

Historical Solar Cycle Context

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What's so special about now?

I'll first try to convince you that the Sun is just business as usual, and that what we see has been seen before and there has been no surprises.

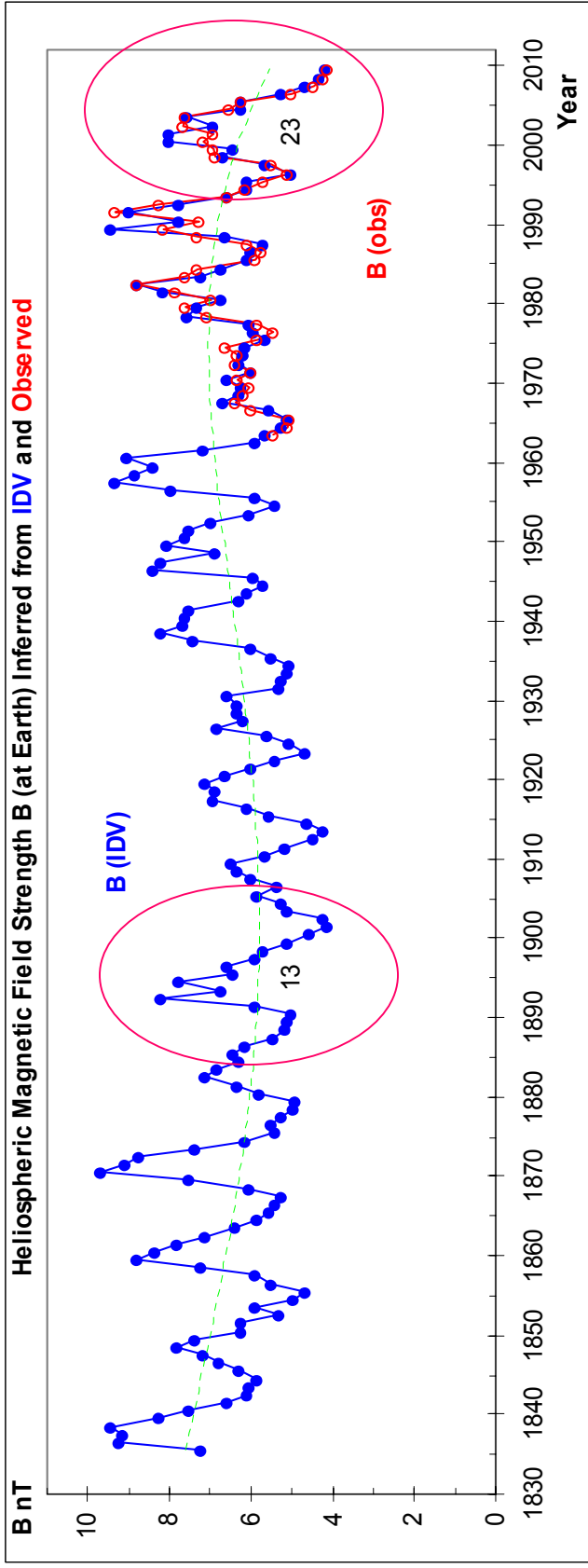
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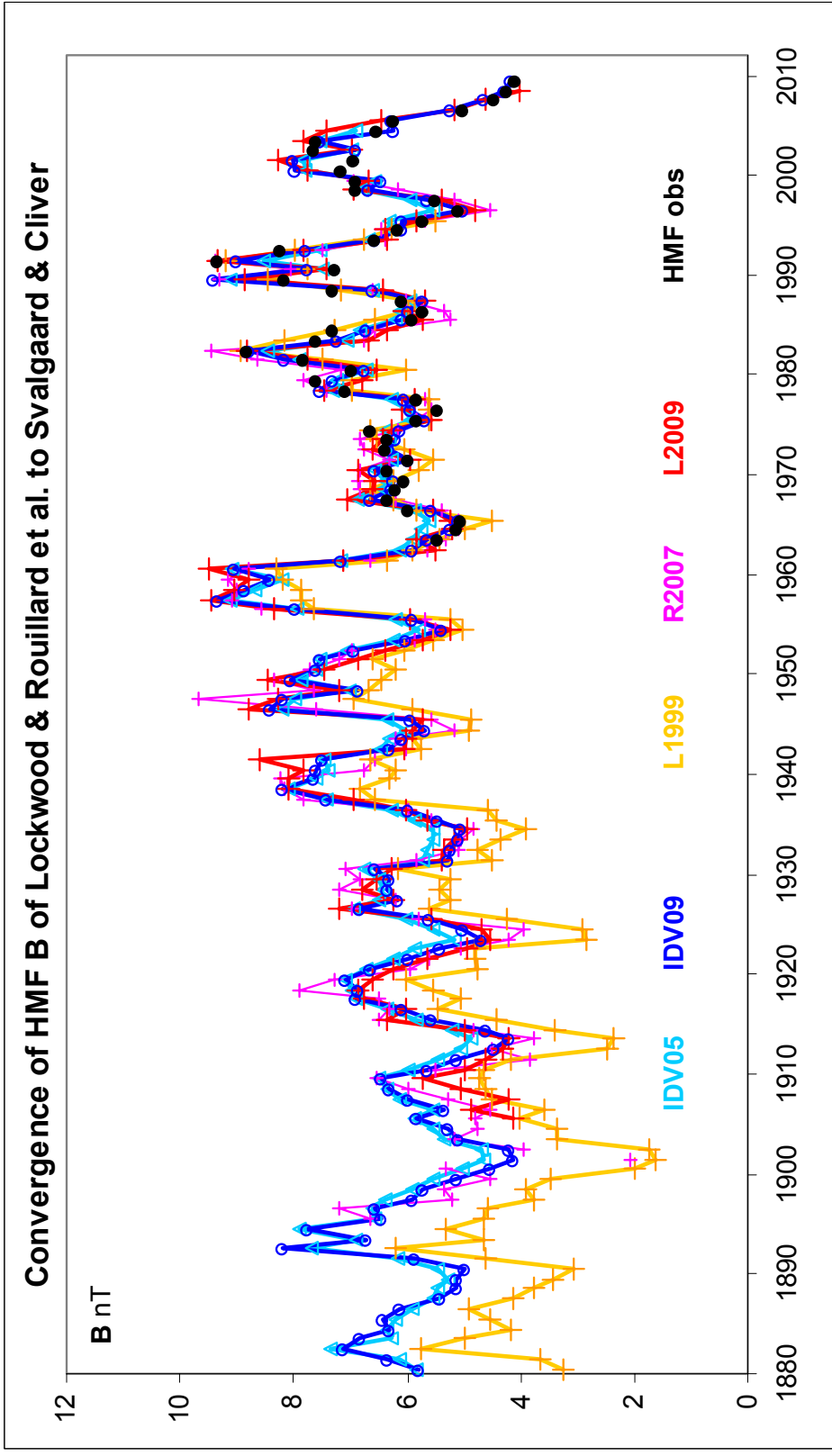
Then I'll try to convince you that perhaps a major change is underway in solar activity.

We have learned how to determine the Heliospheric Magnetic Field (HMF) from geomagnetic records going back almost two centuries.

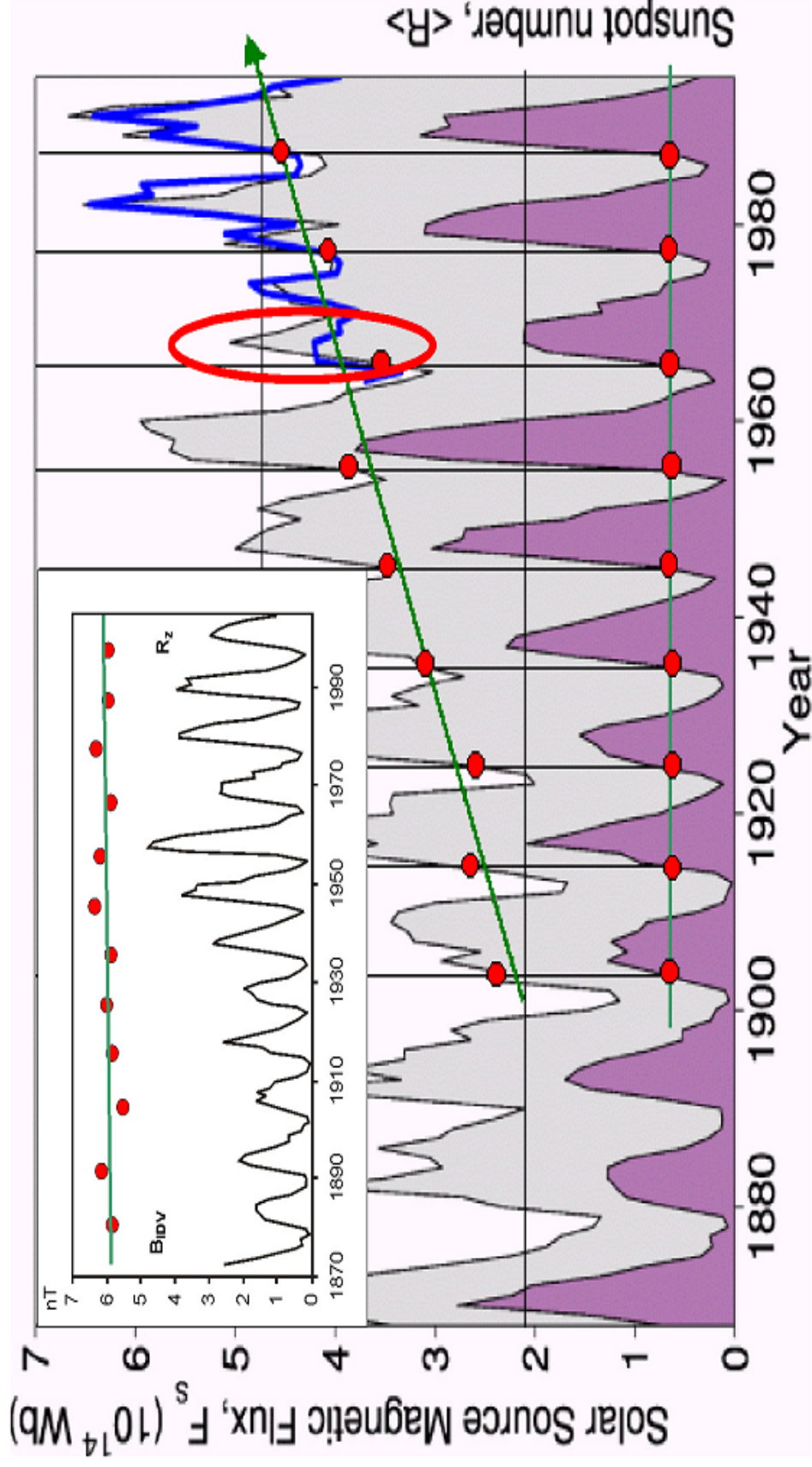
Note how cycle 23 looks like cycle 13, 108 years ago



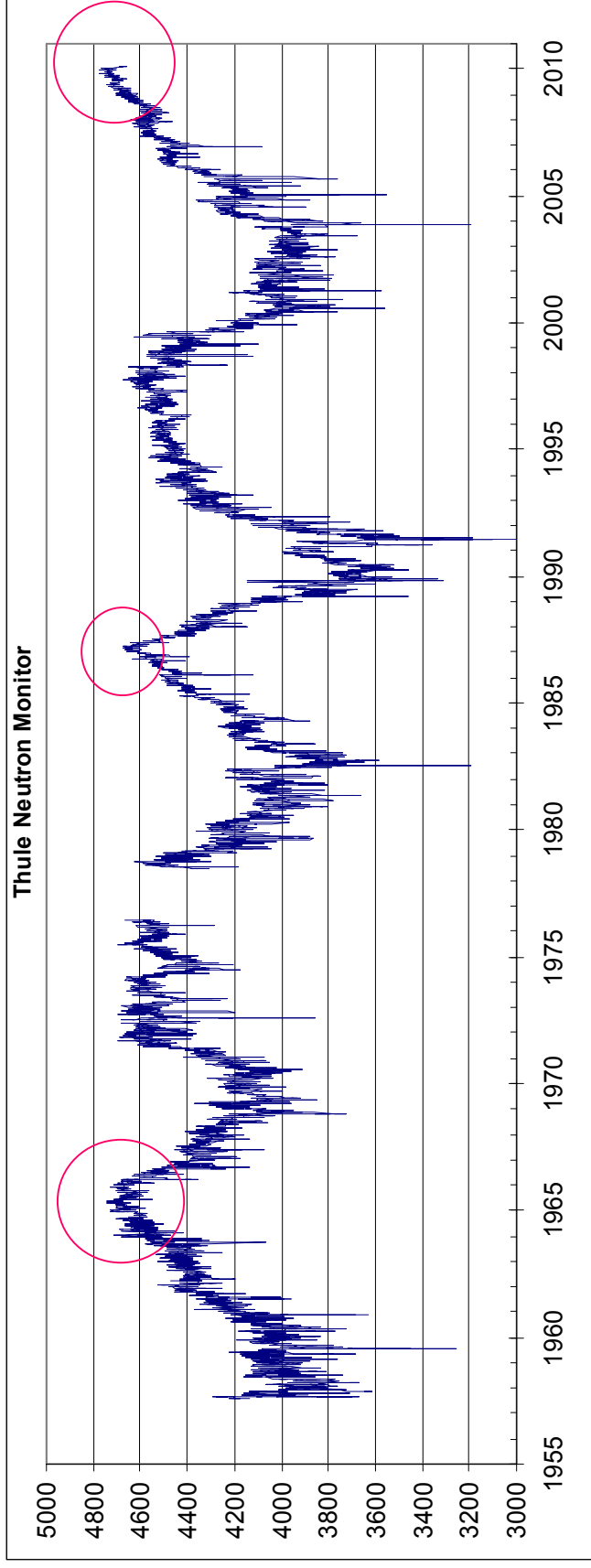
This was once controversial. No longer.
HMF B is constrained to within 10%



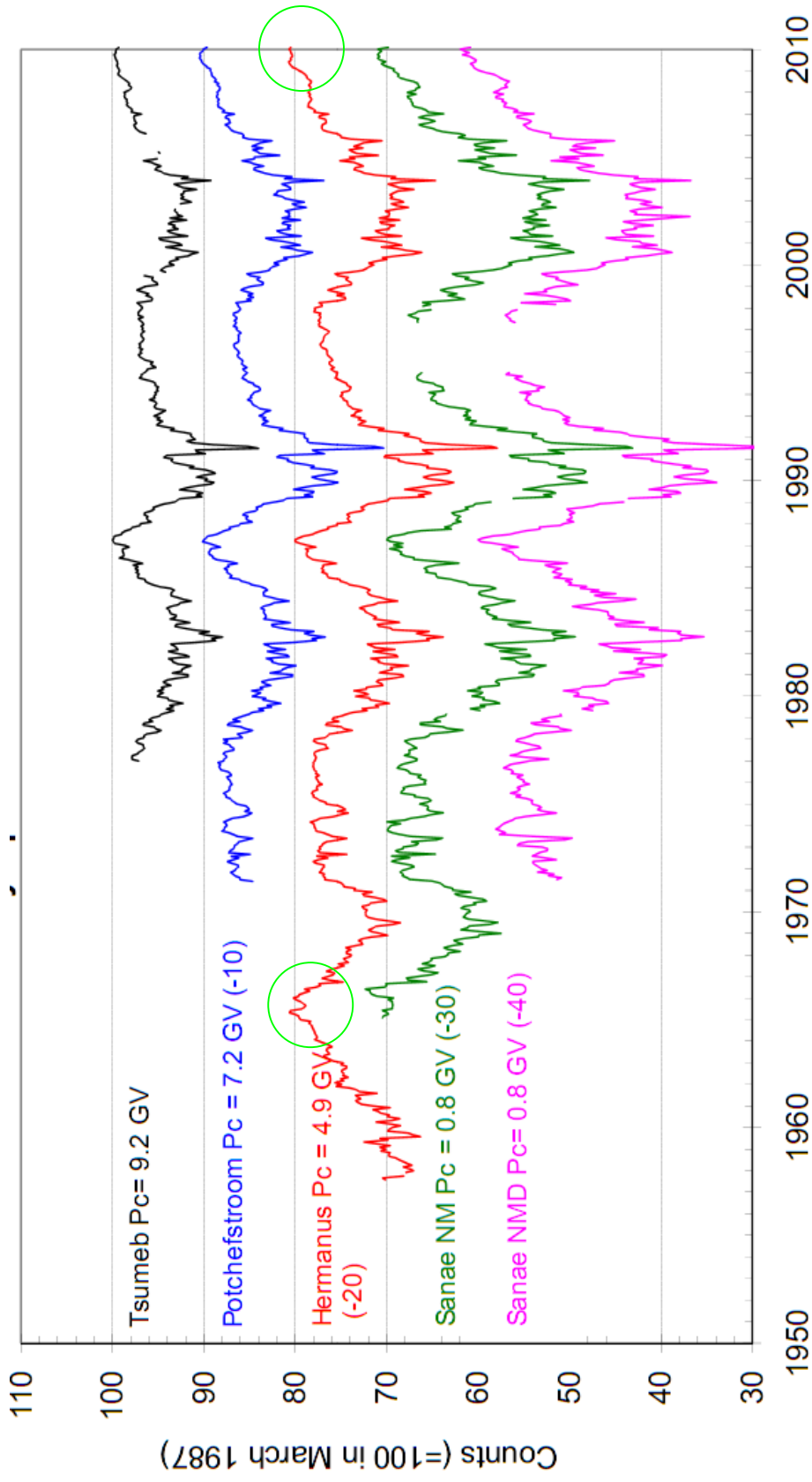
We find that there is no long-term trend in the 'background' magnetic flux



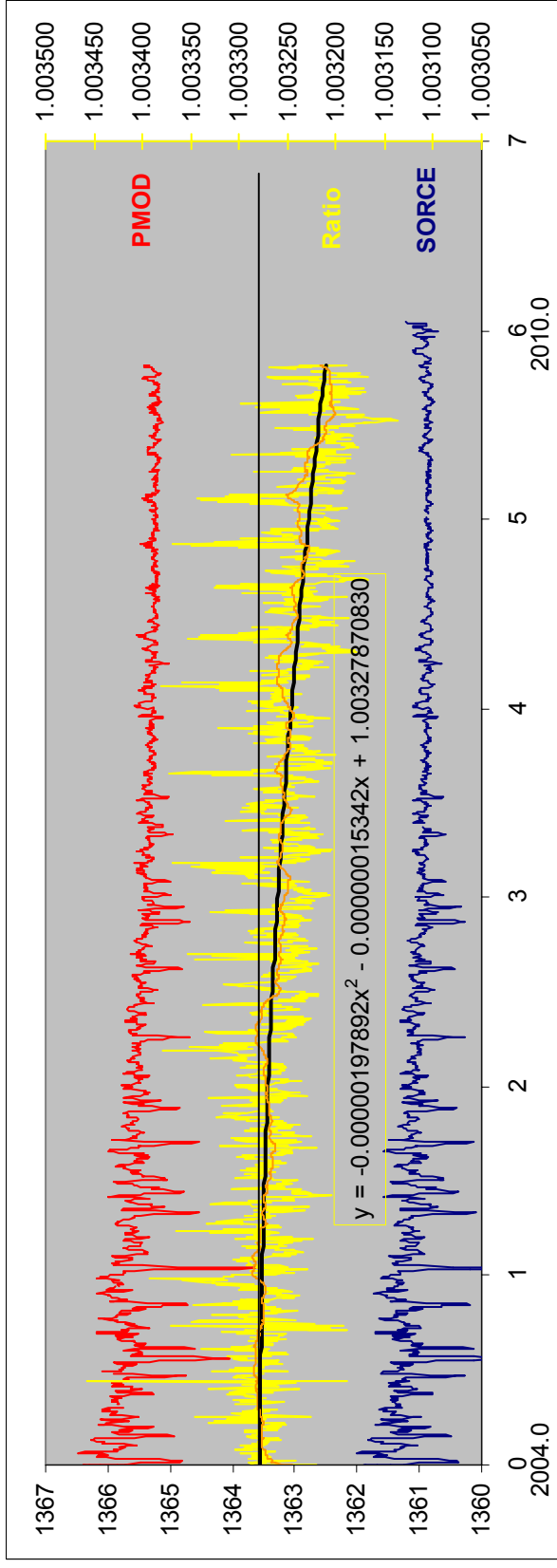
So we would not expect any long-term trend in Cosmic Ray Flux, and none is duly observed

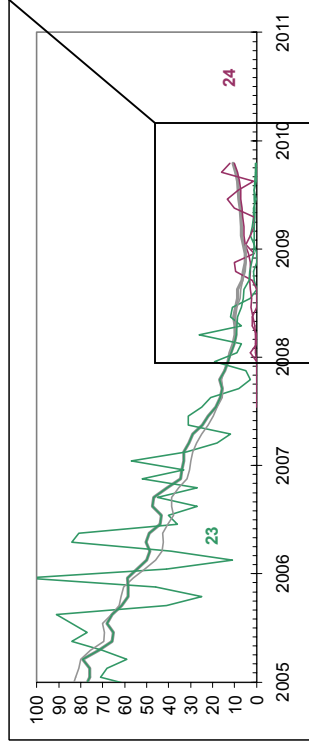
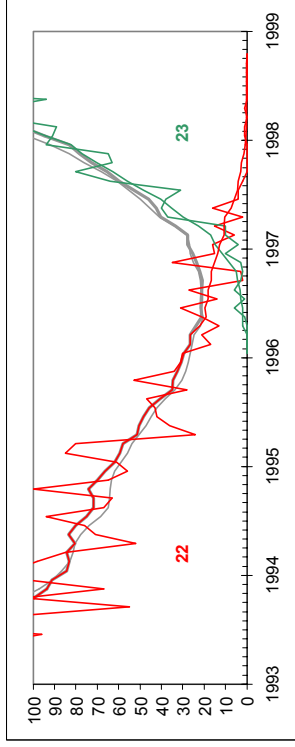
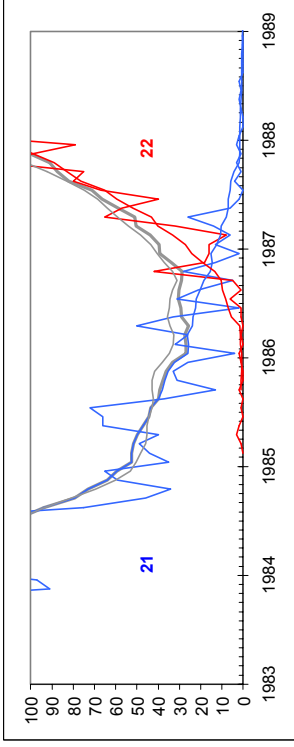
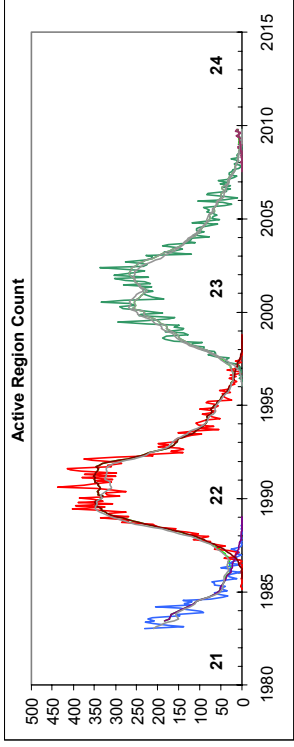


This holds over a wide range of cosmic ray rigidities



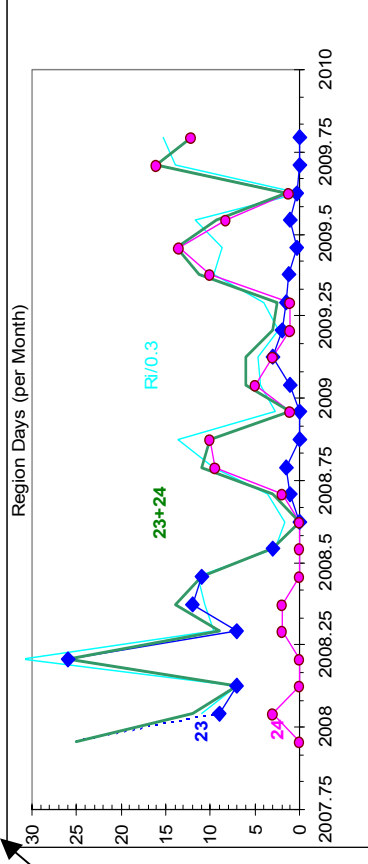
Most of the difference in PMOD TSI
between this minimum and the last
might be due simply to instrument
degradation



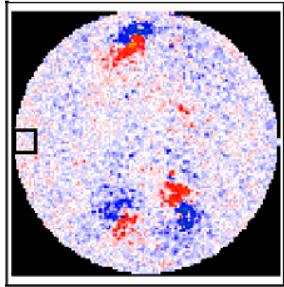


- With all this ‘normality’ how did the cycle 23 to cycle 24 transition play out?

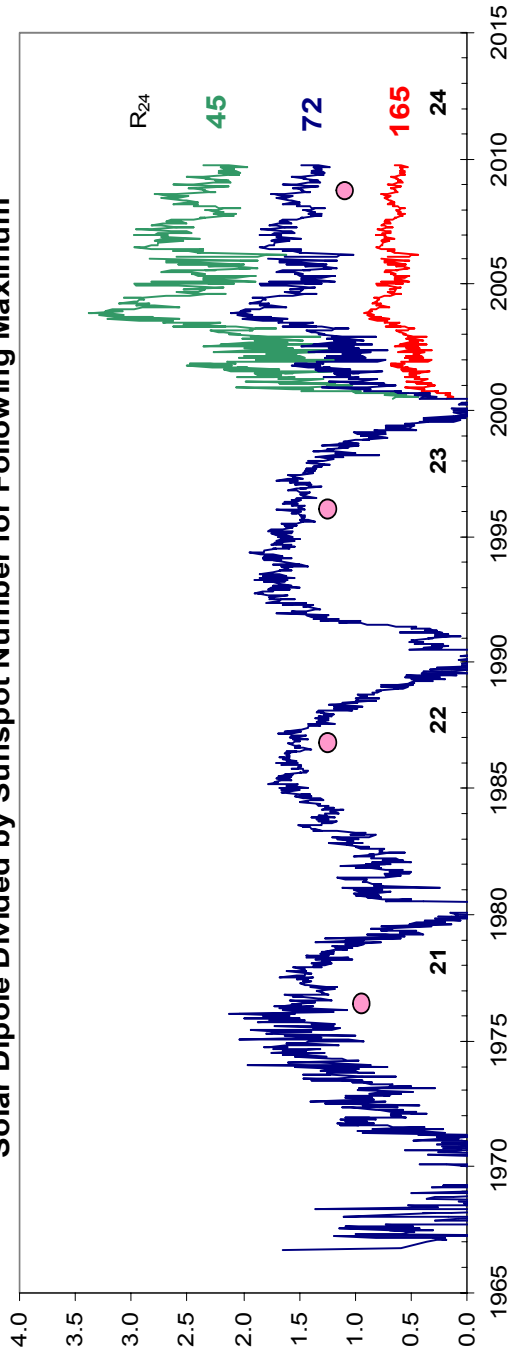
- There can be no doubt that solar minimum is behind us. [Dec 2008?]



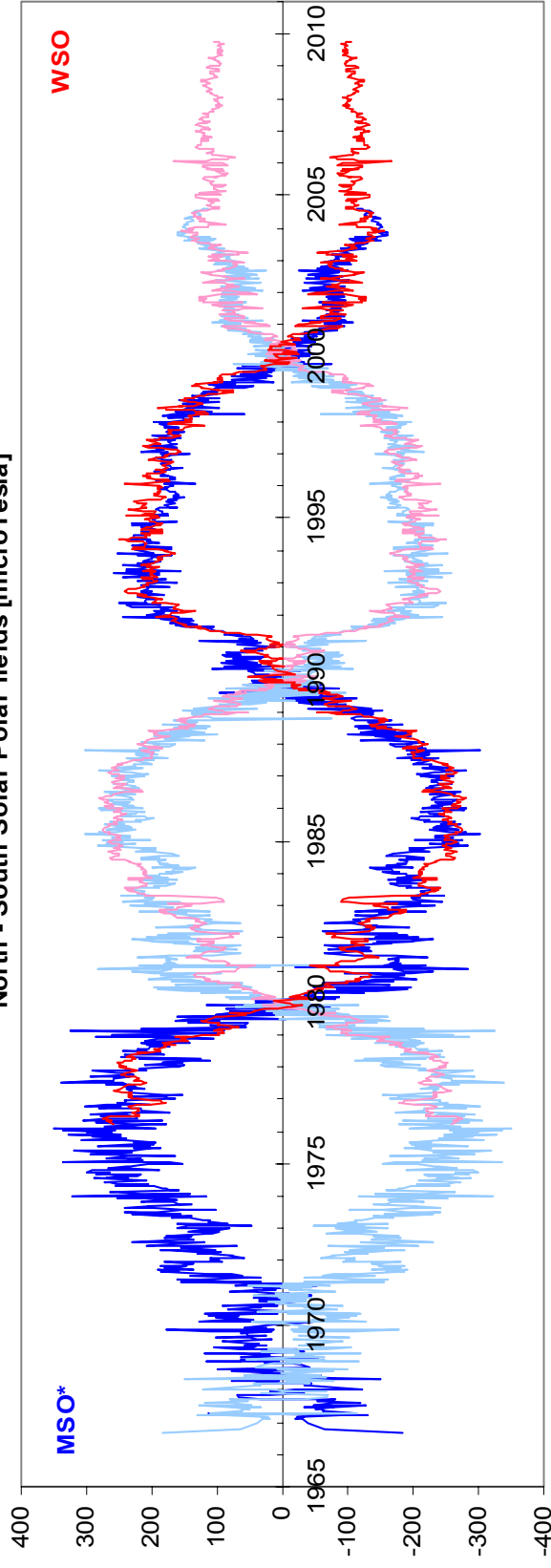
Polar Fields



Solar Dipole Divided by Sunspot Number for Following Maximum

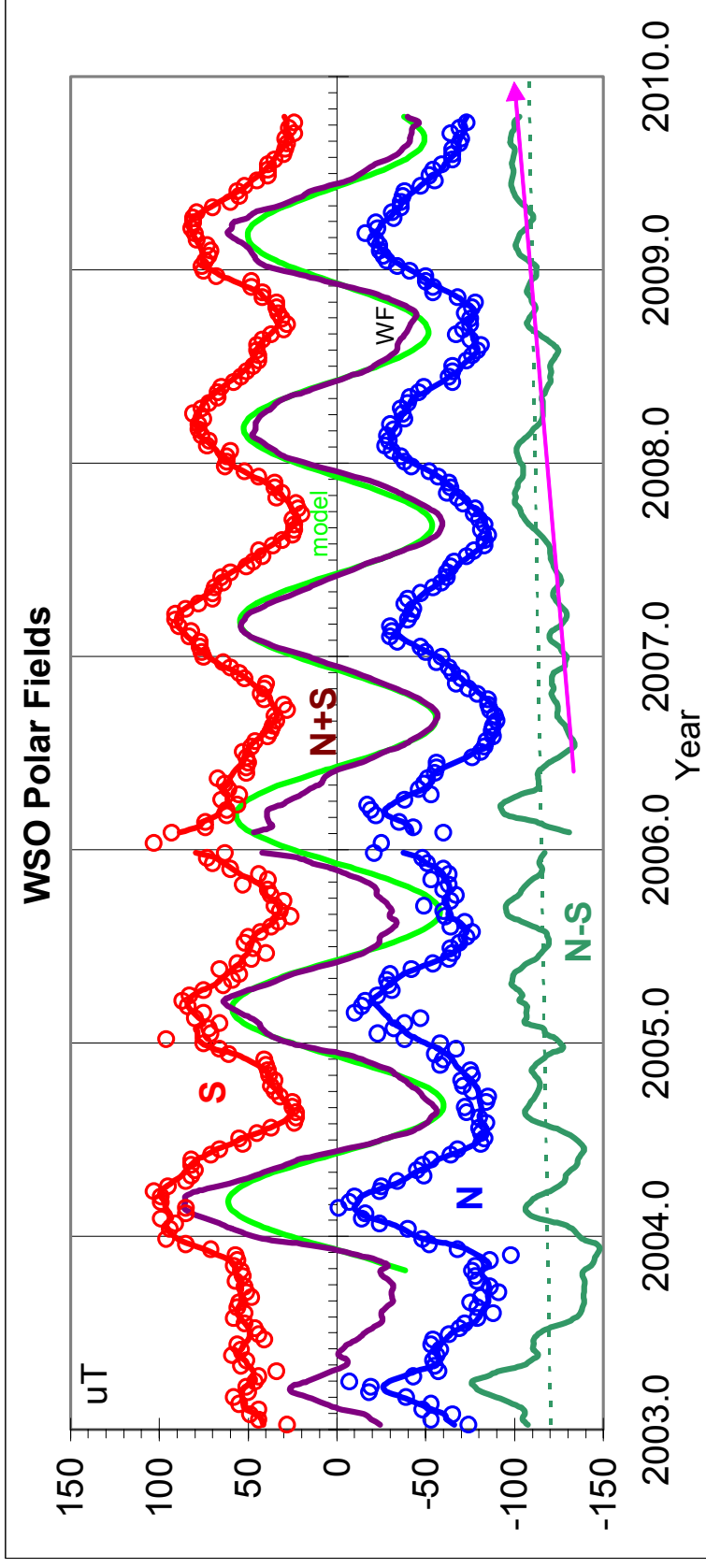


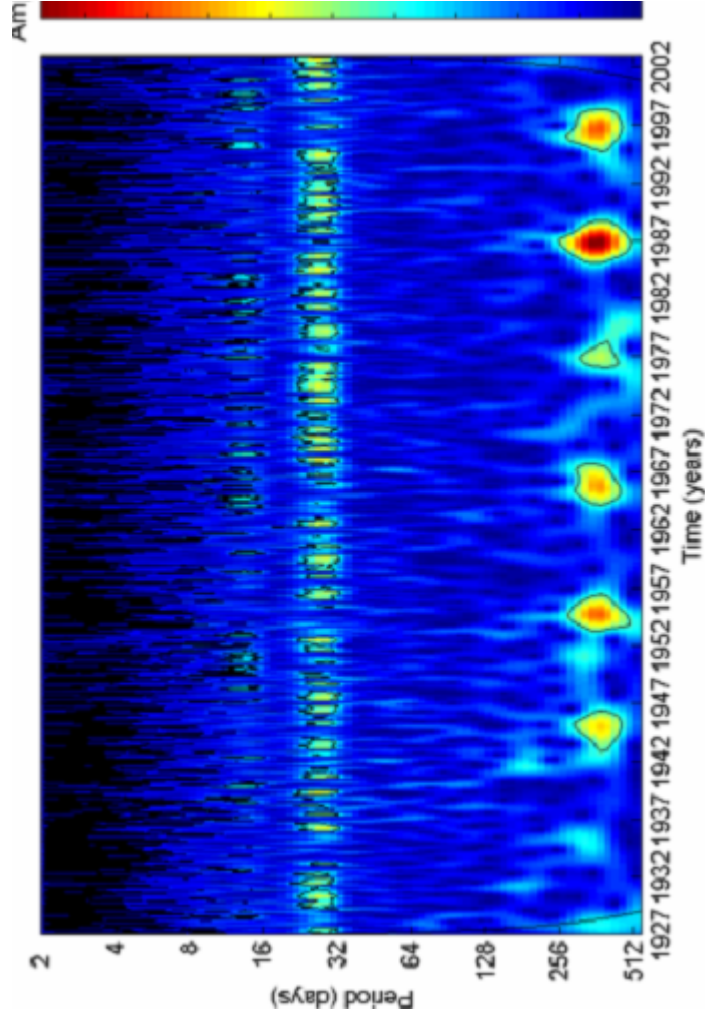
North - South Solar Polar fields [microTesla]



The Annual Modulation

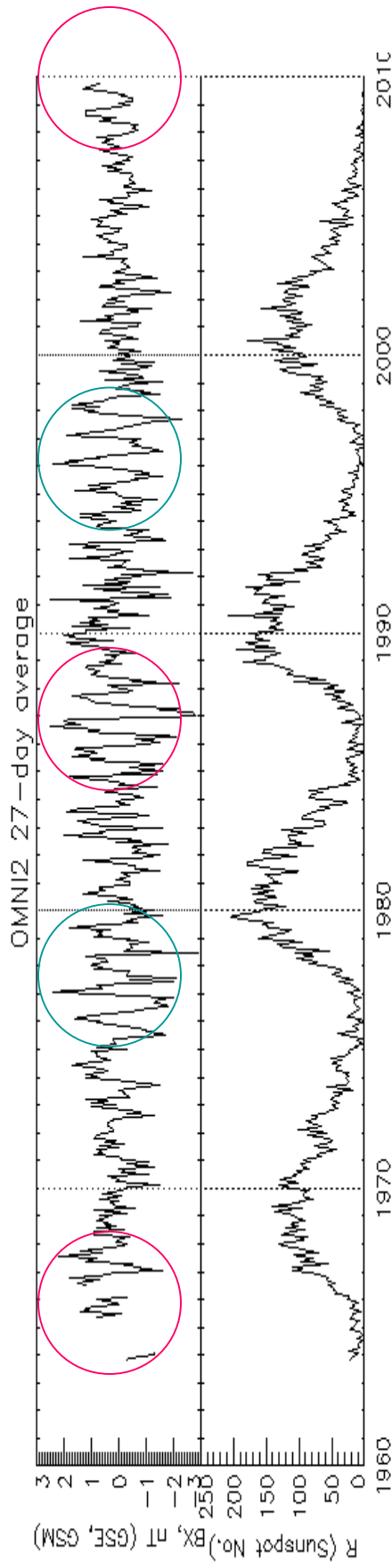
(very good fit to model derived from previous minima)





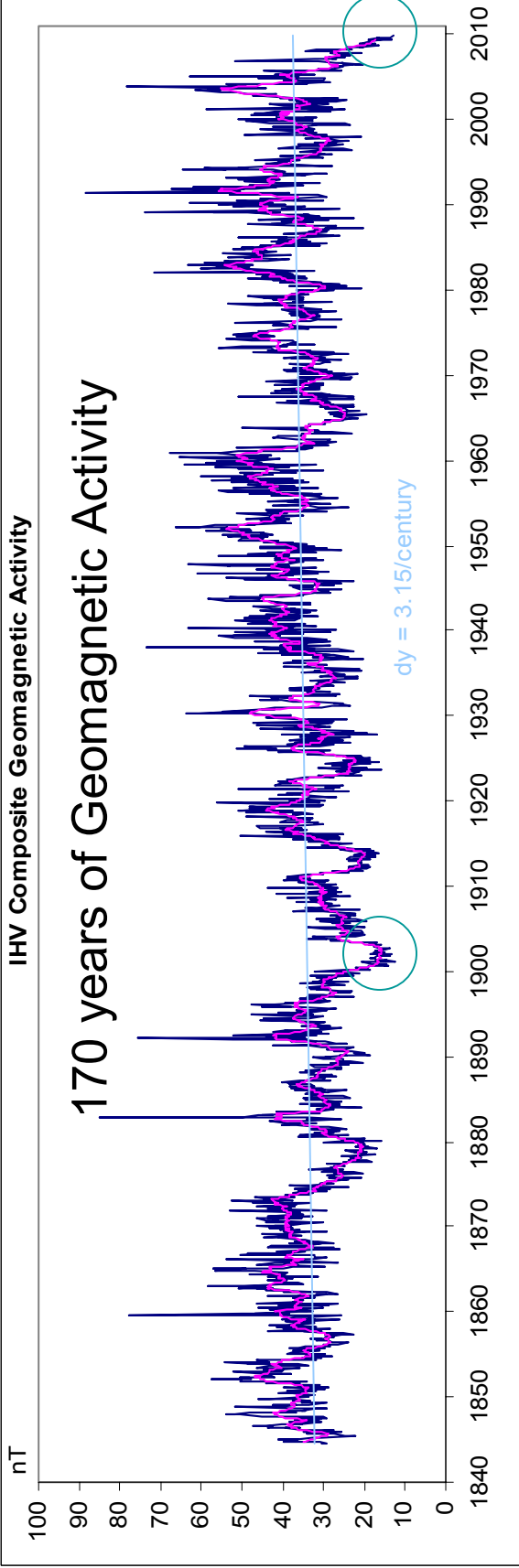
Balance between polar fields and low-latitude fields = Flatness of HCS

- Rosenberg-Coleman Effect at minimum and early rise of cycle
- Reverses sign at cycle maximum
- Past polar field reversals

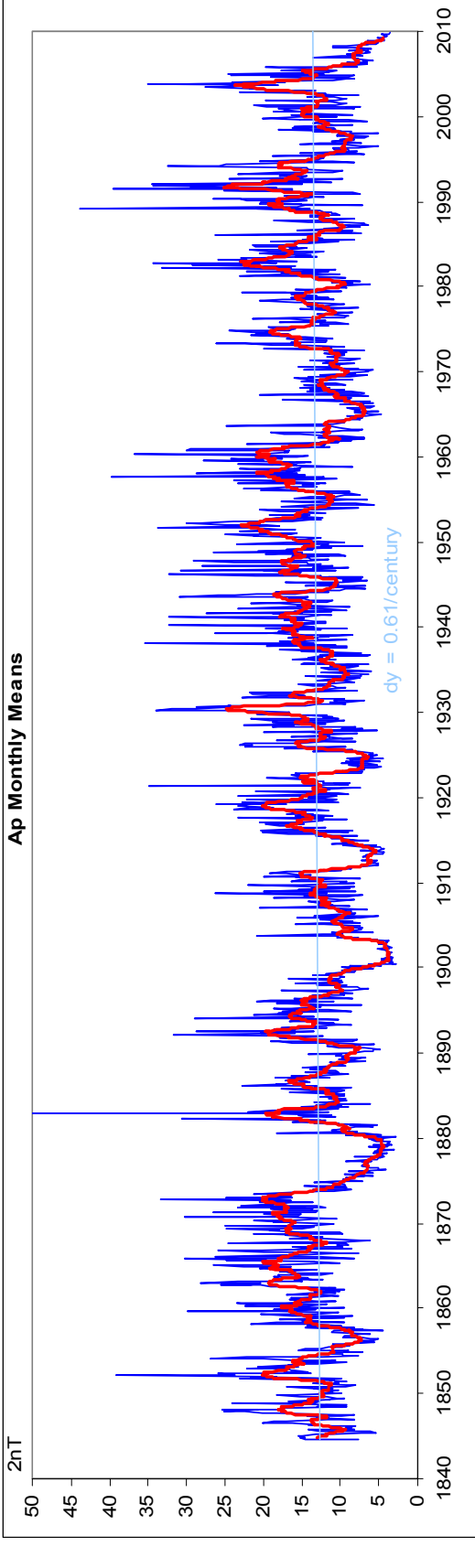


IHV Composite Geomagnetic Activity

170 years of Geomagnetic Activity

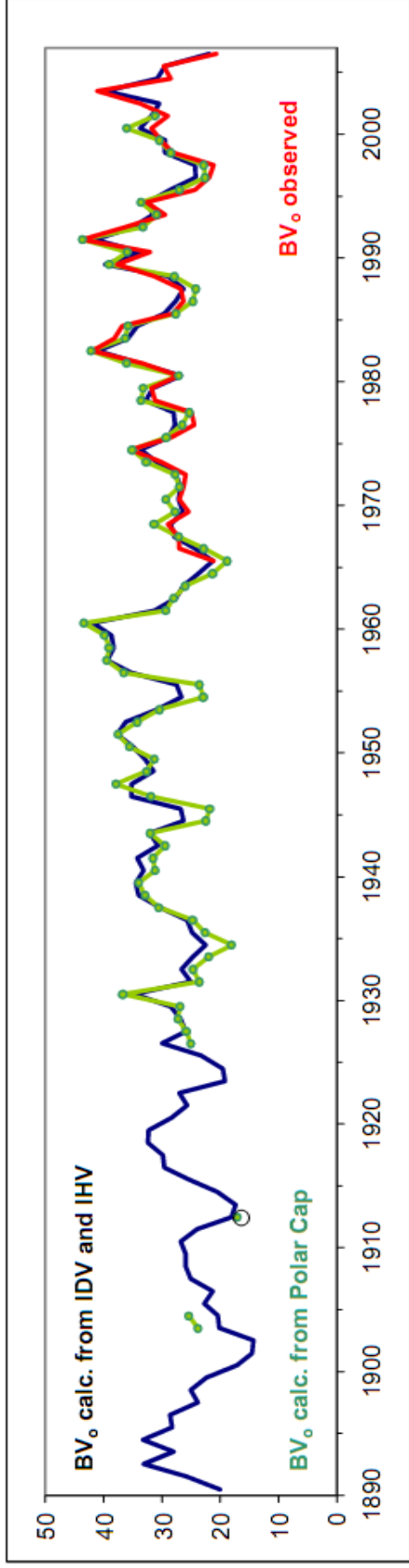
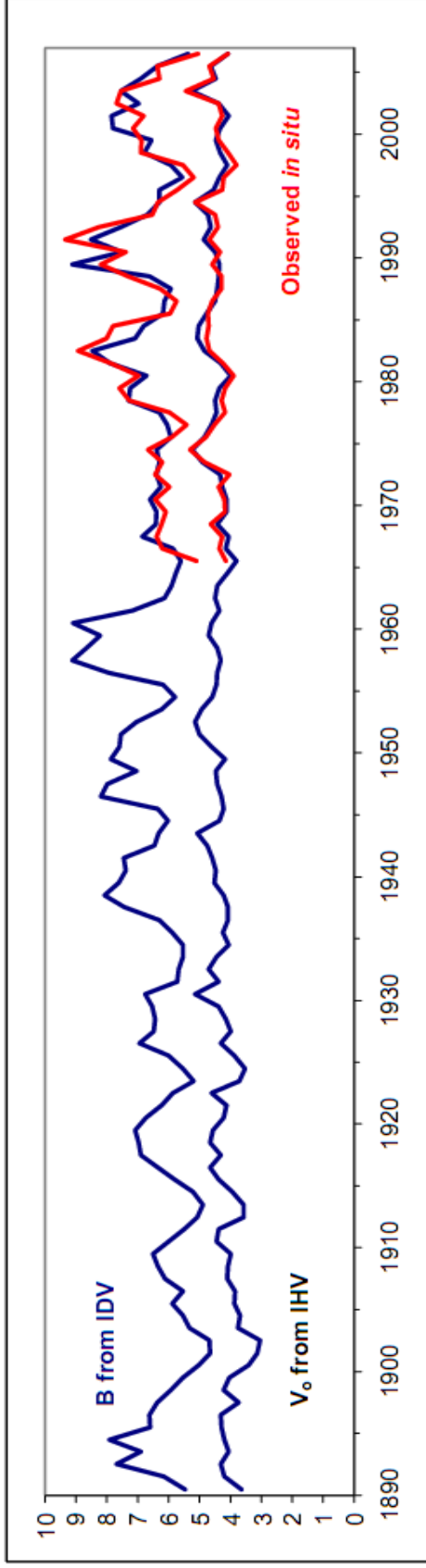


Ap Monthly Means



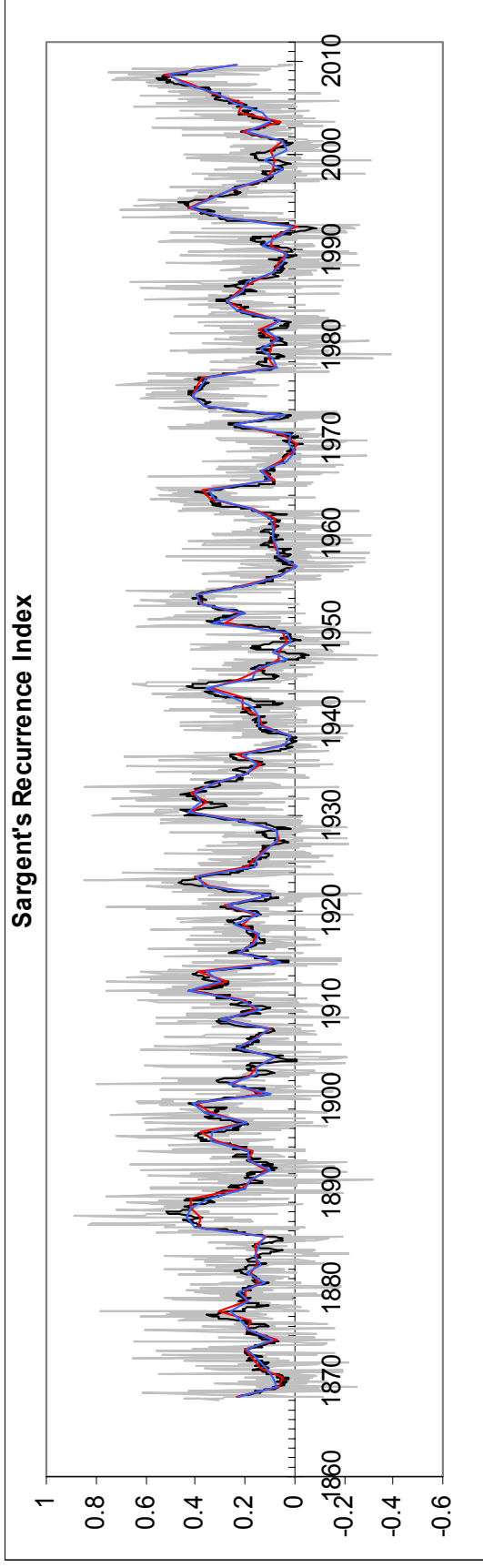
$$IDV \sim B \quad IHV \sim BV^2 \quad PC \sim BV$$

over-determined system allows cross-check



High-Speed Solar Wind Streams Occur Before Every Solar Minimum

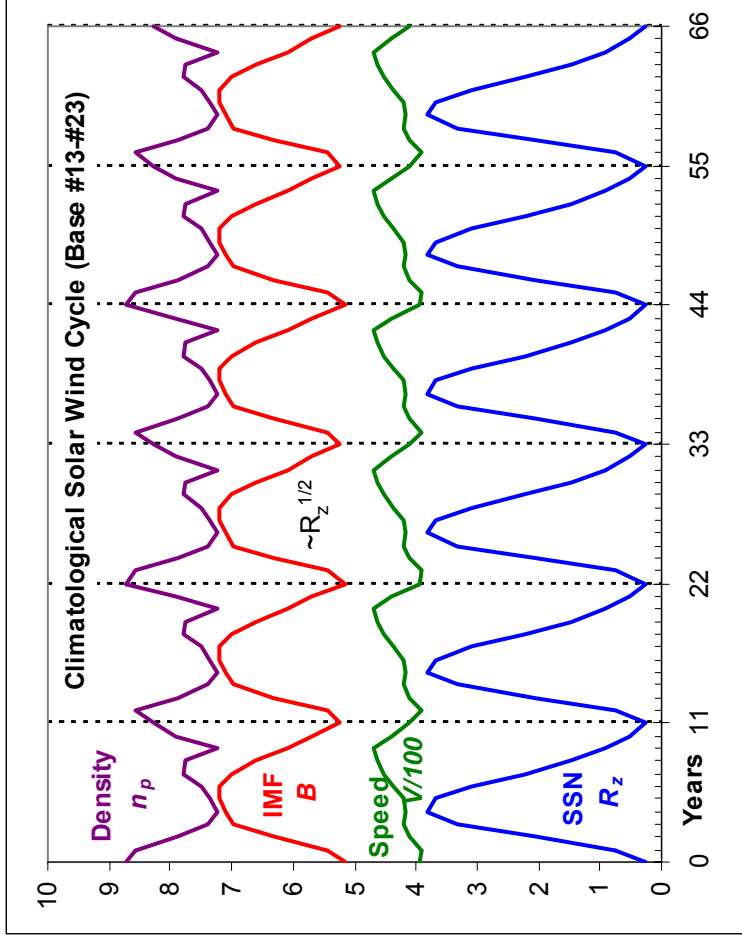
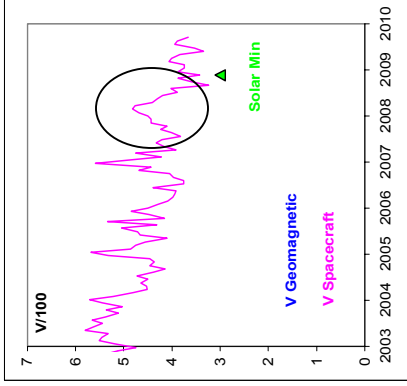
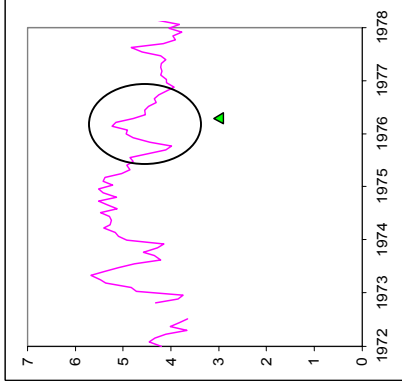
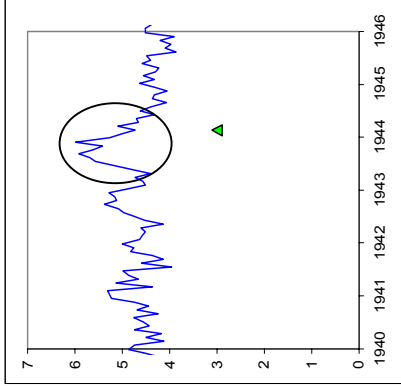
The Sargent Recurrence Index is the cross-correlation coefficient between successive solar rotations of a given parameter, e.g. geomagnetic activity [Solar wind speed from IHV $\sim BV^2$]



“If the Sun was so quiet why was the Earth ringing?”

Because of the high-speed streams that occur prior to every minimum

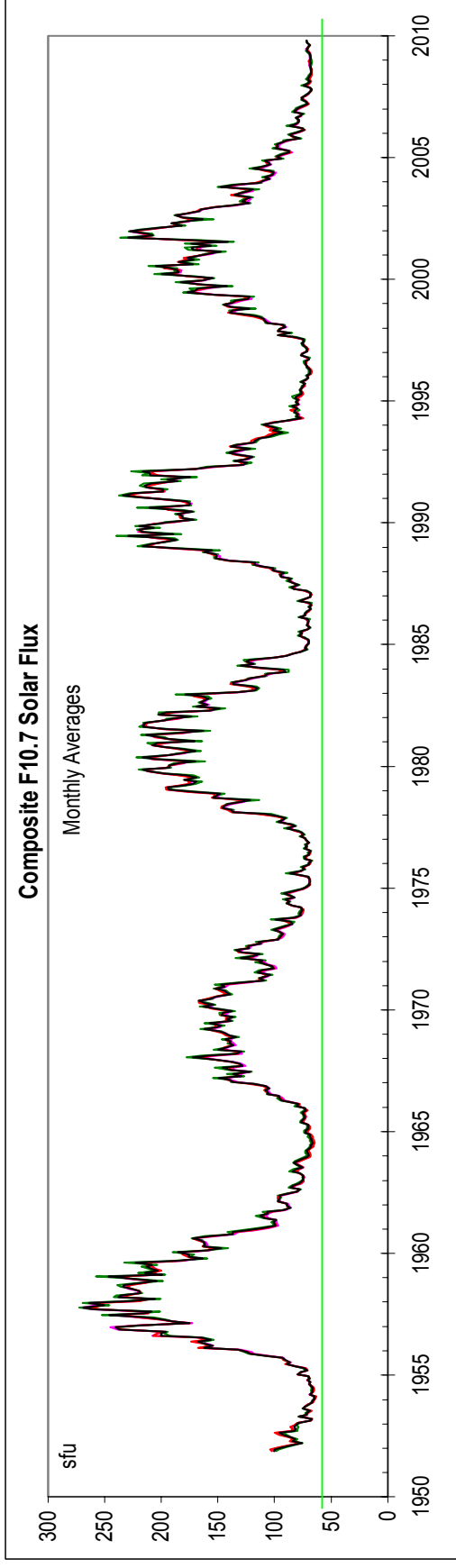
We derive an average solar wind cycle by superposing 11 cycles



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Solar Microwave Flux

F10.7 (2.8 GHz) has been observed since 1947 in Canada and the flux at 1, 2, 3.75, and 9.4 GHz has been observed since 1951 in Japan. A composite dataset of these observations show that the flux at solar minimum (including this one) is as constant as we would expect from no long-term trend in 'background' solar activity.



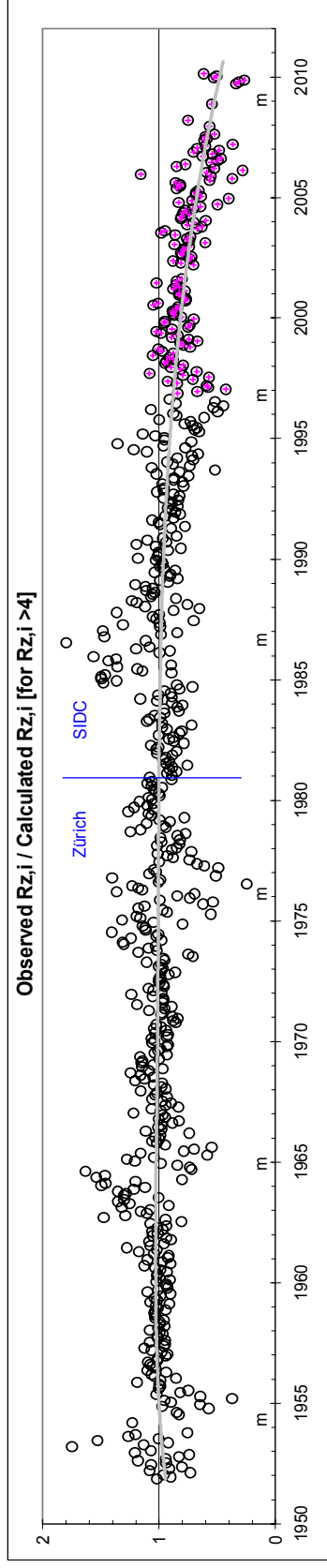
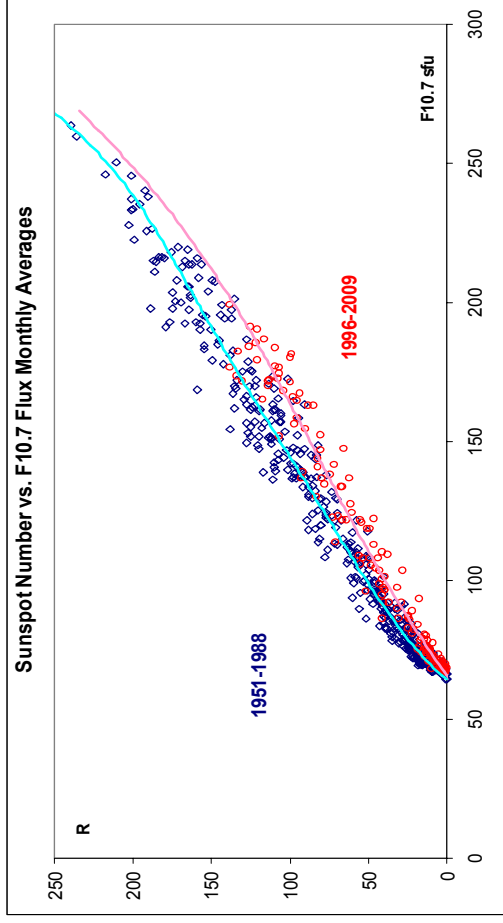
Changing Relationship Between F10.7 Flux and Sunspot Number

$$R = a + b F + c F^2 + d F^3 + \dots$$

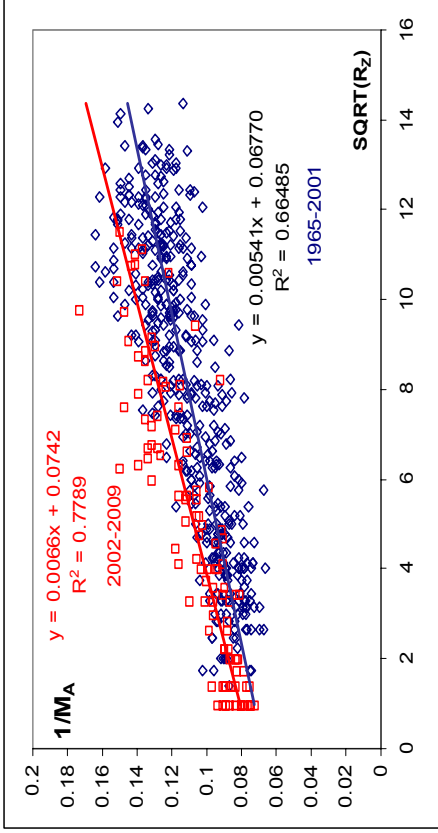
There is a well-established, tight relationship between flux F and R.

For cycle 23 this relationship has changed with R lower for same F.

Ratio between synthetic equivalent sunspot number and observed R suggests a progressive deficit of observed R during cycle 23.

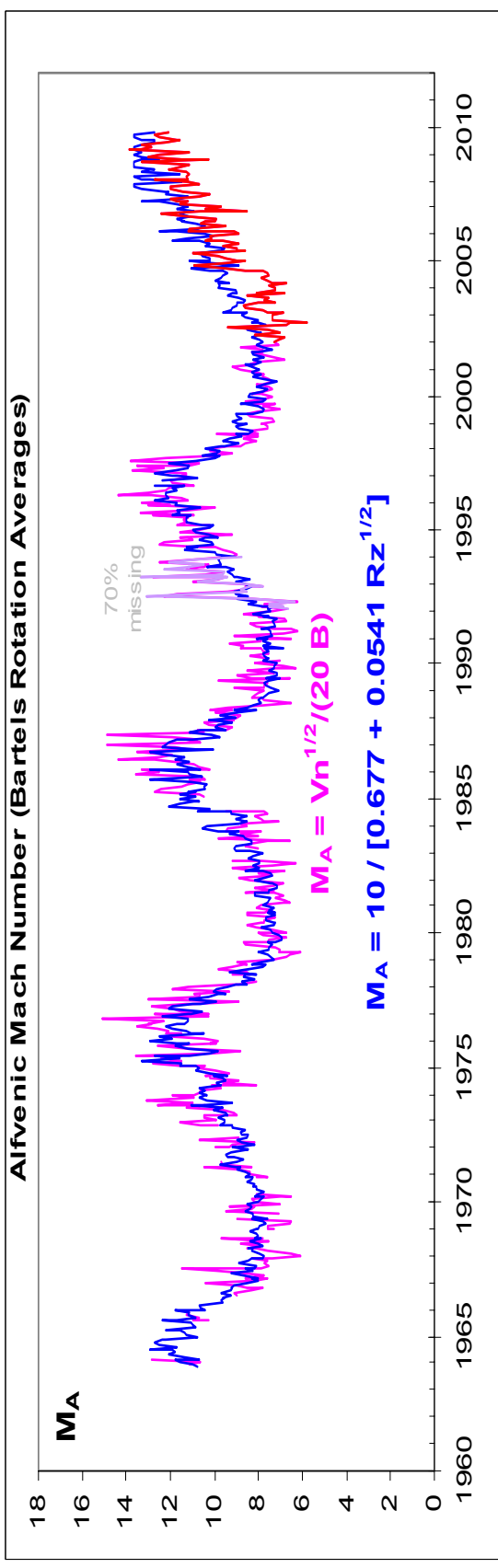


Changing Relationship Between Solar Wind Alfvén Mach Number and Sunspot Number

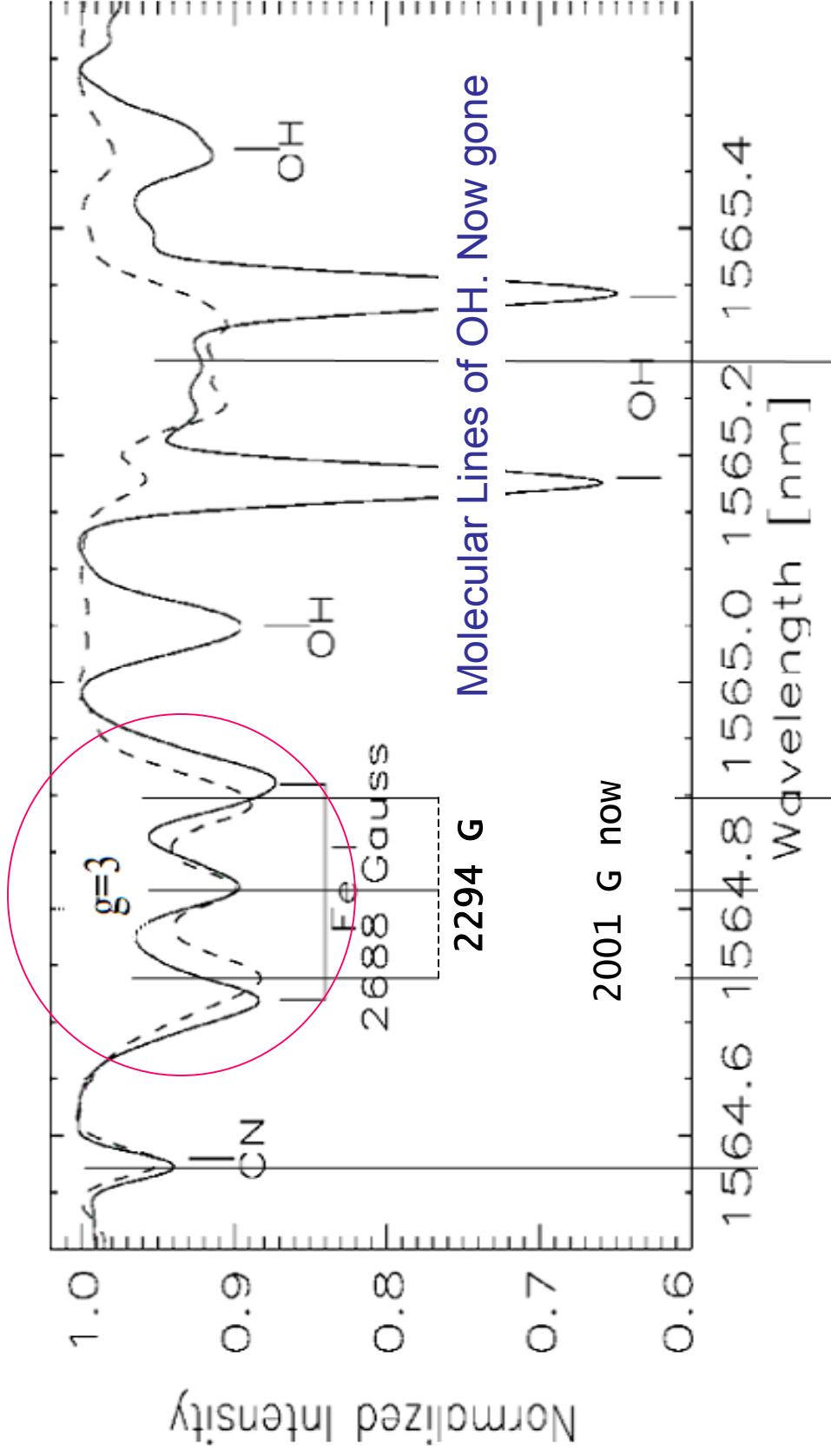


For most of the Space Age there has been a good correlation between the inverse M_A and the square root of R .

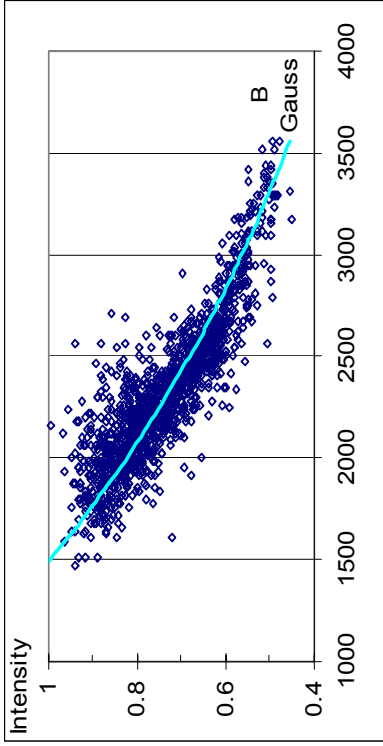
During cycle 23 that relationship has changed corresponding to a lower R for same M_A .



Sunspot umbras: magnetic field, contrast ratio, and temperature

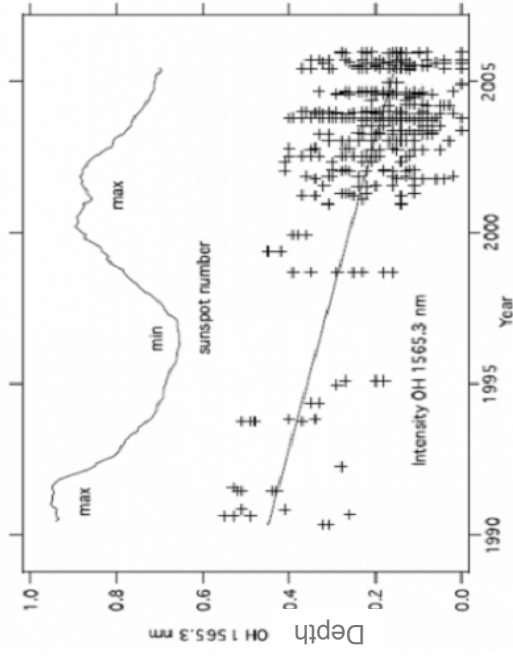
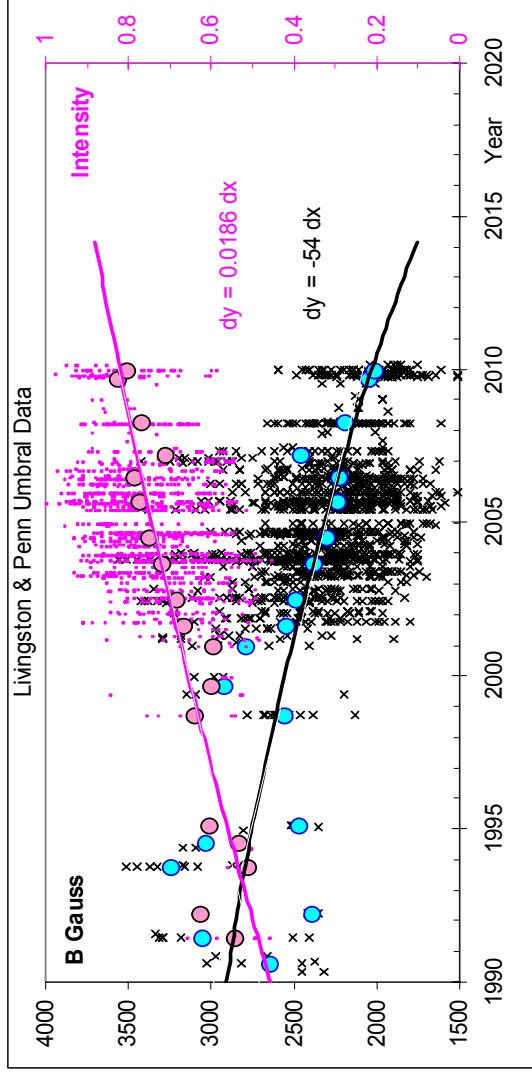


Livingston & Penn Effect ?



As B goes to 1500 G, the contrast ratio goes to 1 and the spot is effectively invisible (in the infrared)

In practice: smaller spots will be undercounted and the sunspot number will be too low.

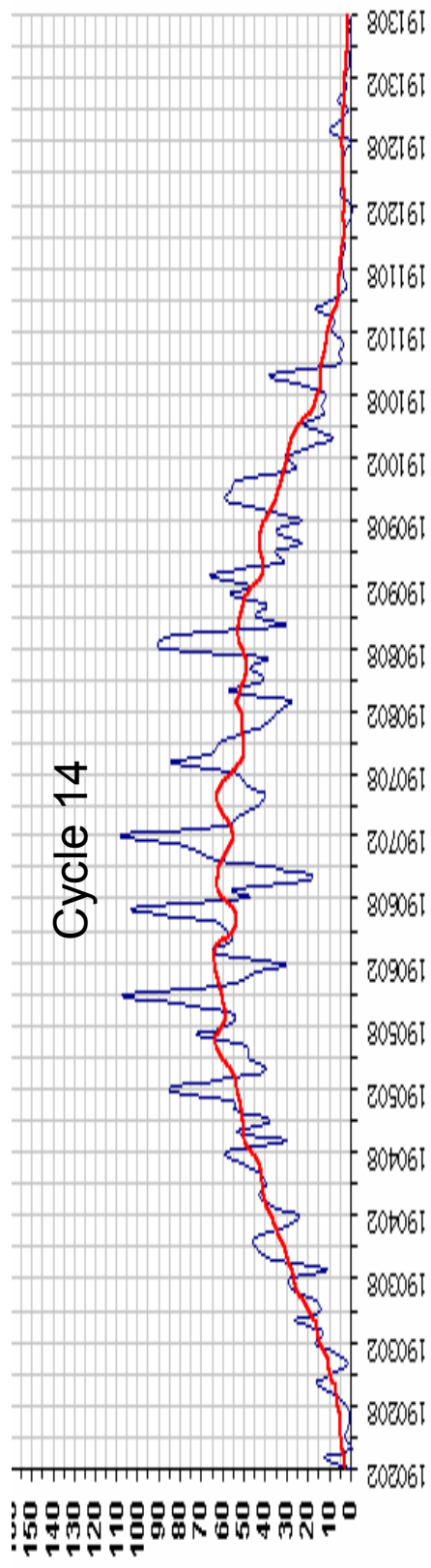


Livingston (pers. comm. 2010) & Penn

What Will Cycle 24 Look Like?

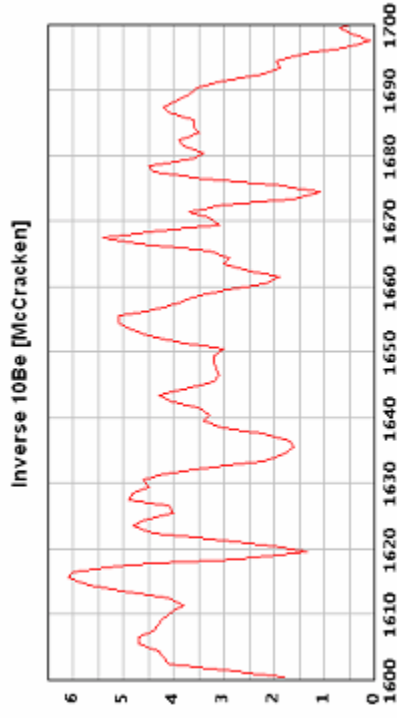
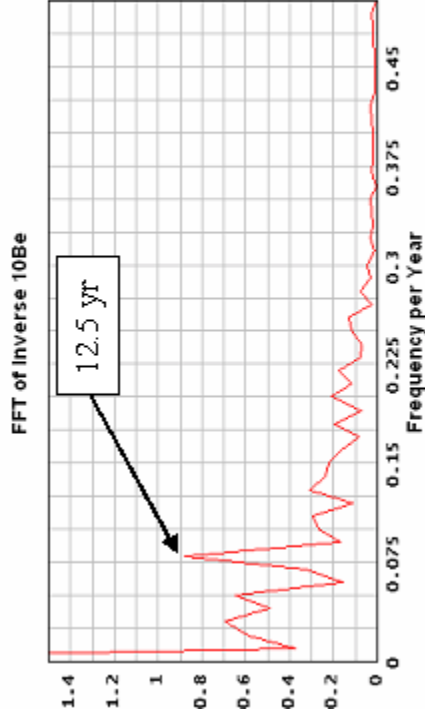
Perhaps Like Cycle 14

- Predicted F10.7 = 123 sfu
- Predicted SSN = 72 or 6 active regions [groups]
- If L&P are correct, then we don't know what the SSN will be expect much lower than 72, but the number of groups and F10.7 might still be correct



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

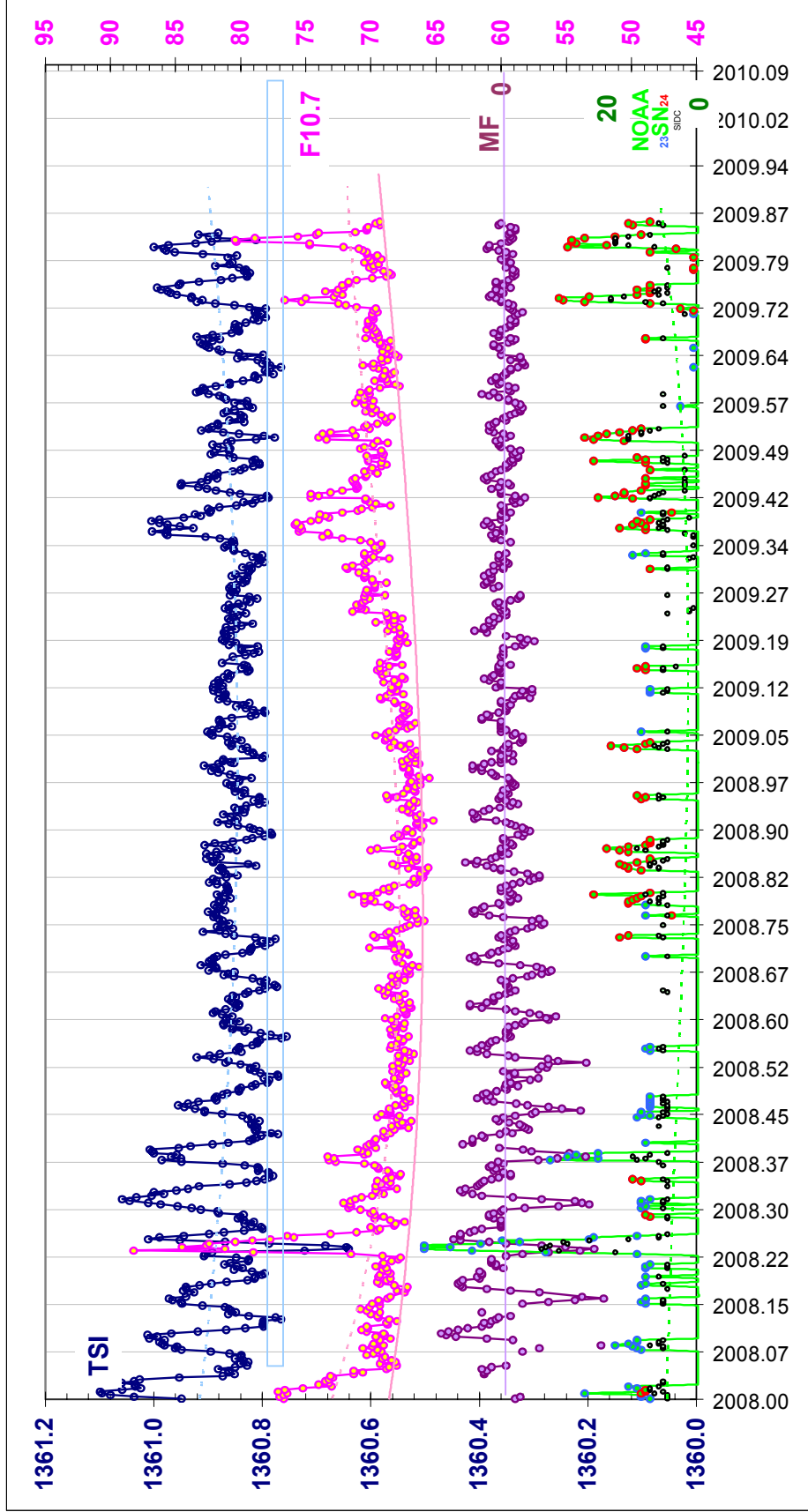
- Cosmic Ray proxies show that both during the Maunder Minimum and the Spörer Minimum the modulation of cosmic rays proceeded almost as 'usual'. So the Heliosphere was not too different then from now, and perhaps the spots were just much harder to see because of low contrast.



Cycle 24 will be an exciting cycle to watch unfold with modern instruments.

Questions?

Current Measurements



Omni Dataset Anomaly

