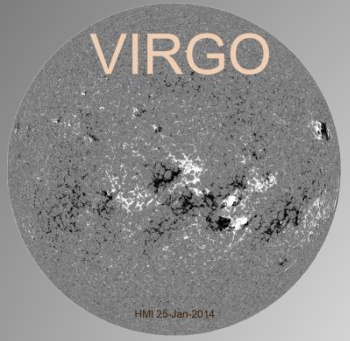
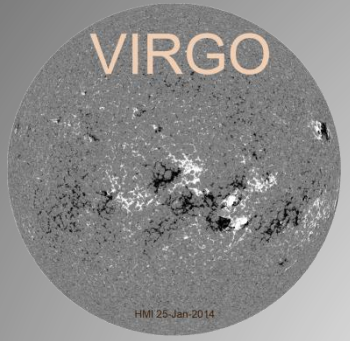


TSI Reconstruction back to 1915 based on sunspots from RGO, Ca-II from Mt. Wilson, B_R from AA-index and the 4-component proxy model calibrated 1978-2015

Claus Fröhlich

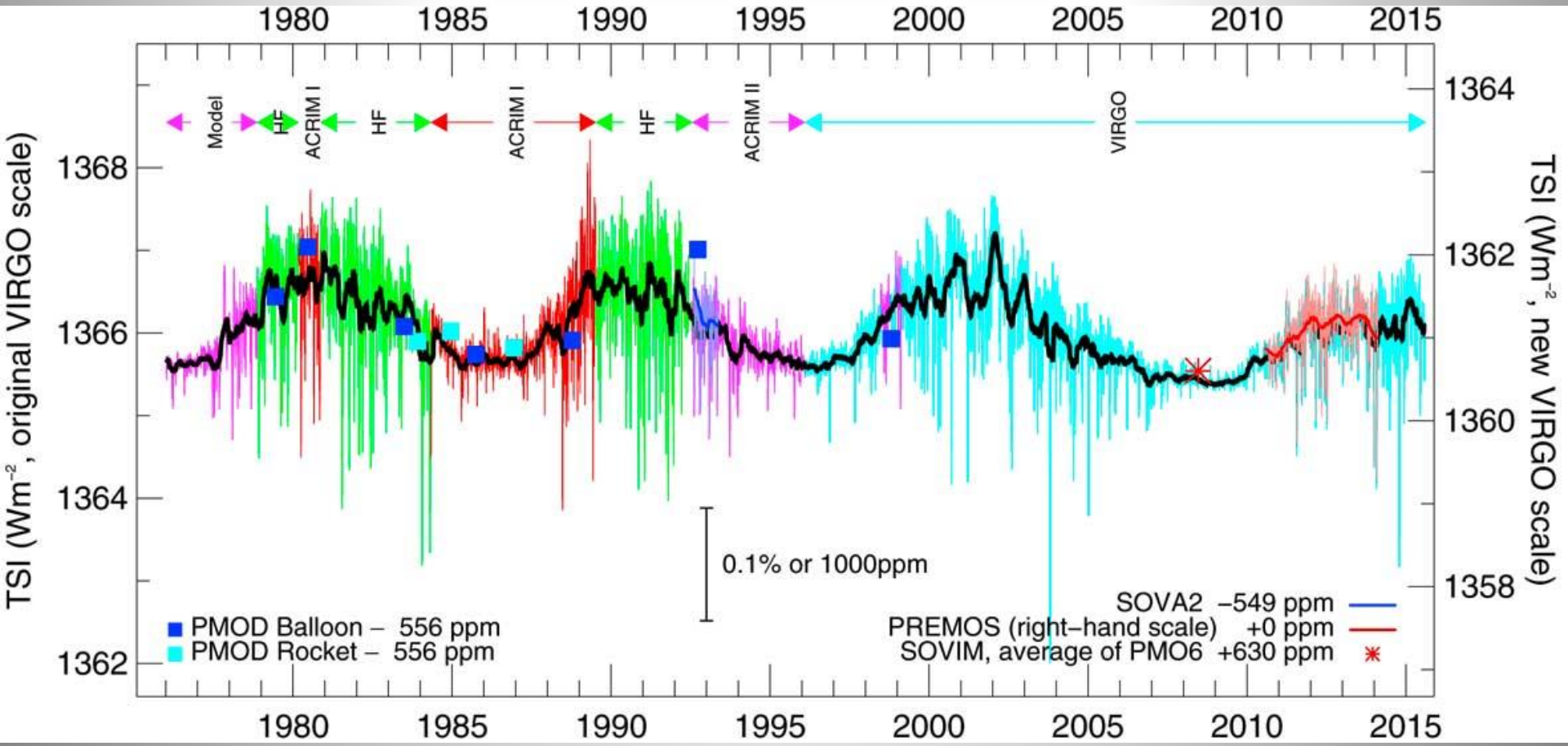
CH 7265 Davos Wolfgang

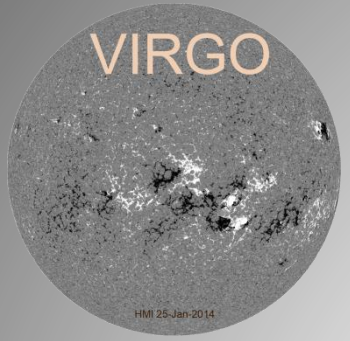


TSI composite as basis

The PMOD composite is the basis for what follows and I will not not discuss how you get it. The absolute scale is based on VIRGO version 6.4 (left scale org and right scale new). Next January the VIRGO TSI record will be 20 years long. I have added all the PMOD determinations from Balloon, rockets and space experiments –overall an interesting contribution.

Will Ball brought up that there is problem with the amount of the minimum change in the new data since August 2015. It is due to still not adequately corrected DARAD data recovering within months.



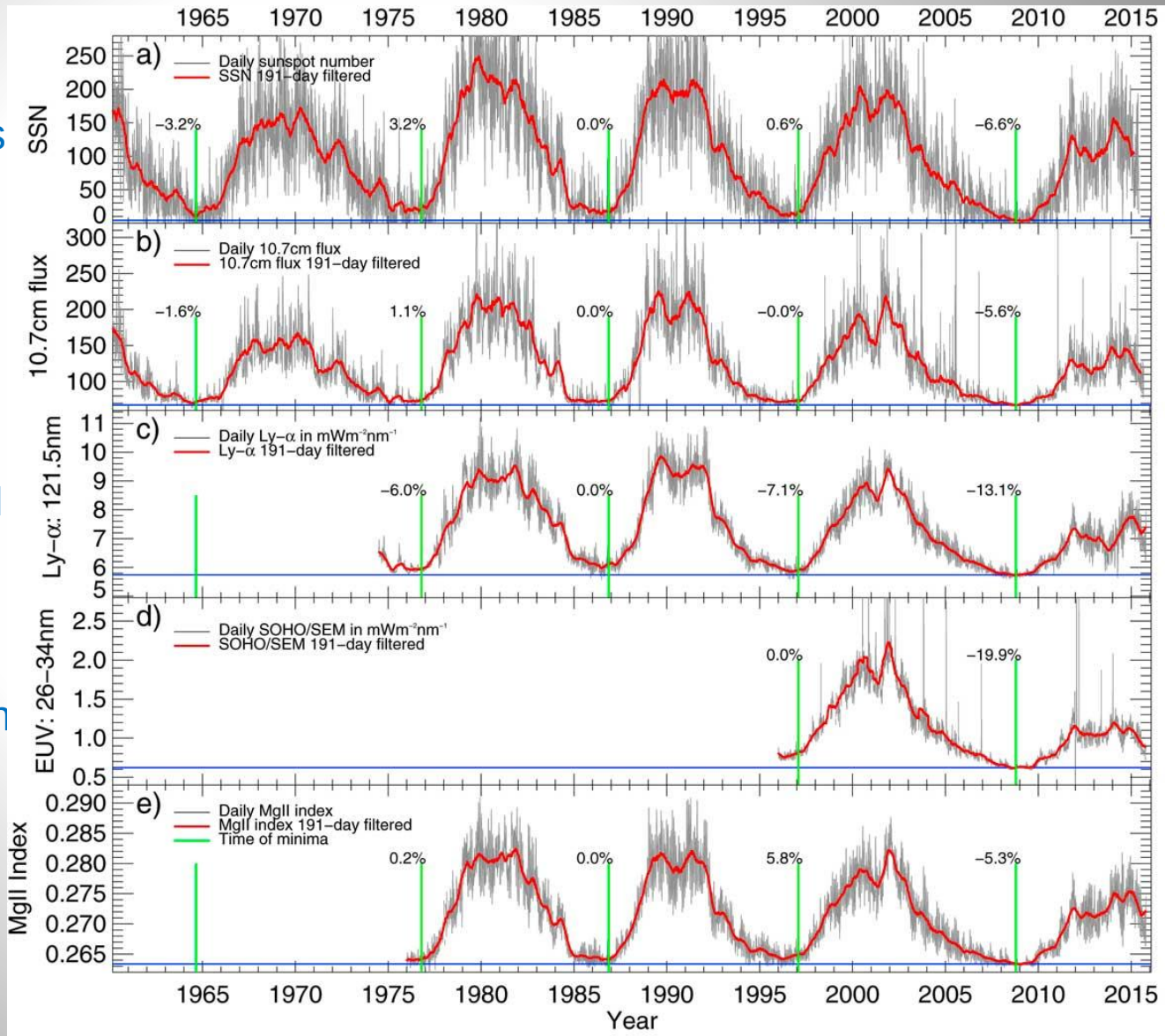


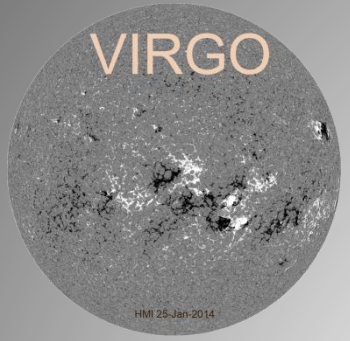
How is the 4-component proxy model constructed ? 1 of 3

An important information is the knowledge of the time of minima (see poster). Almost all proxies have a change over the last cycle of about 5-7% (relative to their mean amplitude).

The only exception is SEM which also influenced by flares on top of the normal magnetic influence.

To explain the TSI variation this 5-7% variation is, however, not sufficient



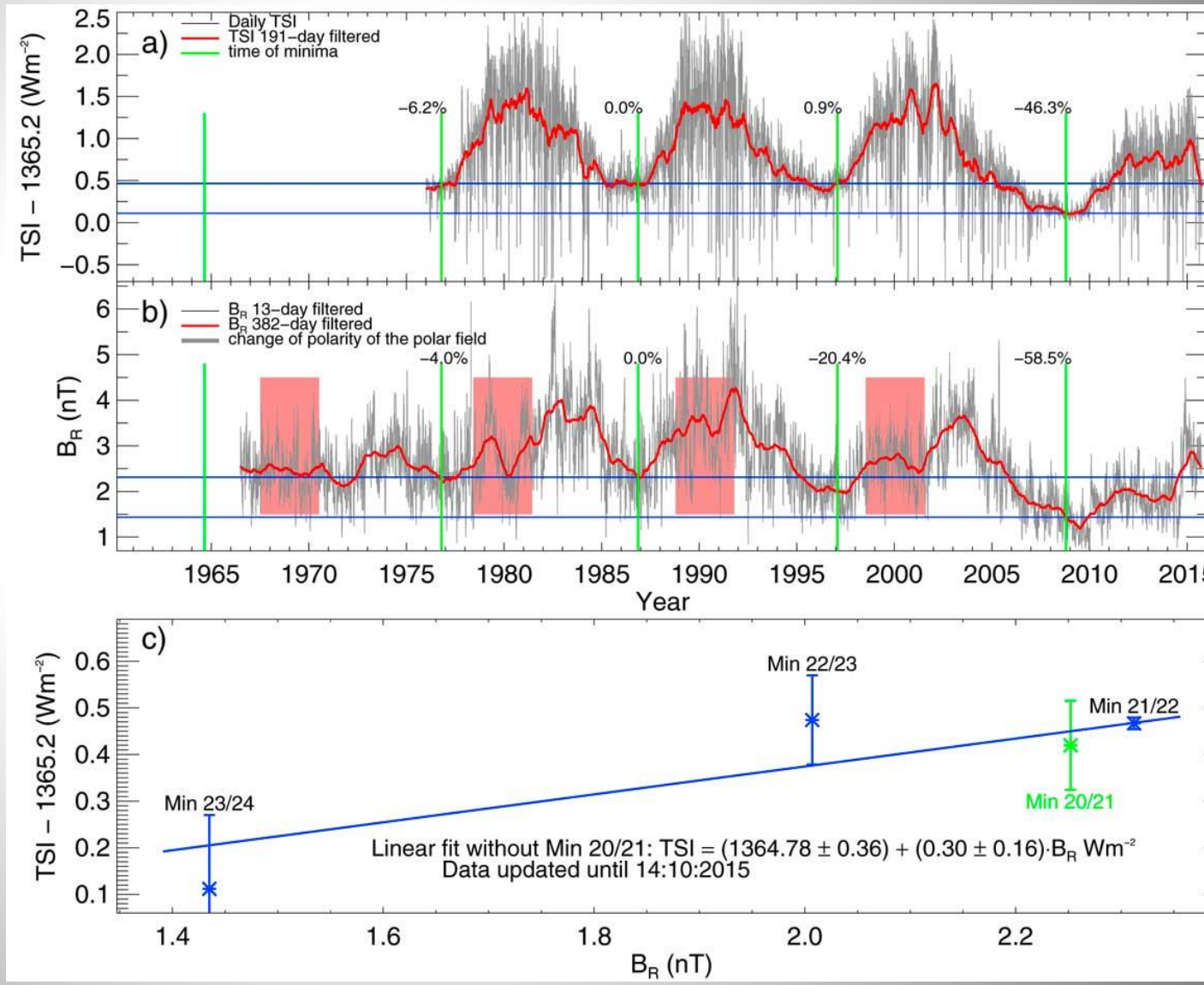


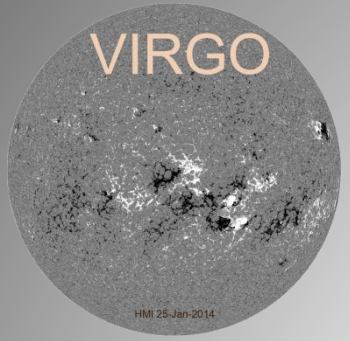
How is the 4-component proxy model constructed ? 2 of 3

The only other parameter with a much higher change over the last cycle is the open magnetic field B_R

We have 4 minima for which we can calculate the regression and get a slope of 0.30 ± 0.15 Wm^{-2}/nT

As the minima of B_R are delayed and with the argument of the minima representing the polar field they would move the left and the correlation is improved. For the same reason the minimum

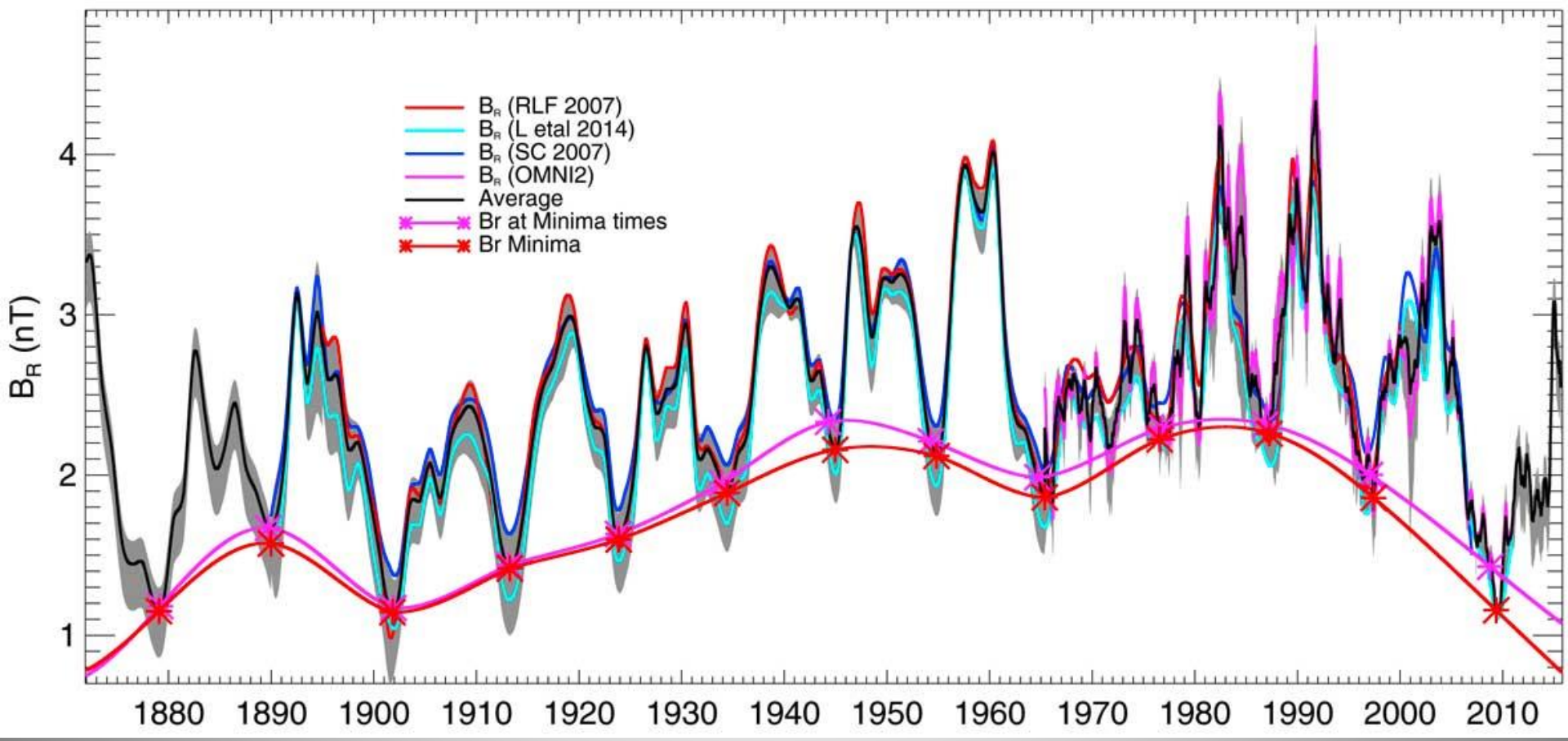


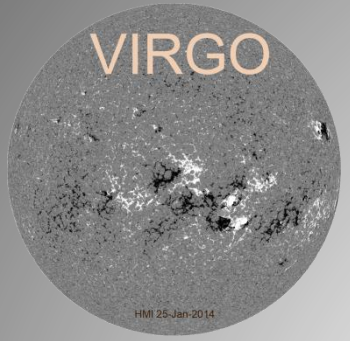


How is the 4-component proxy model constructed ? 3 of 4

This is a reconstruction of B_R back to 1870 from different analysis of the aa index and other parameters by different authors together with the satellite data from OMNI-2 since the sixties – shown in the previous correlation to TSI..

As we need to interpolate the minima values it may be better to consider the whole period and use these average data also during the most recent period.





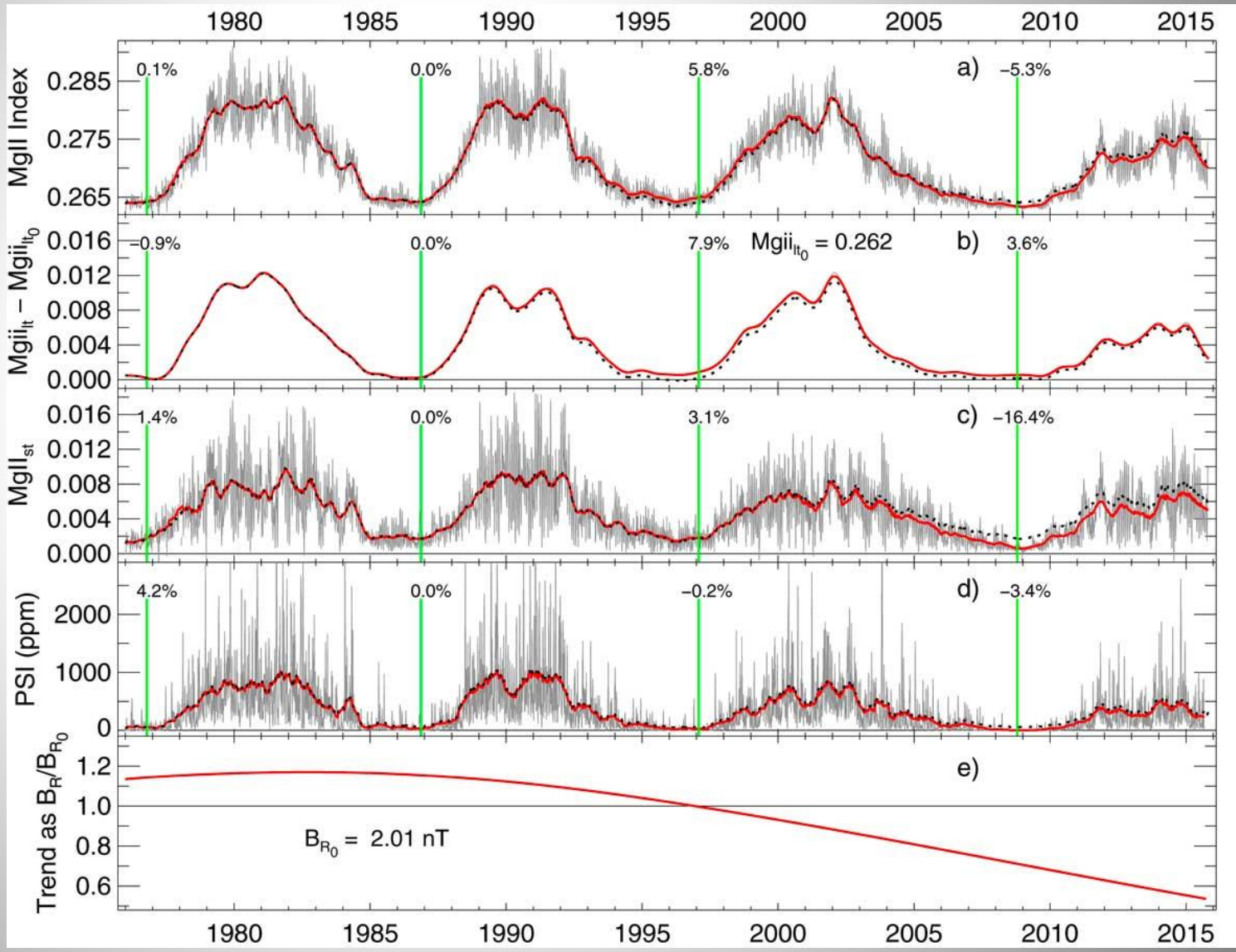
How is the 4-component proxy model constructed ? 4 of 4

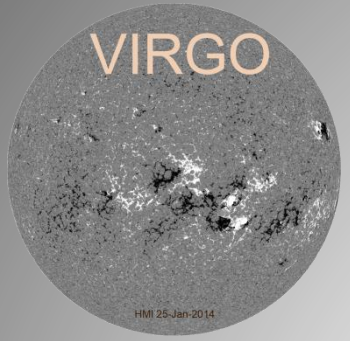
The MgII index (top panel)m is separated it into a long- (2nd panel) and short-term (3rd panel) component to reflect the solar cycle modulation due to network and the active region influence due to faculae.

The 4th panel shows PSI calculated from the SOON data (see also poster).

The bottom panel is B_R from the previous slide

The numbers indicate the relative change of the minima in terms of a mean amplitude.





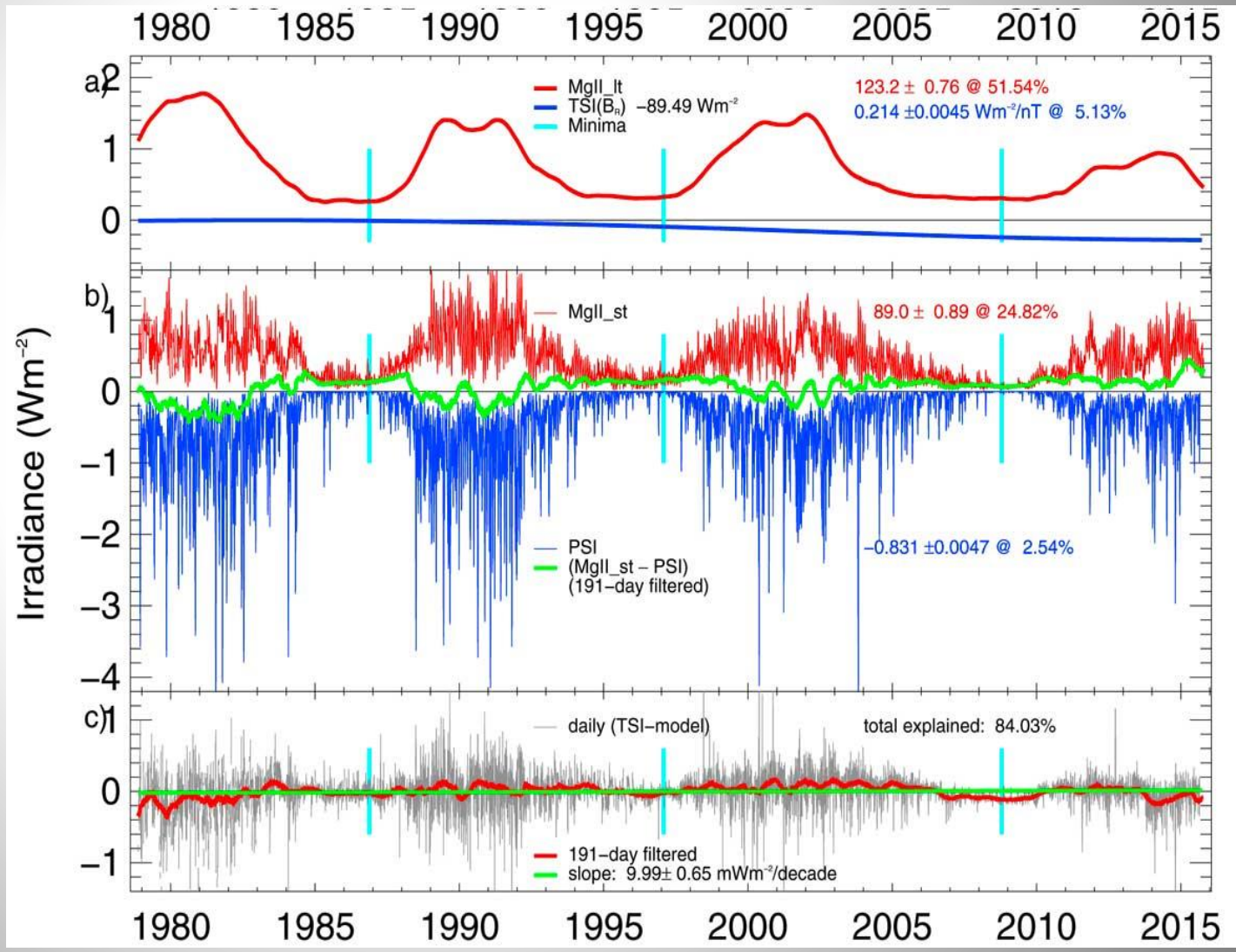
Calibrate the model against TSI

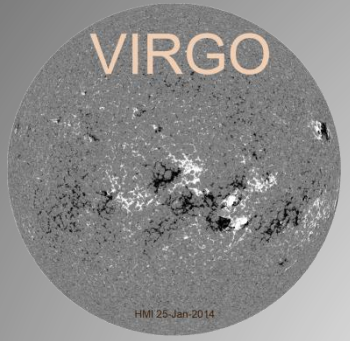
Calibration with multi-linear regression against TSI over the full period 1978-2015.

The overall explanation of the variance is 84% with partition of 52% by the long-term, 25% by the short-term, 2.5% by PSI and 5% by B_R.

For the B_R correlation we get a coefficient of 0.23 Wm^{-2}/nT within the error bars of the slope .

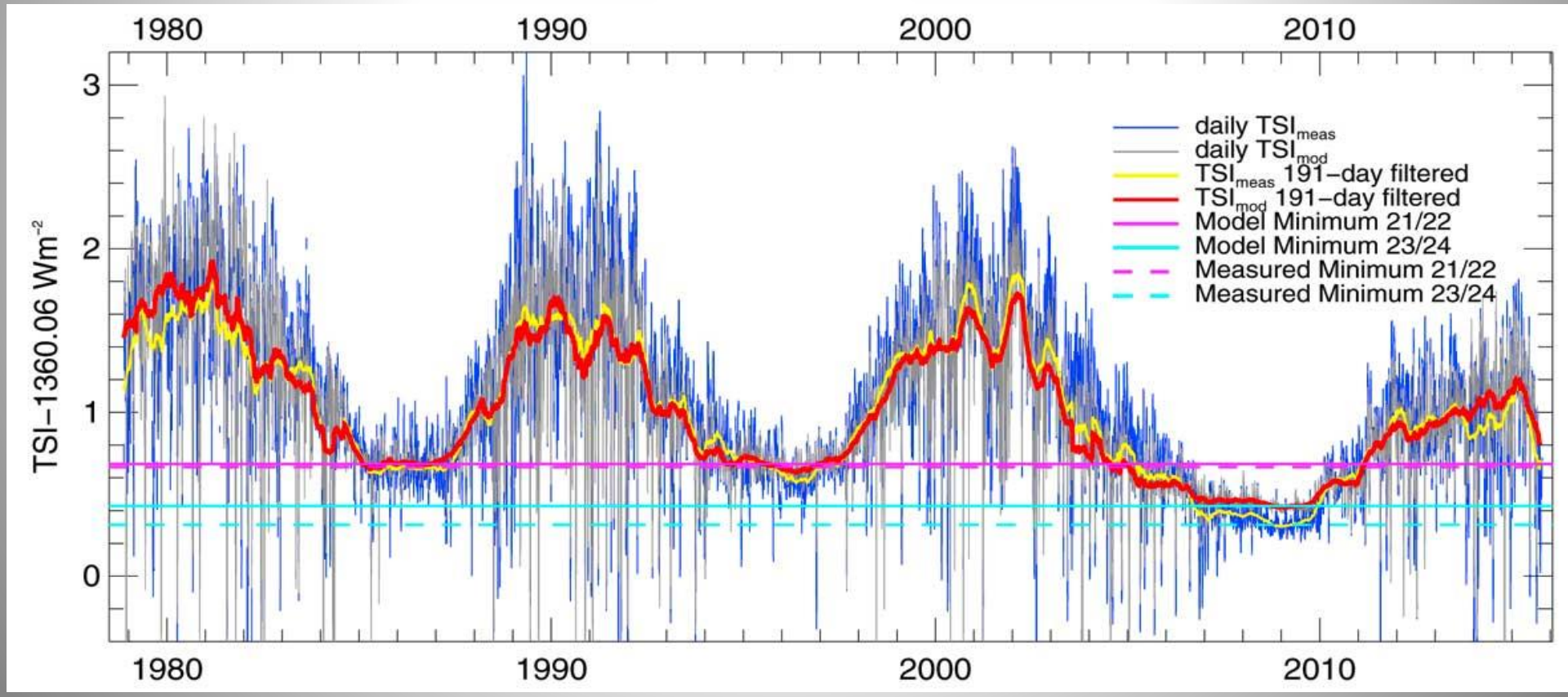
There is an upward trend which is due to the high value of the minimum of TSI at 22/23. For the same reason the 23/24 minimum is not adequately explained.

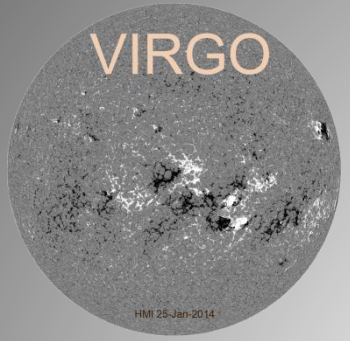




Comparison of the model and TSI

Also during the maxima some discrepancies are obvious. During the maximum of cycle 21 the facular model seems to be too high, whereas it is too low in cycle 23. In cycle 24 PSI after 2014 seems to be too strong. But still 84% of the variance is explained



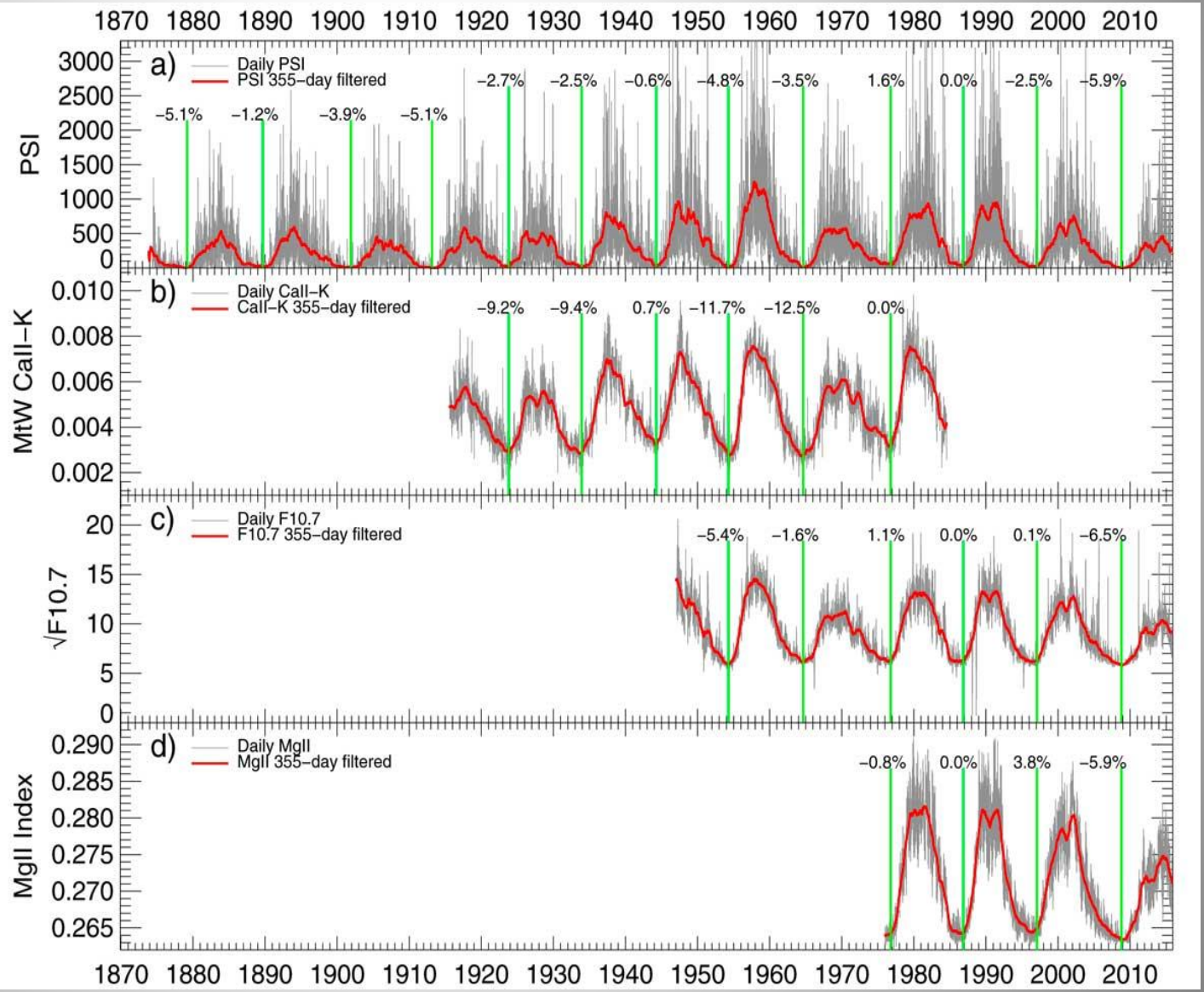


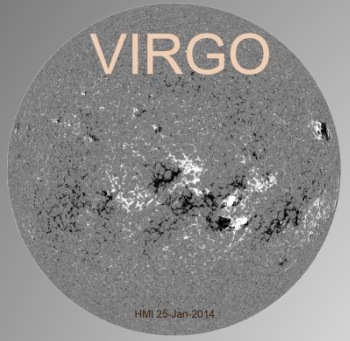
How can we extend the model back to 1900 ? 1 of 4

PSI can be determined from the RGO and SOON data back to 1874 (see also poster)

The CaII-K index can be determined from the Mount Willson plates. The data from Bertello et al 2010 are used here.

We have F10.7 which overlaps the CaK and the MgII irecord,which can be used to transform CaK to MgII index.

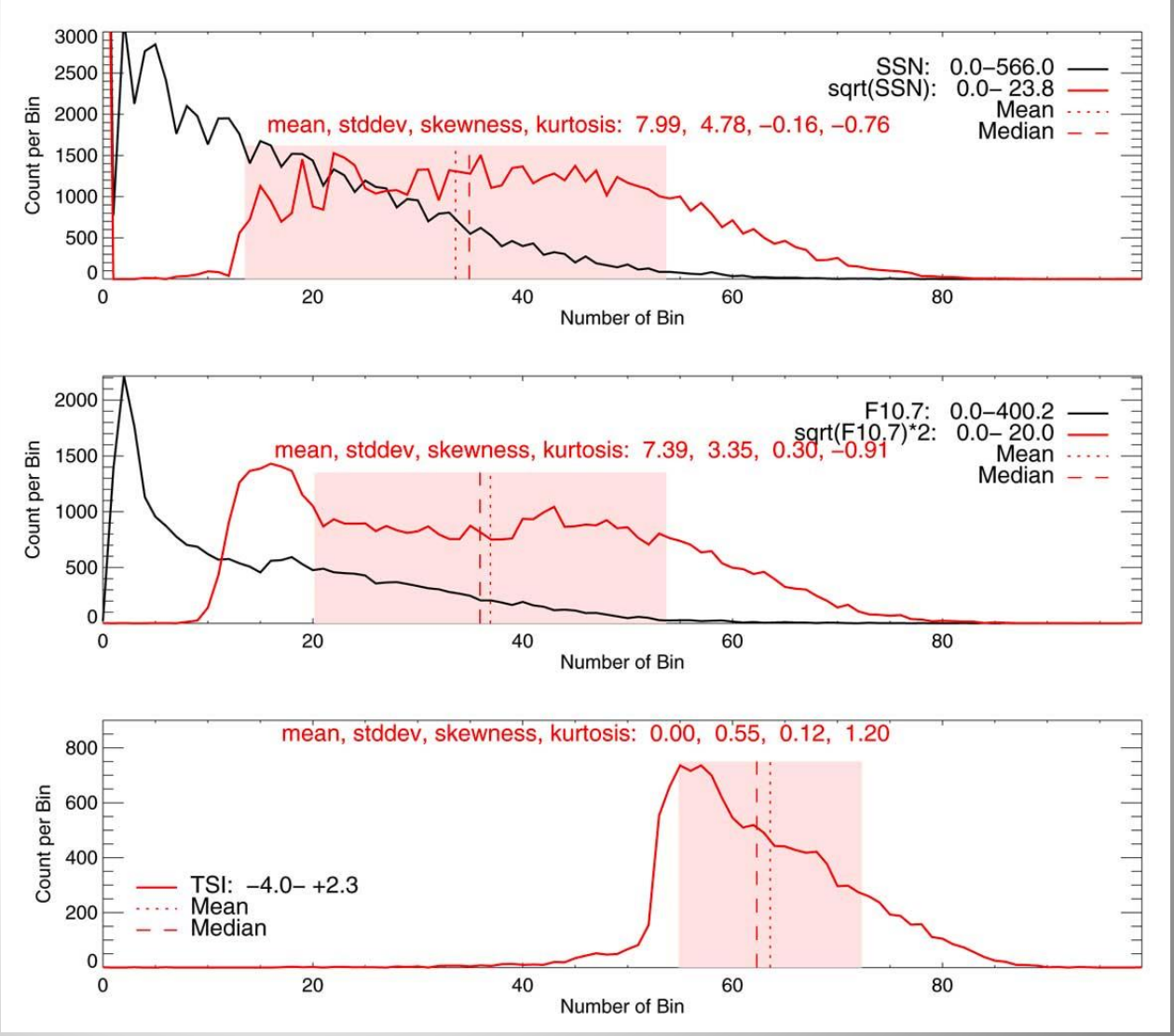


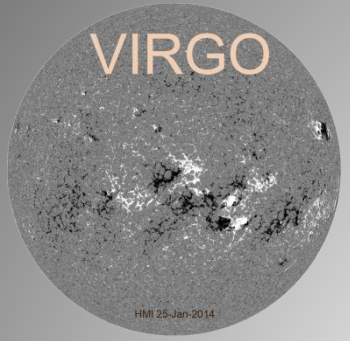


How can we extend the model back to 1900 ? 2 of 4

The sunspot number and F10.7 show a Poisson distribution, whereas TSI is more likely normally distributed (quite asymmetric because of the difference between sunspot darkening and facular brightening).

The square root transforms a Poisson distribution into a normal distribution as shown by the red curves. It is interesting that √F10.7 shows is similar to TSI





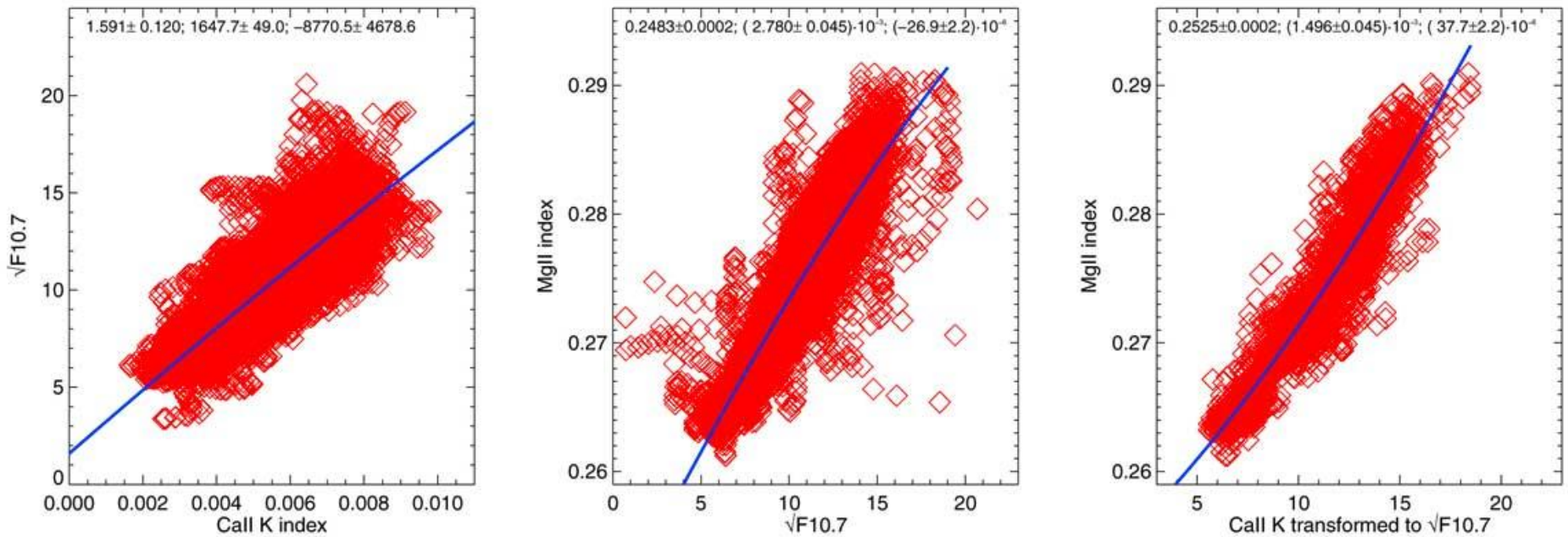
How can we extend the model back to 1900 ? 2 of 4

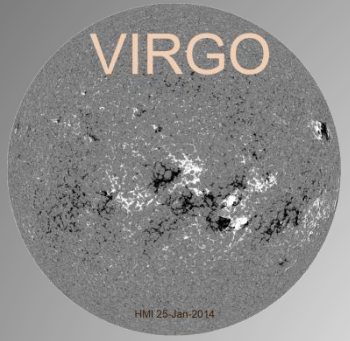
The left panel shows the correlation between CaK and F10.7 over 4 solar cycles

The middle panel shows the correlation between MgII index and F10.7 over 3.6 solar cycles

The right panel shows the translation of the CaK to MgII.

If F10.7 is used directly the strong non-linearity is obvious and the final result somewhat different.



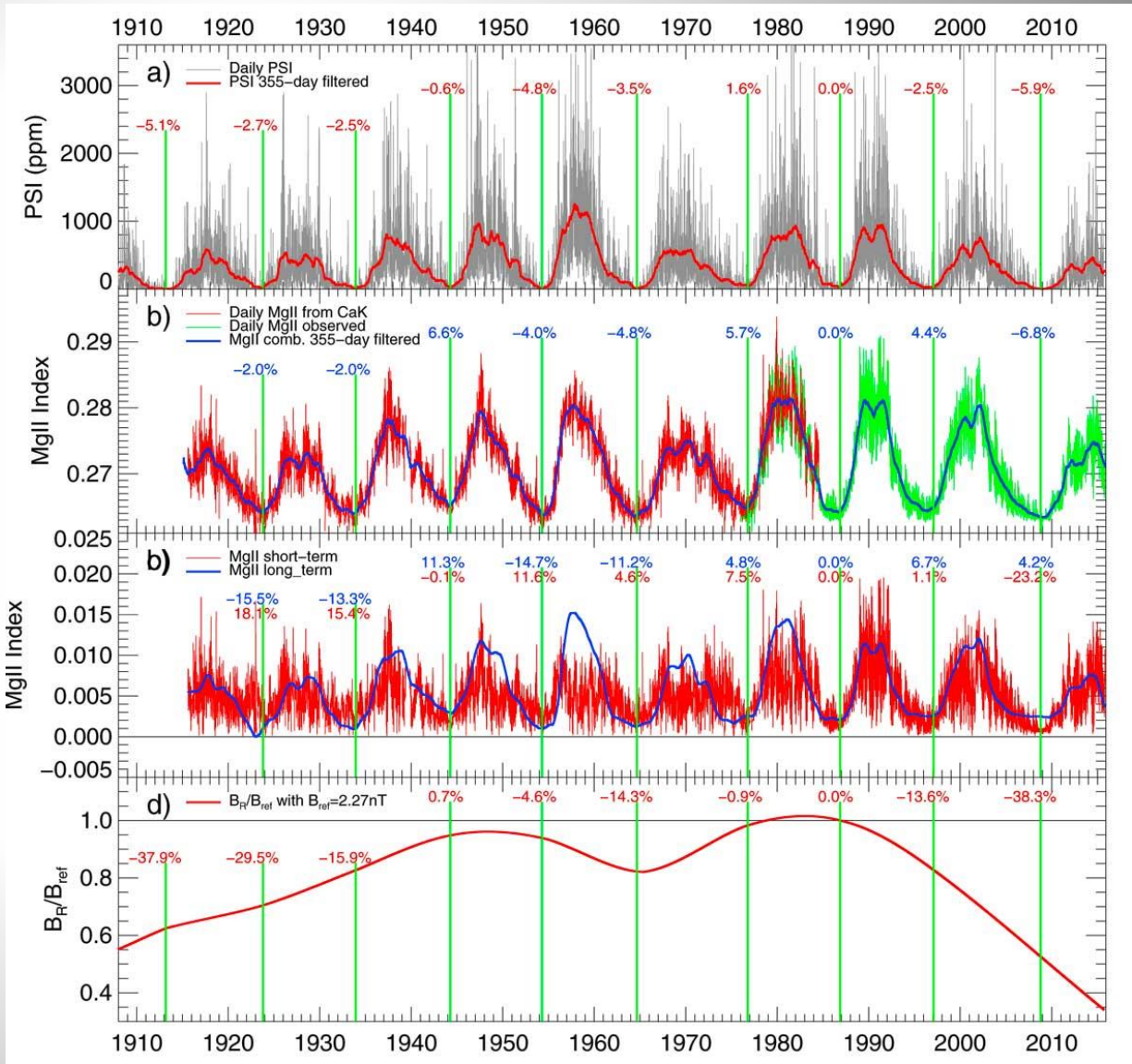


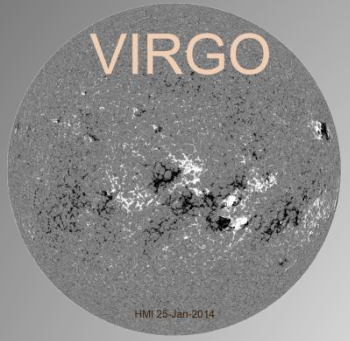
How can we extend the model back to 1900 ? 4 of 4

All parameters for the proxy model are now available and the MgII index can also be separated into the long-term and short-term part..

The fact that the amplitude of the long-term for cycle 21 may explain the discrepancy between TSI and model..

The numbers indicate the relative change of the minima in terms of a mean amplitude.



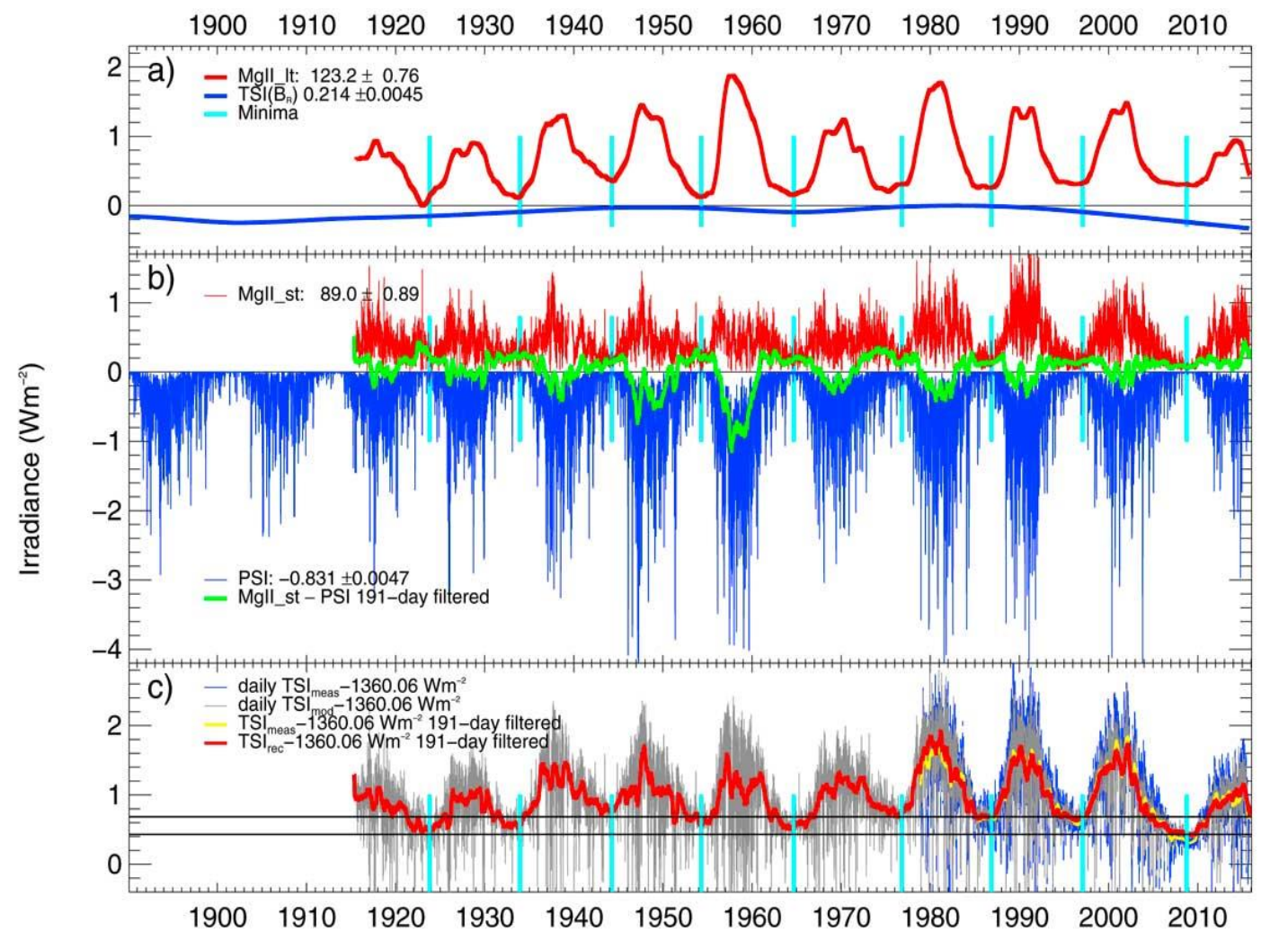


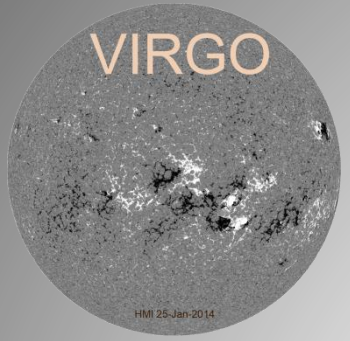
Using the calibration during the last three cycles.... 1 of 2

With the calibration during the last 3 cycles we can now determine the 4 components of the proxy model back to 1915

As mentioned before the amplitude of cycle 21 may be to high.

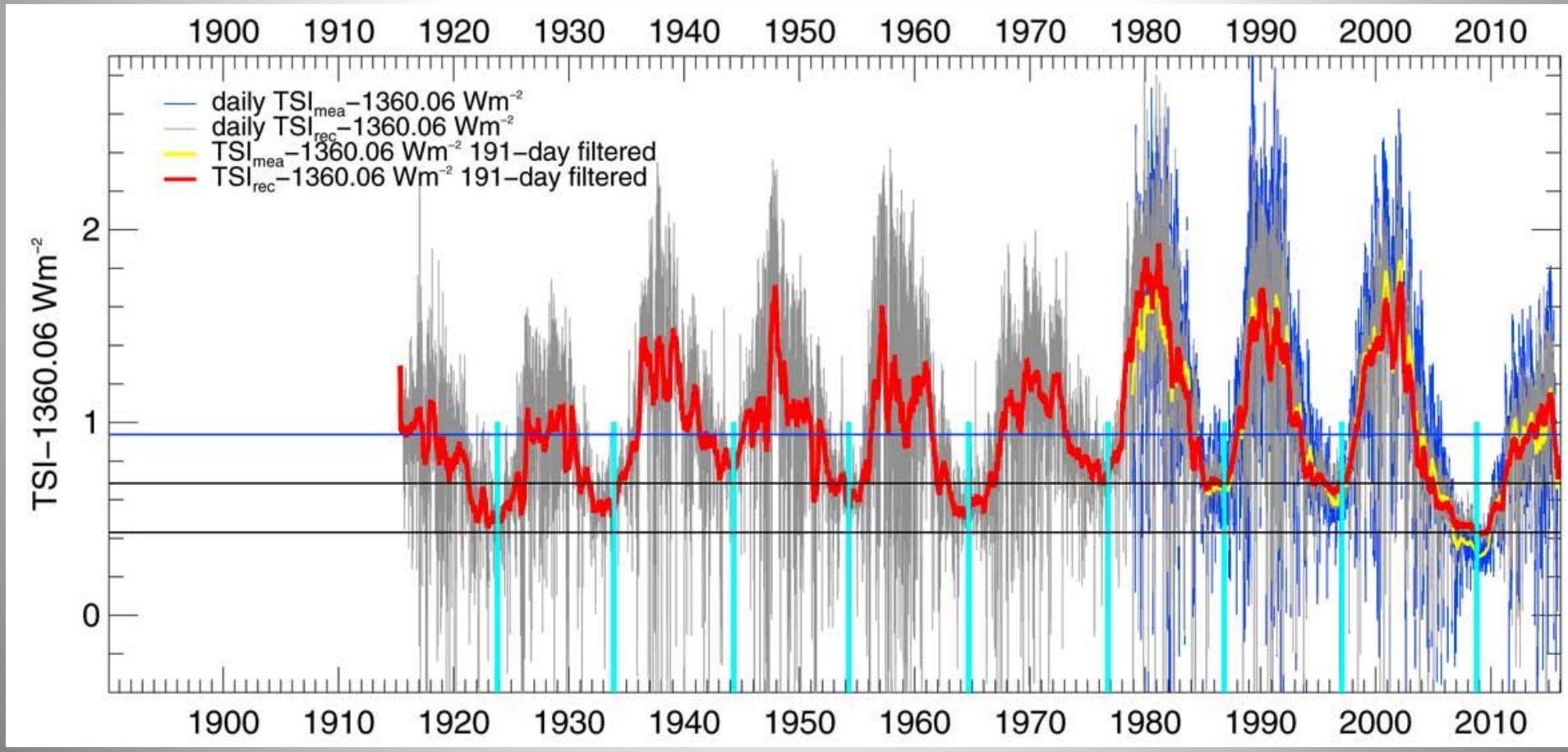
There are substantial differences between the different cycles of the share of sunspot darkening and facular brightening, in particular for cycle 19

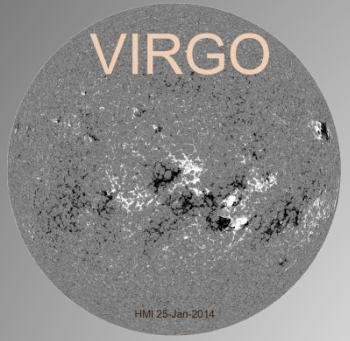




Using the calibration during the last three cycles.... 2 of 2

The result of the model compared to TSI during the last 3 cycles shows again the possible amplitude problem with cycle 21. We probably need to review the MgII index, as indicated at the overlap.

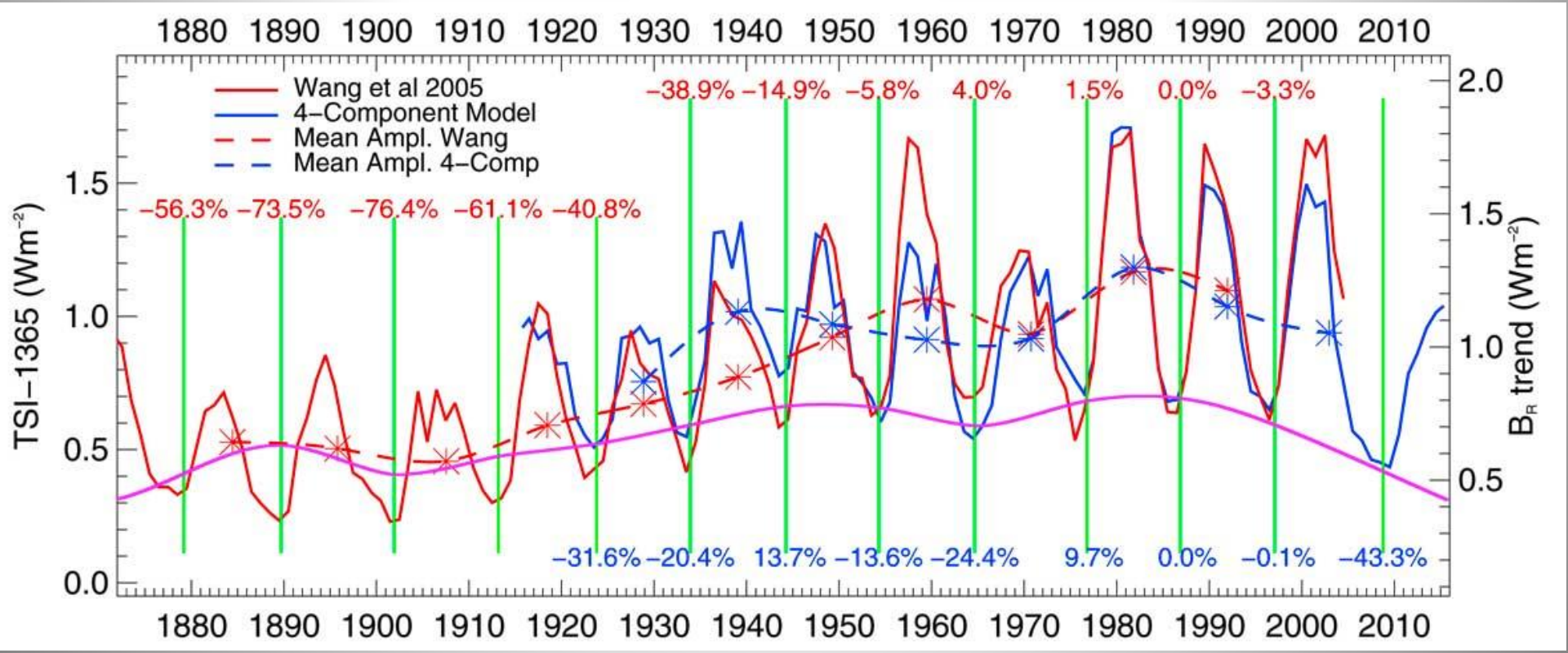


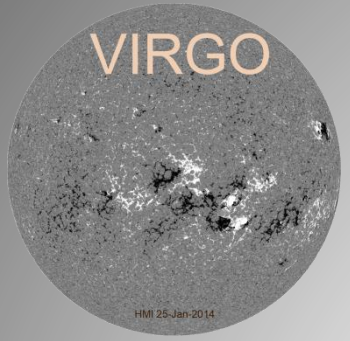


Comparison to Wang et al. 2005

The annual values of Wang et al. 2005 are compared to annual values of the present reconstruction. The asterics indicate the cycle average.

There some differences at the minima and my general trend seems to be weaker. The minimum of the amplitude around the 60ties is not in Wang et al.





Conclusions

The proxy model calibrated during the last three cycles works pretty good and explains 84% of the variance of TSI during this period.

For the period back to 1915 we have PSI, CaK and open solar field. With the CaK translated into a MgII index we can extend the model with the calibration during the last 3.6 cycles back to 1915. There are still some problems with e.g. the amplitude of cycle 21 or the minimum in 1920 which needs improvement.

The comparison with Wang et al. 2005 shows similarities, but also differences. The downward trend seems to be stronger for Wang et al. which has consequences for the Maunder Minimum value. .