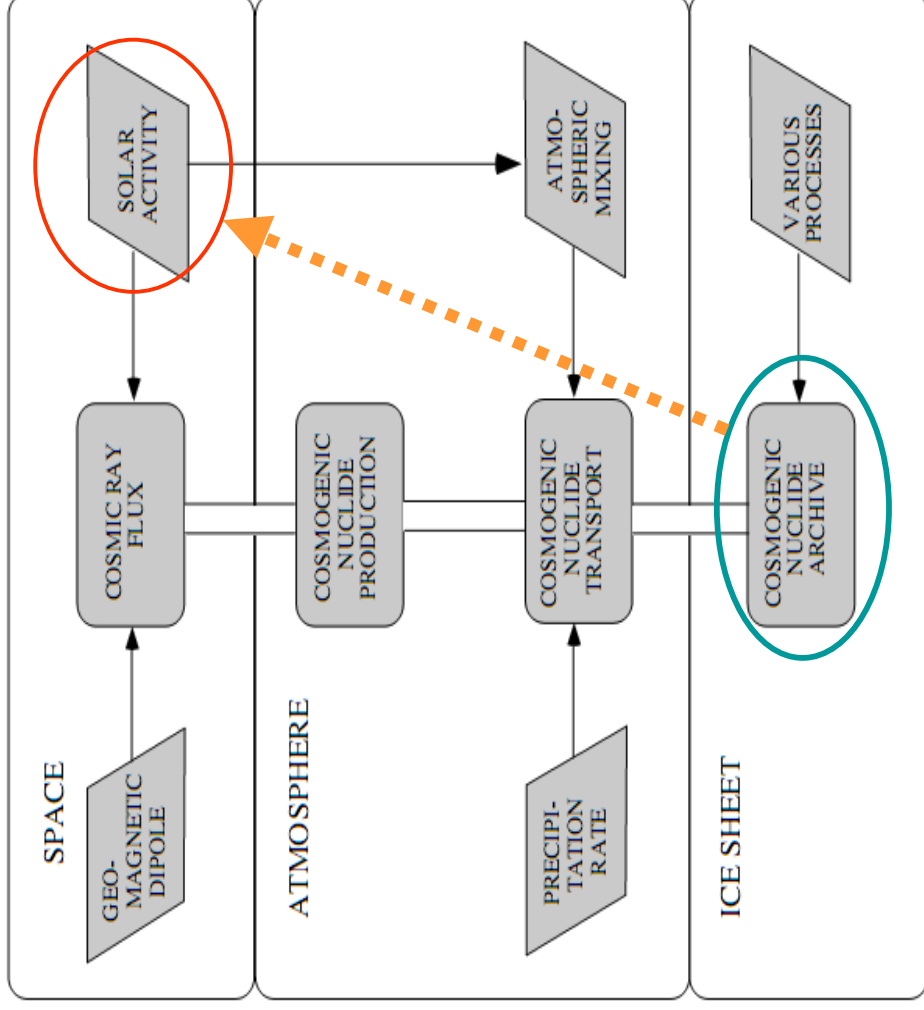
data: Fröhlich & Lean, AARev, 2004 <http://www.pmodwrc.ch>
<http://lasp.colorado.edu/sorce>



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



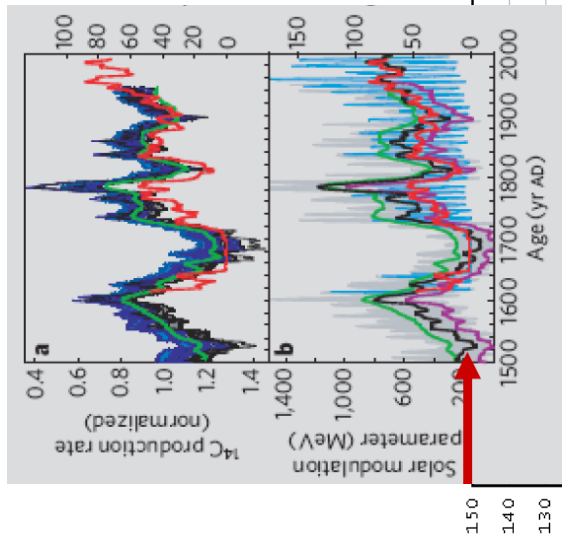
Solar Activity Influences the Production of Radioactive Nuclides



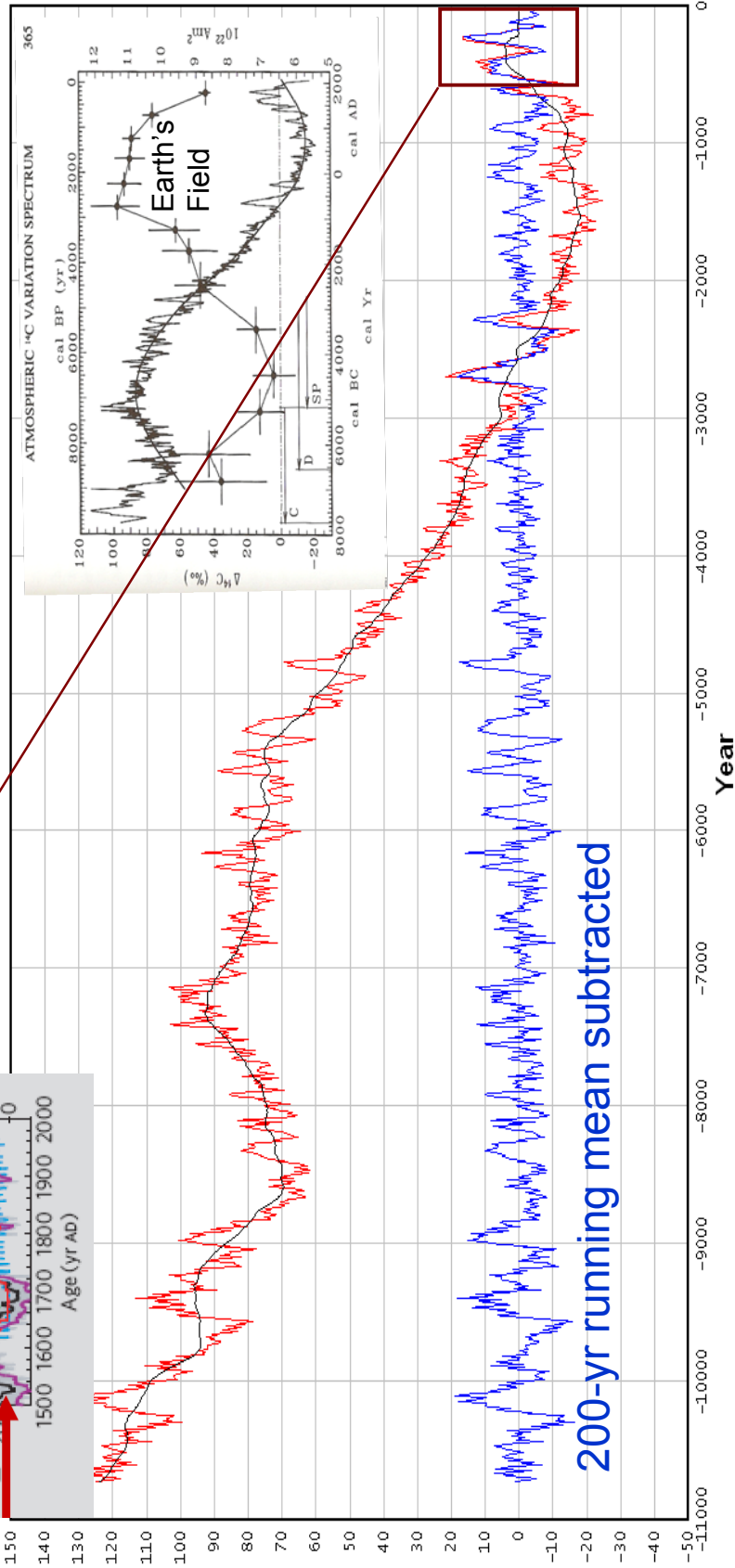
If we can understand the various processes involved it might be possible to **reconstruct** solar activity from the cosmogenic isotopes deposited in ice (^{10}Be).

If the ^{14}C production varies, there will be a difference between the age calculated from the assumption of constant production and the age determined by other means [e.g. tree rings]

14C Age Differences Partly Due to Solar Activity

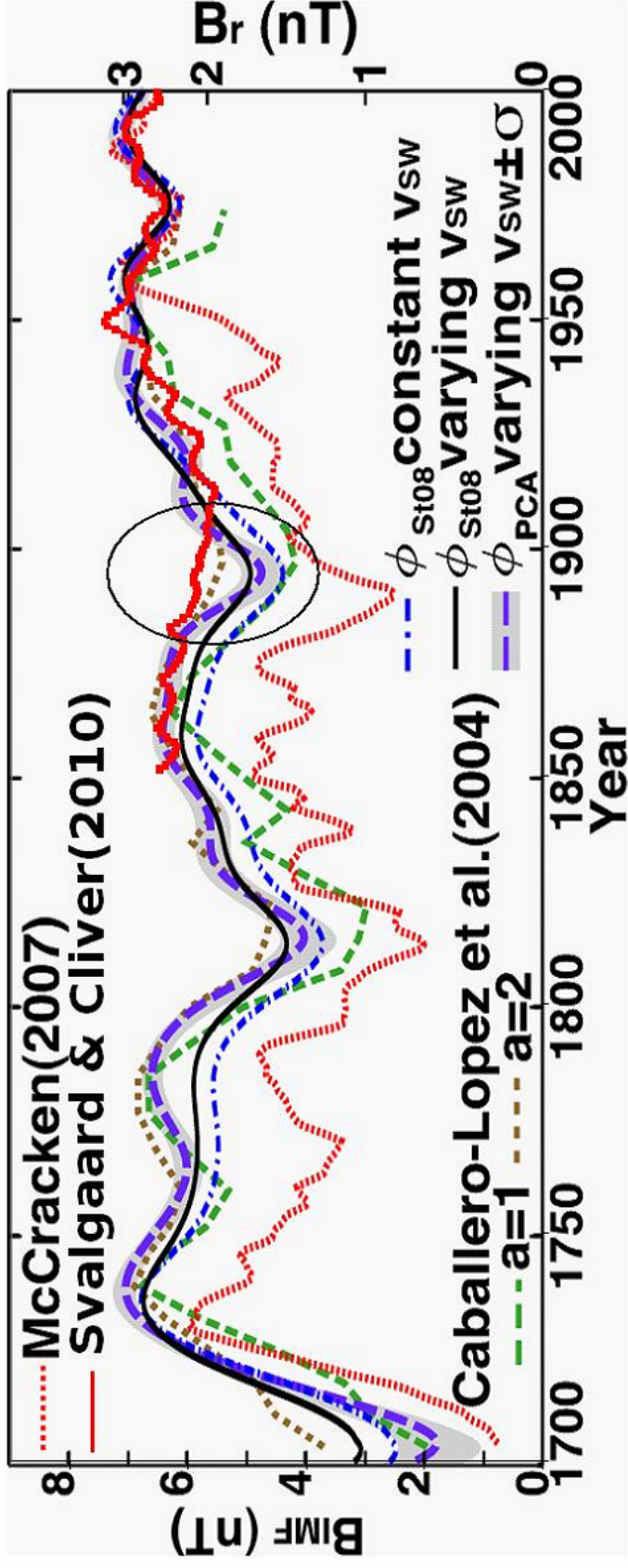


Delta 14C per mil



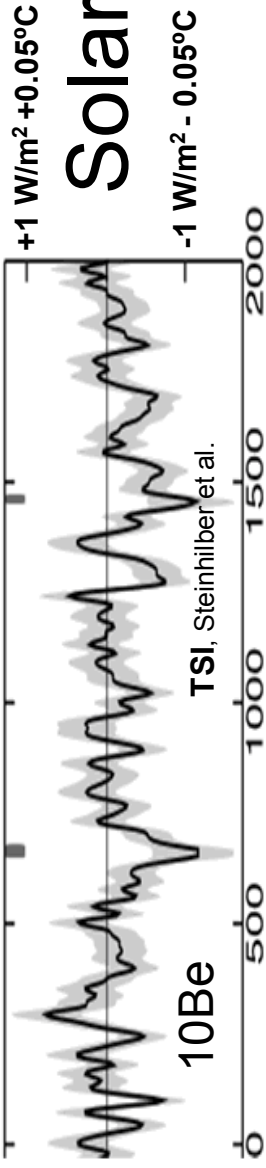
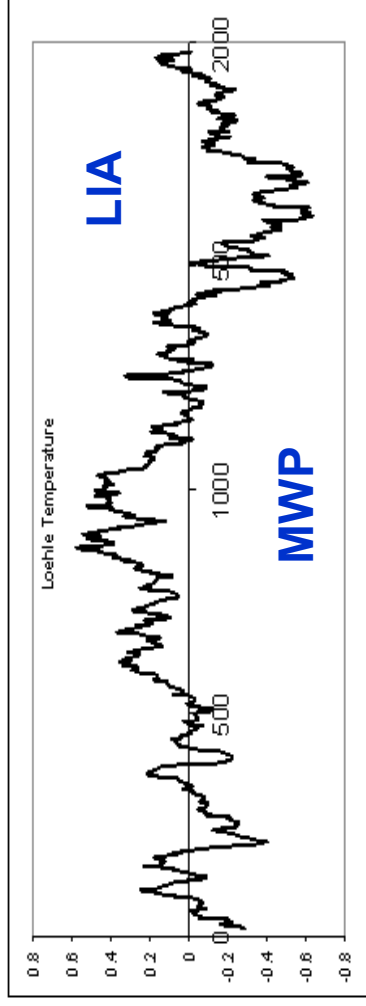
200-yr running mean subtracted

^{10}Be -based Reconstructions of Heliospheric Magnetic Field

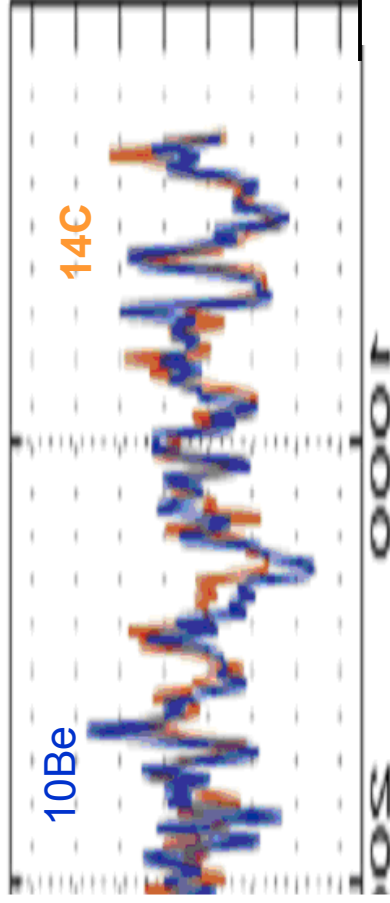


The 'dips' may be influenced by volcanic activity; Krakatoa, Tambora, Hekla. Or even by climate changes [circular argument?]

Global Temp.




Solar Output, TSI



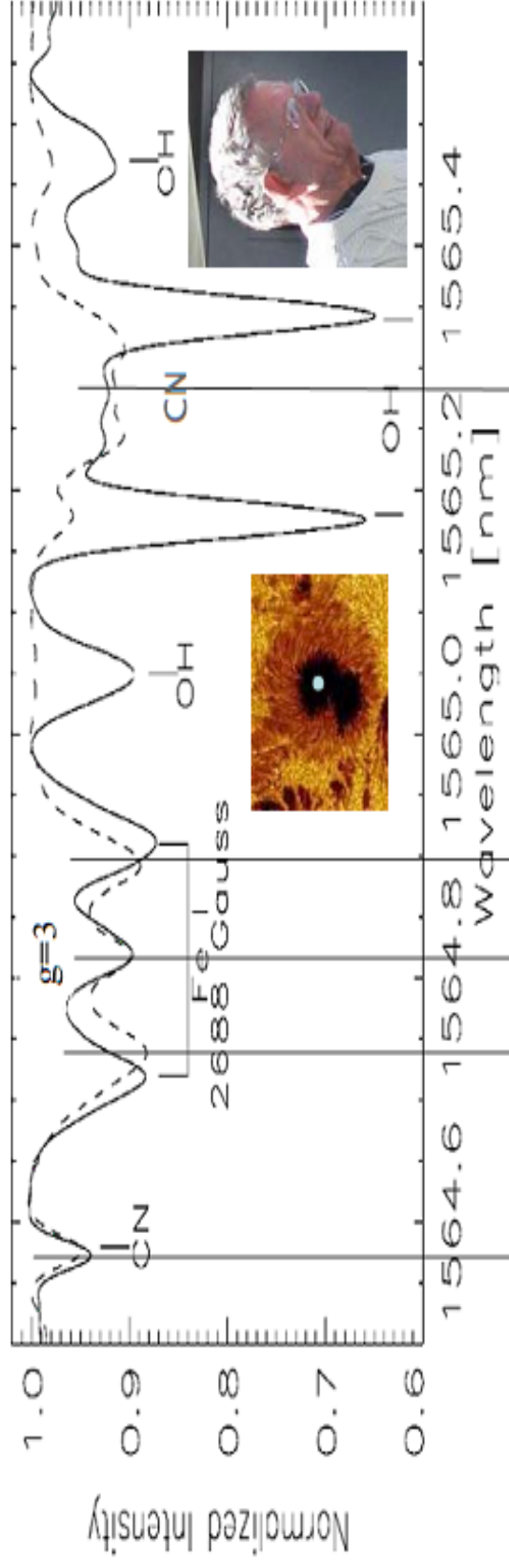
¹⁰Be and ¹⁴C-based reconstructions are largely in agreement

Conclusion

- Variation in Solar Output is a Factor of Ten too Small to Account for The Little Ice Age,
- **Unless** the Climate is Extraordinarily Sensitive to Very Small Changes,
- **But**, Then the Phase ('Line-Up of Wiggles') is Not Right
- Way Out: Sensitivity and Phases Vary Semi-Randomly on All Time Scales. 

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.

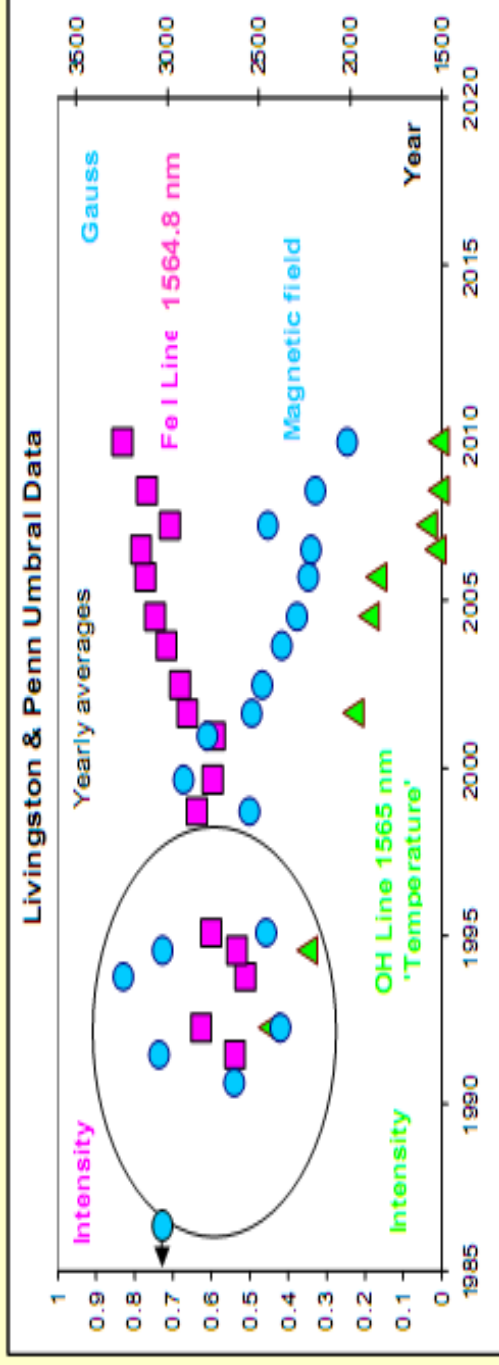


Courtesy Bill Livingston

When the Magnetic Field of a Sunspot Falls Below 1500 G, the Spot Becomes Invisible

The Magnetic Field has Steadily Decreased During SC23. The Temperature has Steadily Increased. At $B = 1500$ G, the Spot is Effectively Invisible.

Decreasing Visibility due to this Effect may lead to an Undercount of Sunspots and partly Explain the Changed Relationship with the Microwave Flux

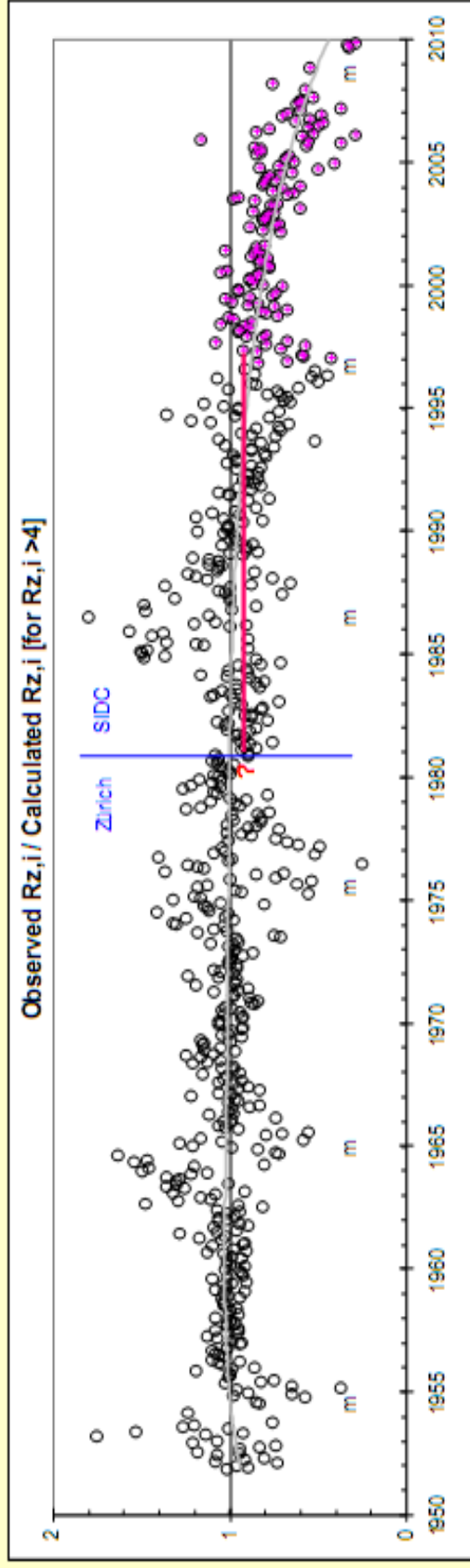


1403 measurements since 1998

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 $B \approx 1500$ G.

