

### TSI Reconstruction back to 1915 with a Proxy Model and the Sunspot Number

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### **TSI composite as a basis**

I will not discuss the different TSI composites, I use the PMOD composite, which is the only one with a corrected cycle 21. These corrections are based on internally consistent degradation corrections for HF and ACRIM-I and have nothing to do with an adjustment to a model. Moreover it is extended back to 1976 with a proxy model (see later). The VIRGO data are the new version 6.4, which shows a somewhat smaller decrease towards the recent minimum and the difference between the last two minima is still 24% of the cycle amplitude (version 6.2 showed 29%).





#### We want reconstruct back to 1900, so we need the time of Minima for this period 1: 1879-1913

- The analysis is based on PSI determined from the RGO and SOON sunspot regions. The PSI time series is shown in the middle panel. The top panel shows the mean latitude, weighted by the area and the bottom one the butterfly diagram of PSI.
- To determine the time of minima we determine first the time of rise from low to high latitude by fitting a tanh with different asymptotes before and after.
- Then we search the minimum by fitting a decreasing straight line before and a quadratic fit after. This result is close or identical to the latitude change and is used as final time of the minimum



25 May 2014



#### We want reconstruct back to 1900, so we need the time of Minima for this period 2: 1923-1964

- The analysis is based on PSI determined from the RGO and SOON sunspot regions. The PSI time series is shown in the middle panel. The top panel shows the mean latitude, weighted by the area and the bottom one the butterfly diagram of PSI.
- To determine the time of minima we determine first the time of rise from low to high latitude by fitting a tanh with different asymptotes before and after.
- Then we search the minimum by fitting a decreasing straight line before and a quadratic fit after. This result is close or identical to the latitude change and is used as final time of the minimum



25 May 2014



#### We want reconstruct back to 1900, so we need the time of Minima for this period 3: 1976-2008

- The analysis is based on PSI determined from the RGO and SOON sunspot regions. The PSI time series is shown in the middle panel. The top panel shows the mean latitude, weighted by the area and the bottom one the butterfly diagram of PSI.
- To determine the time of minima we determine first the time of rise from low to high latitude by fitting a tanh with different asymptotes before and after.
- Then we search the minimum by fitting a decreasing straight line before and a quadratic fit after. This result is close or identical to the latitude change and is used as final time of the minimum





# How is a proxy model constructed ? 1 of 3

- Almost all proxies have a change over the last cycle of about 5-7%. The only exception are the SEM results in the EUV which are probably influenced by flares on top of the normal magnet influence.
- To explain the TSI variation this 5-7% variation is not sufficient



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# How is a 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<sub>R</sub>

IRGC

We have 4 minima for which we can calculate the regression and get a barely significant slope of 0.15 ± 0.15 Wm-2/nT (in version 6.2 it was 0.31 Wm<sup>-2</sup>/nT)



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# How is a proxy model constructed ? 3 of 3

So we use the MgII
index (top panel)m
and separate it into a
long- (2<sup>nd</sup> panel) and
short-term (3<sup>rd</sup> panel)
component to reflect
the solar cycle
modulation due to
network and the active
region influence due
to faculae.

/IRGO

- The 4<sup>th</sup> panel shows PSI calculated from the SOON data.
- The bottom panel shows the smoothed variation of B<sub>R</sub> at minima.





### **Calibrate the model against TSI**

- Now we calibrate the model with a multi-linear regression against TSI over the full period.
- The overall explanation of the variance is 84% with partition of 59% by the long-term, 19% by the short-term 1% by PSI and 5% by the trend related to B<sub>R</sub>.
- For the B<sub>R</sub>. Correlation we get a larger factor of 0.23
   Wm-2/nT than we found be linear regression
- There is an overall upward trend which may be due to a low TSI during cycle 21.



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

- We have PSI from the RGO and SOON data
- We have a CaK index determined from Mount Willson plates.

We have F10.7
which overlaps the
CaK and the modern
MgII index period.
And can thus be
used to transform
CaK to MgII index.





# 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 solar cycles
- The right panel shows the translation of the CaK to MgII which is almost linear.



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# How can we extend the model back to 1900 ? 3 of 4

- This is a reconstruction of B<sub>R</sub> 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.
- With the determined times of minima a smoothed curve through the minima is produced and it is interesting that most values are before the minima of B<sub>R</sub>. The recent minimum was also reached in 1900.





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

- Now we have all parameters needed for the proxy model and we can with the same method also determine the separation of the MgII index.
- It seems that we may have a problem as we get an amplitude of the long-term component for cycle 21 which is higher than the original one. We get also an extra low minimum in 1924 Both may be a problem due to the analysis and need some more investigation.



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# 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
- differences between
  the different cycles in
  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 overlap of the reconstructed and measured MgII index.





# Let us try to reproduce the components of the proxy model with SSN. 1 of 5

Instead of straight SSN we use the square root (top panel).as e.g. the square root of F10.7 is used to model Ly-α.
The middle panel shows again the calibrated short and long-term components and the bottom panel the calibrated PSI.





### Let us try to reproduce the components of the proxy model with SSN. 2 of 5

- The different correlations between the square root of SSN and long-term MgII (left panel), the short-term MgII (middle panel) and PSI (right panel) are quite different from cycle to cycle.
- A polynomial fit is always possible, but in all three correlations e.g. cycle 19 sticks out as slowly varying at low values and cycle 15 as more rapidly increasing. Maybe we need to do it cycle-by-cycle.
- For the short-term MgII and PSI a steep increase is observed which obviously cannot be described with the

present fits and explains the bad representation of these components in the result.



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# Let us try to reproduce the components of the proxy model with SSN. 3 of 5

- The top panel shows the difference between the calibrated long-term and the reconstructed from SSN. Obviously we need an updated SSN without the Waldmeier and other changes.
- Although the overall standard deviation is quite small (the percentage is relative to the full TSI value) the representation is not very good. Moreover it is typically asymmetric because of the improper treatment of the high model values. .

26 May 2014





# Let us try to reproduce the components of the proxy model with SSN. 4 of 5

The reconstruction of daily values from the SSN as done by overall fitting does not seem to work properly. Both the short-term MgII and PSI are not well represented. This is due to the strong increase of the model components with increasing SSN which is not properly fitted. We need to find a better way to represent the components.





### Let us try to reproduce the components of the proxy model with SSN. 5 of 5

It works somewhat better for the reproduction of 81-day running means. However, the amplitude is smaller due to again the improper treatment of relatively high daily values of the shortterm facular and the sunspot influence. As already mentioned the reproduction of the last three cycles is not very good.



### 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 three 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 trial to reconstruct the three components from the SSN is still work in progress and needs substantial improvement and also a more consistent SSN time series.