Twenty-two Years of Total Solar Irradiance from VIRGO on SoHO

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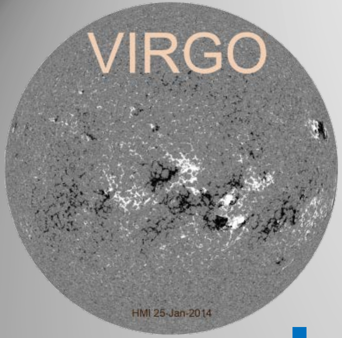
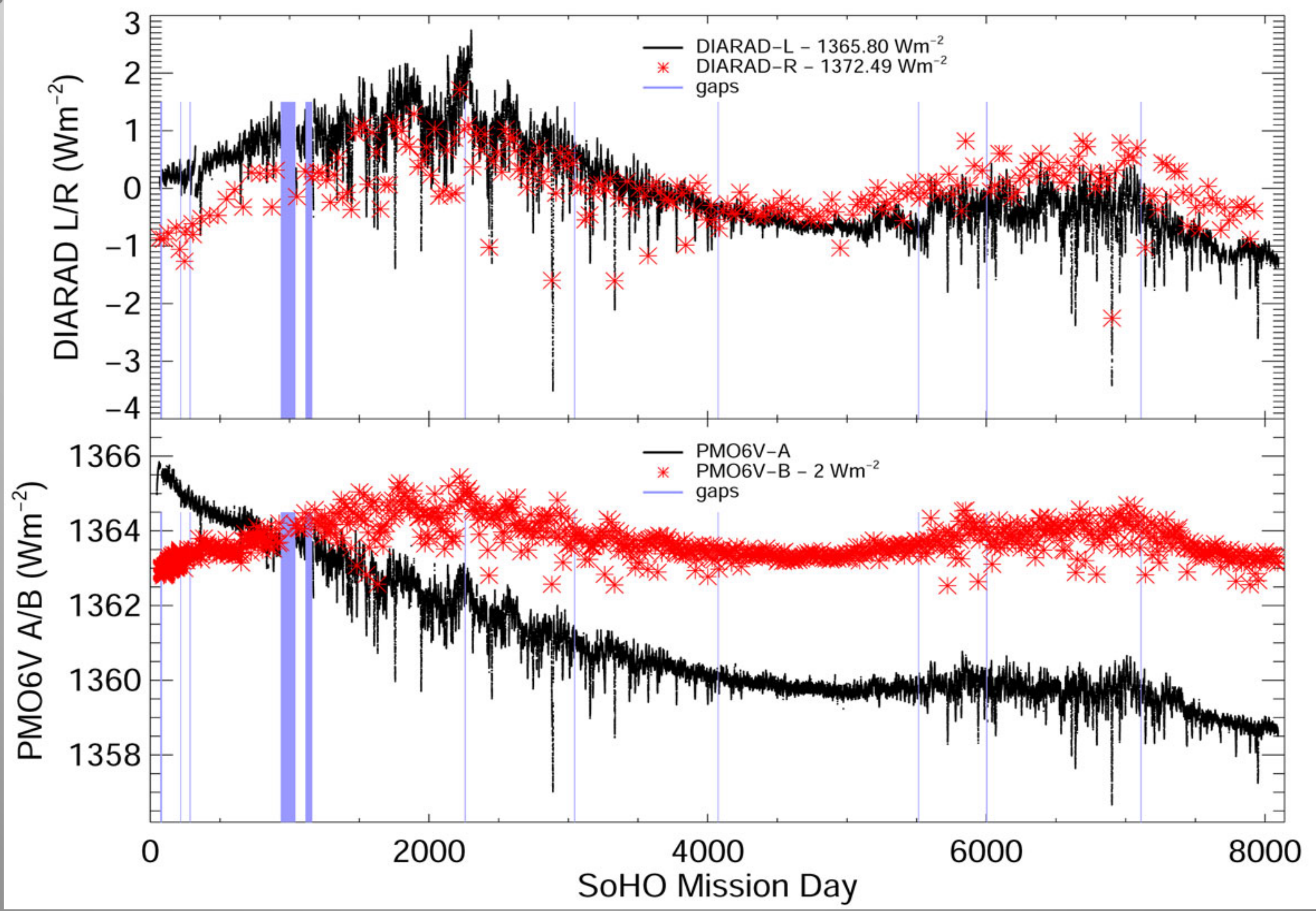


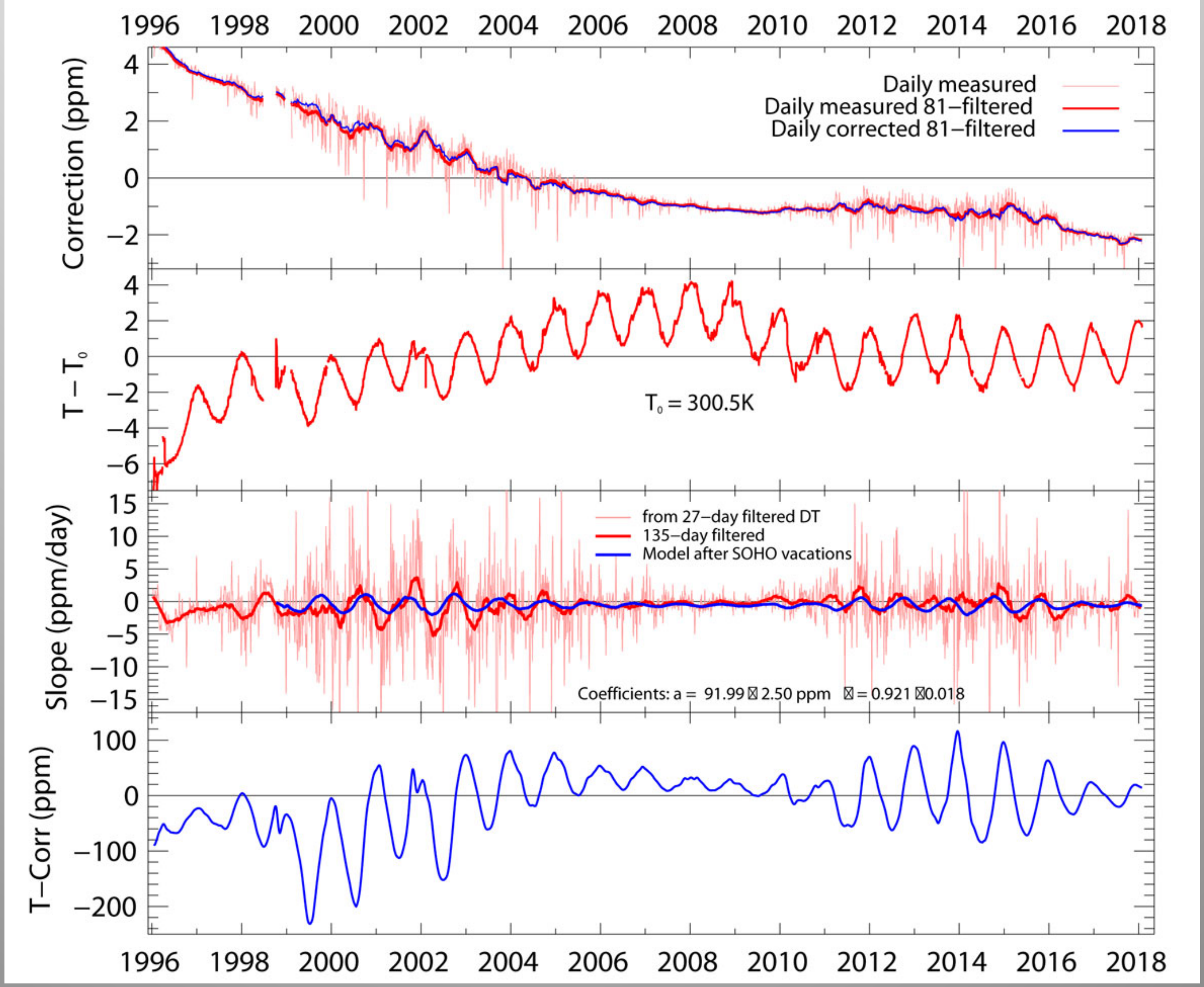
Overview: What is the issue?

- To analyse such a long record needs aprofound understanding of what influences the long-term changes. But it provides also the oportunity to really get an overview of what influences radiometers in space.
- VIRGO has two differnt types of radiometers which were intended to better understand possible changes
- The analysis is based on a model for the changes which is an indispensable ingredient to the analysis of such time series
- To apply such a model with many parameters we use MPFITFUN from Craig Markwalder as an IDL version of the Levenberg-Markwalder least-squares method. It allows also to use several different timeseries at the same time which avoids to deal with e.g. exposure time separately
- The model is based on quartz changing to silicon under strong UV radiation which yields a hyperbolic function which in turn ican be approximated by a exponential function, which means that some of the interpretation of the parameters is lost

This is what we have to start with: the hourly level-1 data

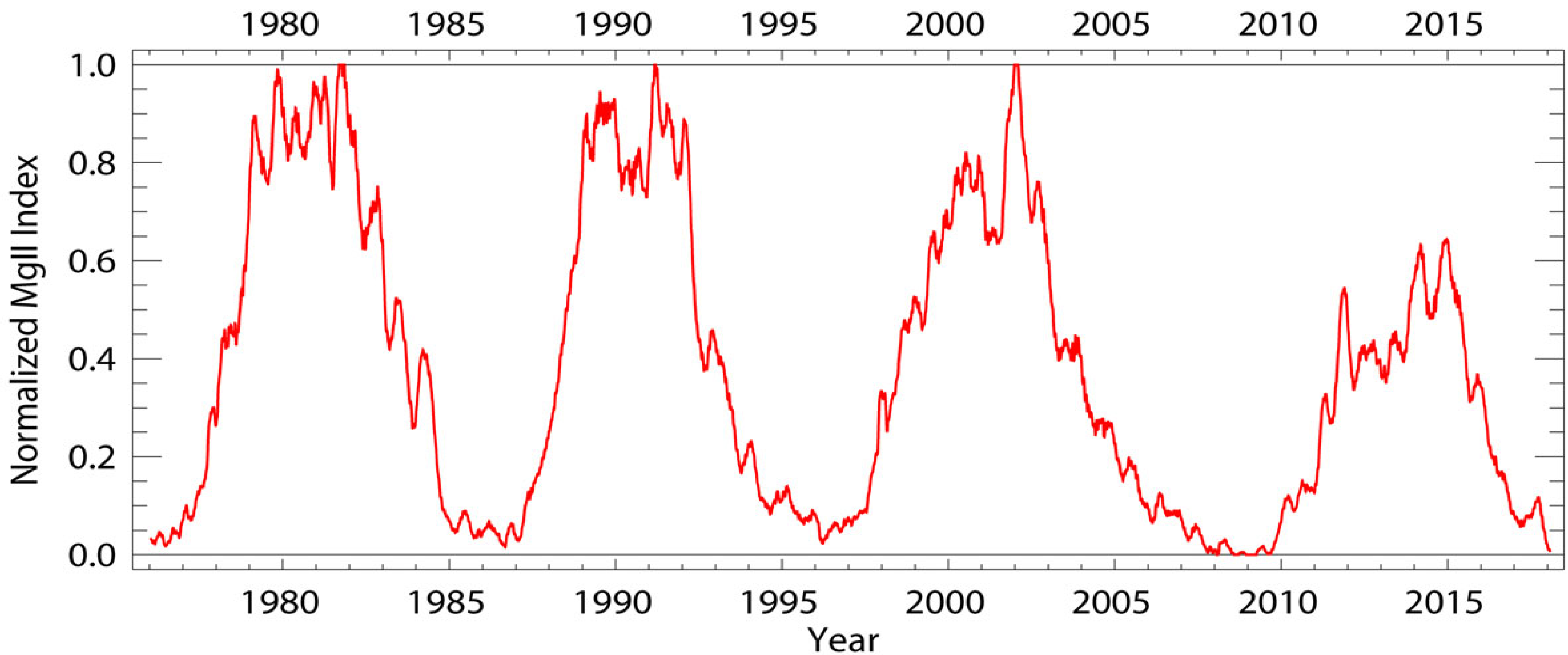


Obviously we need to include a temperature effect



How does the model describe degradation?

- The model is based on exponential functions which depend on different timeseries in the exponent and have also a modulation of their amplitude
- For *m(t)* we use a normalized MgII index

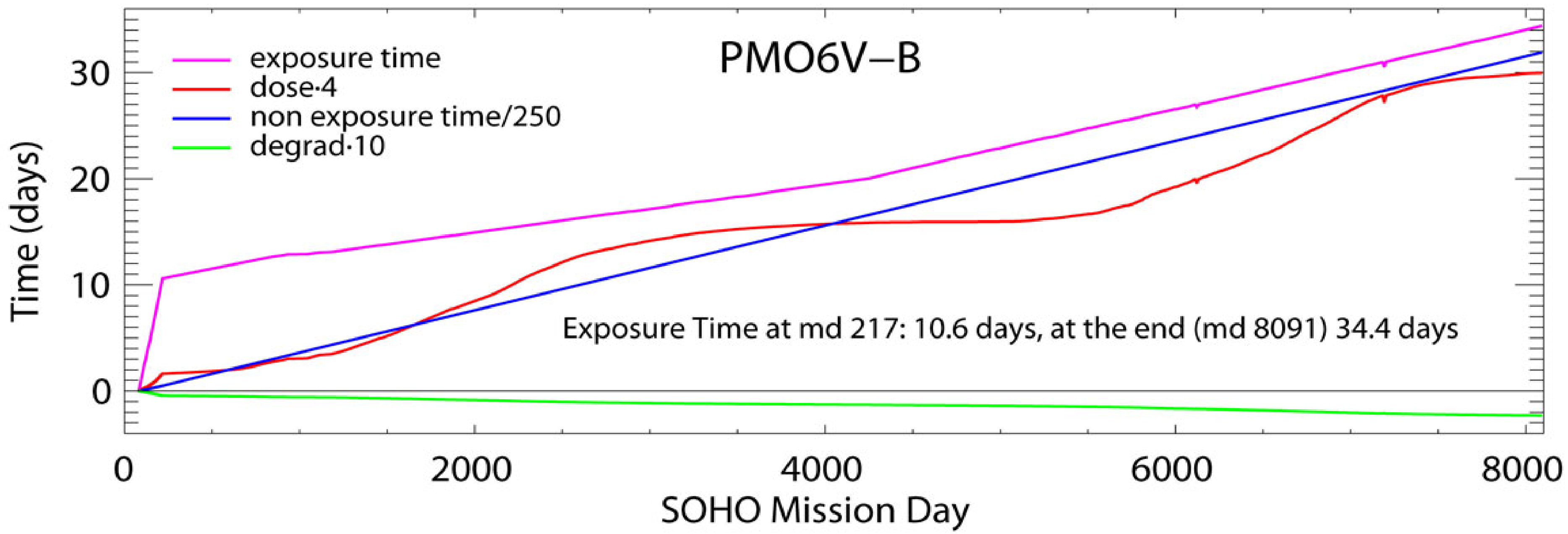


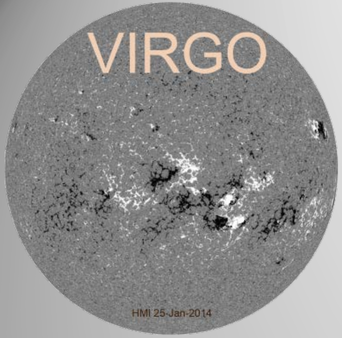
How does the model describe degradation?

- As an example we show also the different time series for PMO6V-B

$$D(t) = \int_0^t dt_{\text{exp}} + \lambda \int_0^t m(t_{\text{exp}}) dt_{\text{exp}} - r_0 \int_0^t dt_{\text{nexp}}.$$

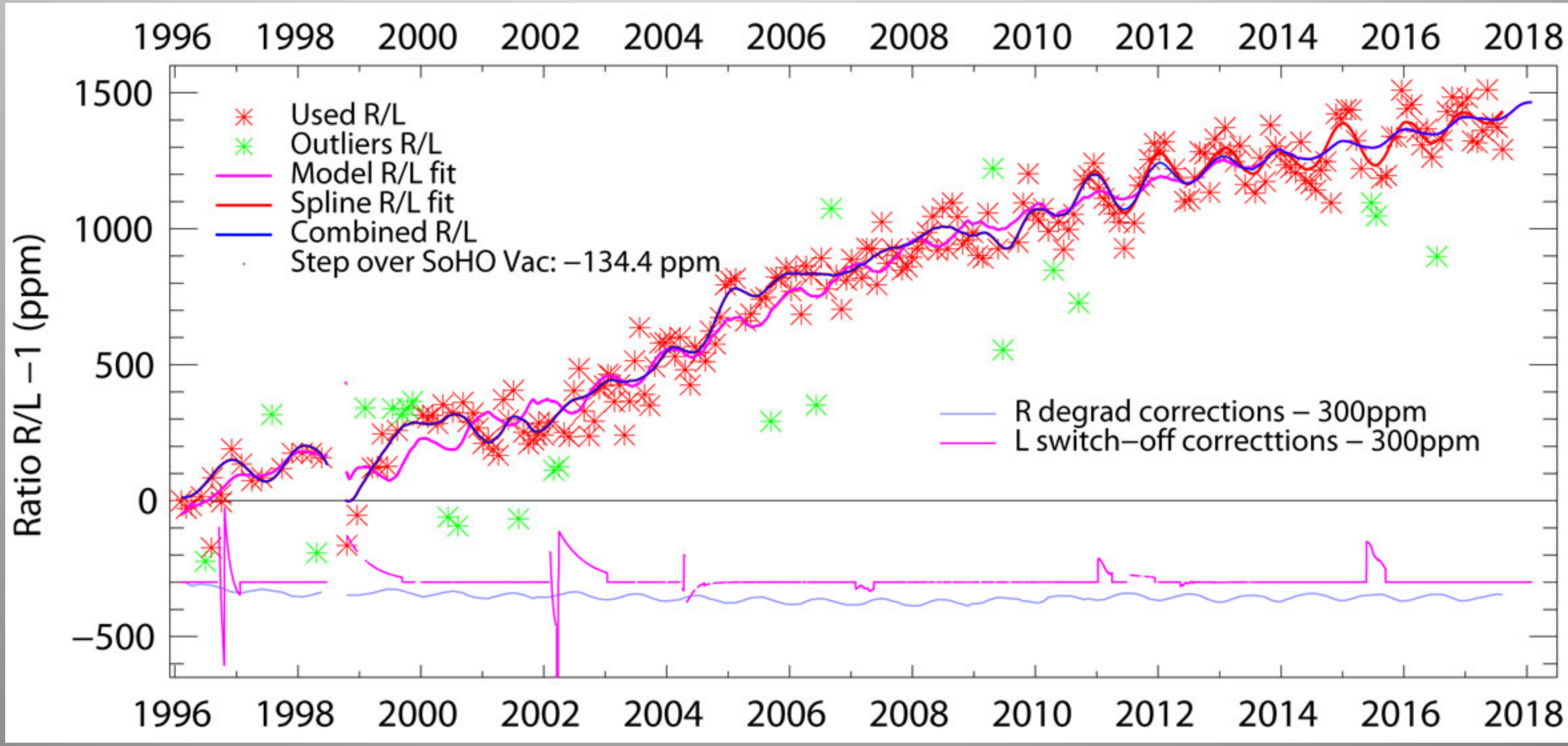
$$C(t) = c\left[(1+\alpha\Delta T(t))\exp\left(-\frac{D(t)}{\tau}\right) - (1+\alpha\Delta T(0))\right]$$

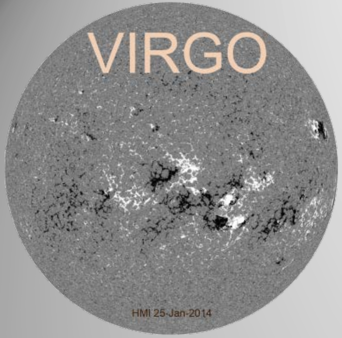




The start of a new analysis is due the loss of results from DIARAD R after October 2017

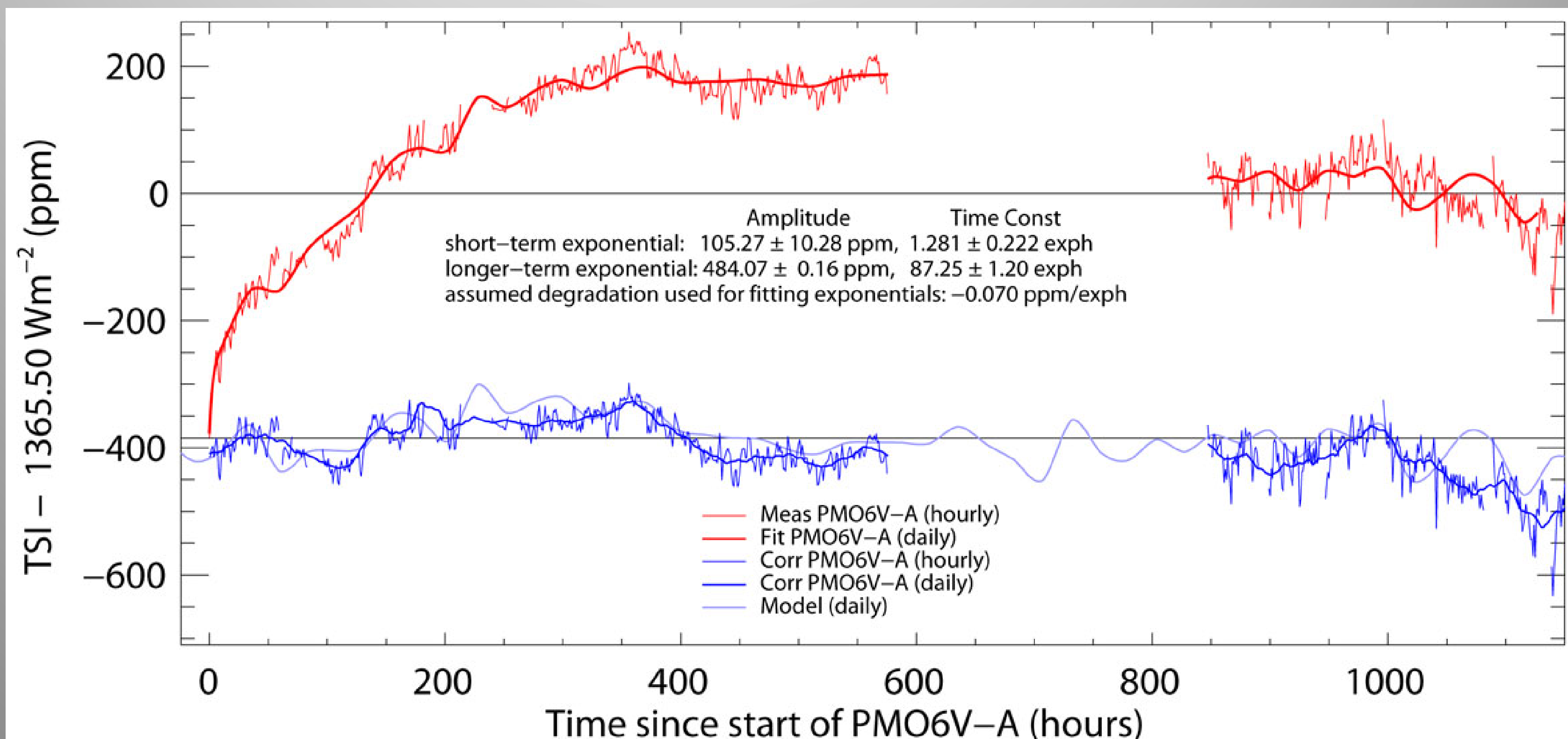
- The loss meant that we need some way of extarapolating the L/R data to continue to use these data to correct DIARAD L
- A combination of the model for the future and the original corrections for the past seemed adequate (from about 2014 the model is preferred)





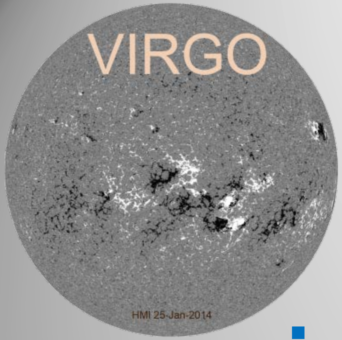
Early increase of PMO6V-A

- The early increase is an important issue not only for the PMO6V radiometers but also for the ACRIMs
- To explain the temporal behaviour of the early increase we need two exponentials: one with a very short time constant (1.3 hours) and one with a much longer one (3.6 days).



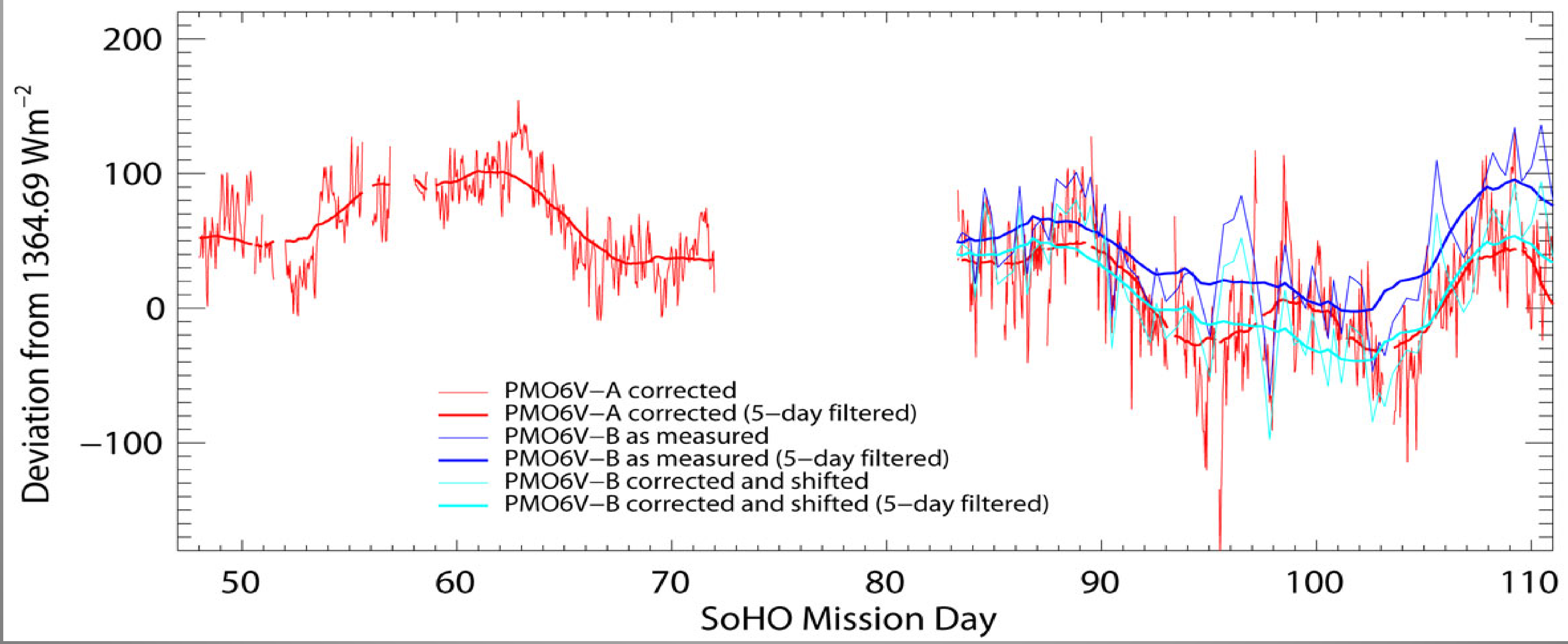
Explanation of the early increase

- The sudden increase is due to a change of the optical properties of the oxyd layer under UV irradiation in space, mainly from Ly-α. For our stainless steel apertures the oxyd is mainly Cr_2O_3 and as shown experimentally irradiation with UV changes the optical properties
- The reflectance increases (see my poster Fig.6) and hence the solar α decreases which decreases the aperture heating and increases the straylight
- The retrieved EURECA radiometer show a strongly reduced aperture heating after exposure in space (see Fig. 2 of my poster) which can be explained by a change of α
- The observed short-term change is acombination of a decrease of the aperture heating and a increase of stray light (Fig.8 of my poster)
- The longer time constant is due to a further increase of the scattering by e.g. loosing the oxygen and making the now metallic surface rougher and hence illuminate more of the baffle which increases the stray light to the cavity



Early increase corrections of PMO6V-B: short-term

- For the change of PMO6V-B from shuttered to covered operation we may use the change determined for A, but it is easier to simply adjust it to A as we are not using the absolute value of B anyway
- The short-term changes we apply those of PMO6V-A with the coresponding exposure time.

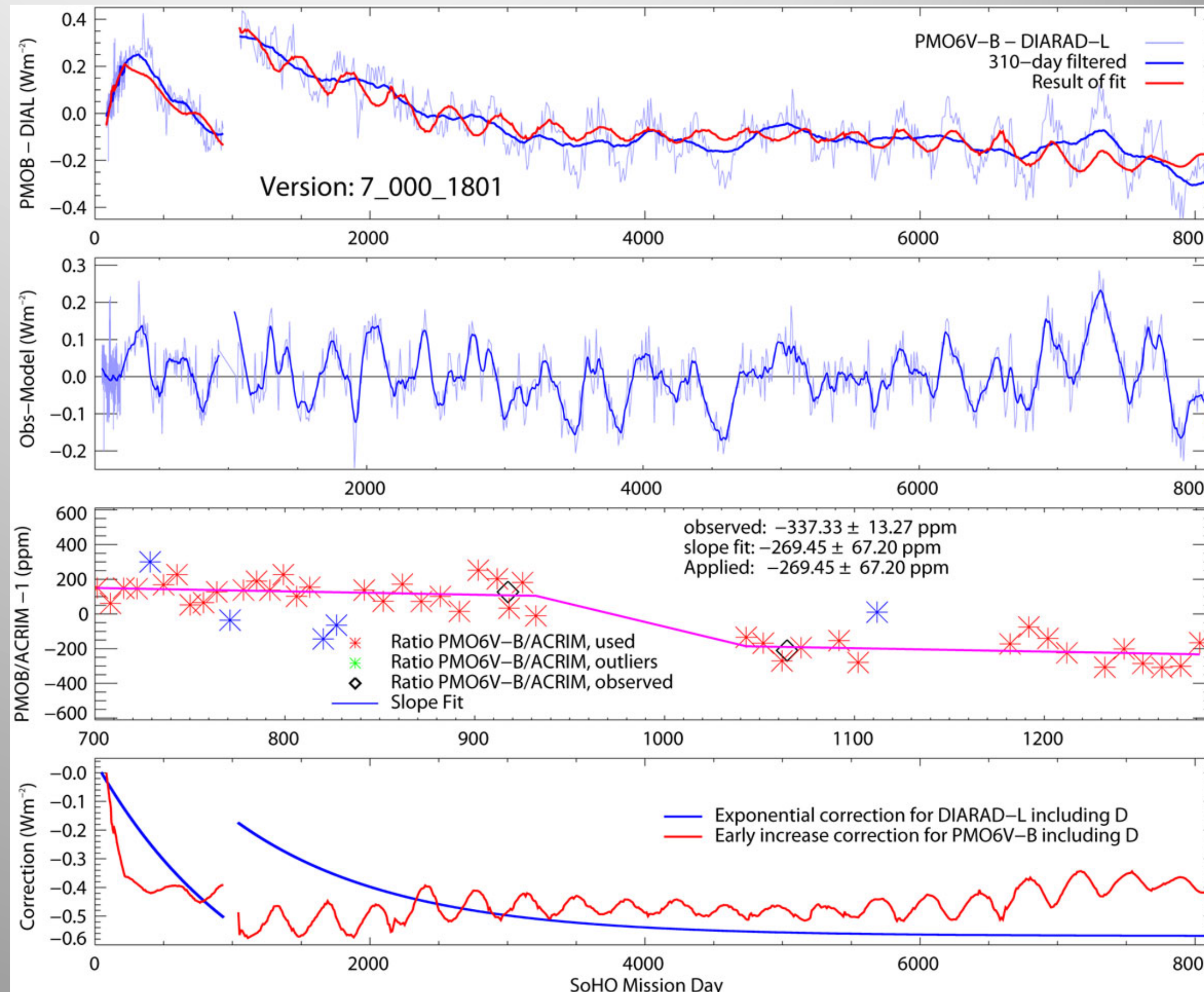


Now we need to correct PMO6V-B

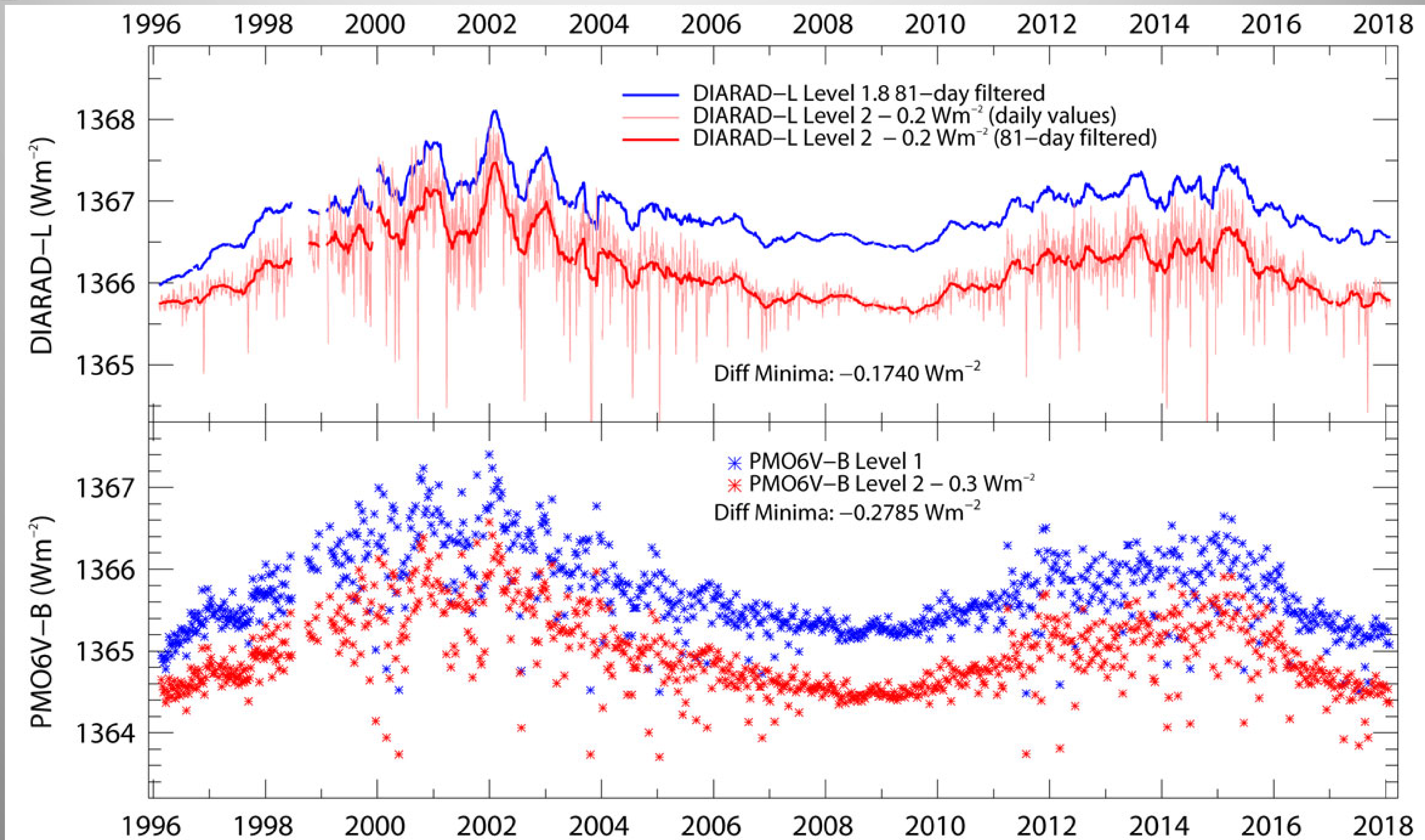
- From the comparison of DIARAD-L with R we get a internally corrected DIARAD-L time series, which we call level 1.8
- It has been shown that DIARAD has a non-exposure dependent change of its sensitivity (probably due to a change in the thermal resistance of the heat-flow meter) which depends only on the time in space and can be modeled by a simple exponential
- PMO6V-B shows the early increase and to some less extent degadation which can be described with the degardation model
- The difference (PMO6V-B – DIARAD-L) allows to analyse both completely different physical mechanisms at the same time
- The so determined parameters of two completely differen effects at the same time ncreases the reliability of the two resulting corrected time series

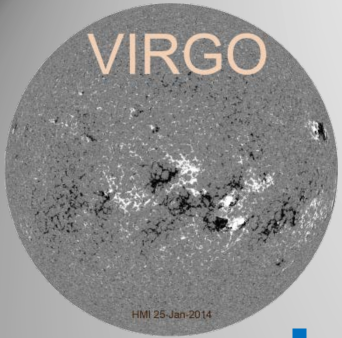
Corrections for DIARAD-L and PMO6V-B by fitting adequate functions of time

- The top panel shows the deviations from the fit
- The 2nd panel shows the deviation from the fit
- The 3rd panel shows the comparison of the total shift produced during the SOHO vacations with ACRIM. For value of B and the rest is due to L
- The last panel shows the corrections to be applied to DIARAD-L and PMO6v-B respectively



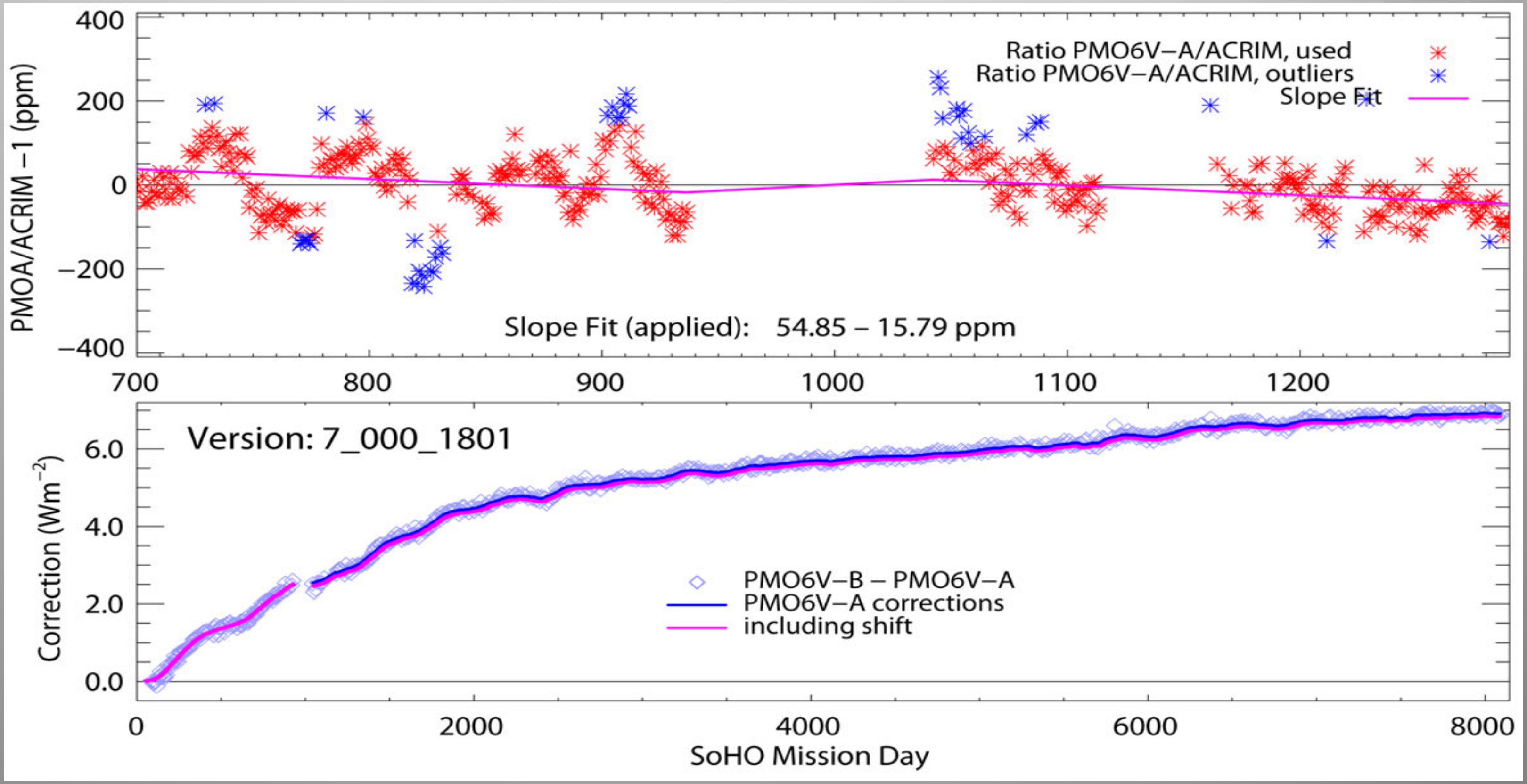
Final Results for DIARAD-L PMO6V-B





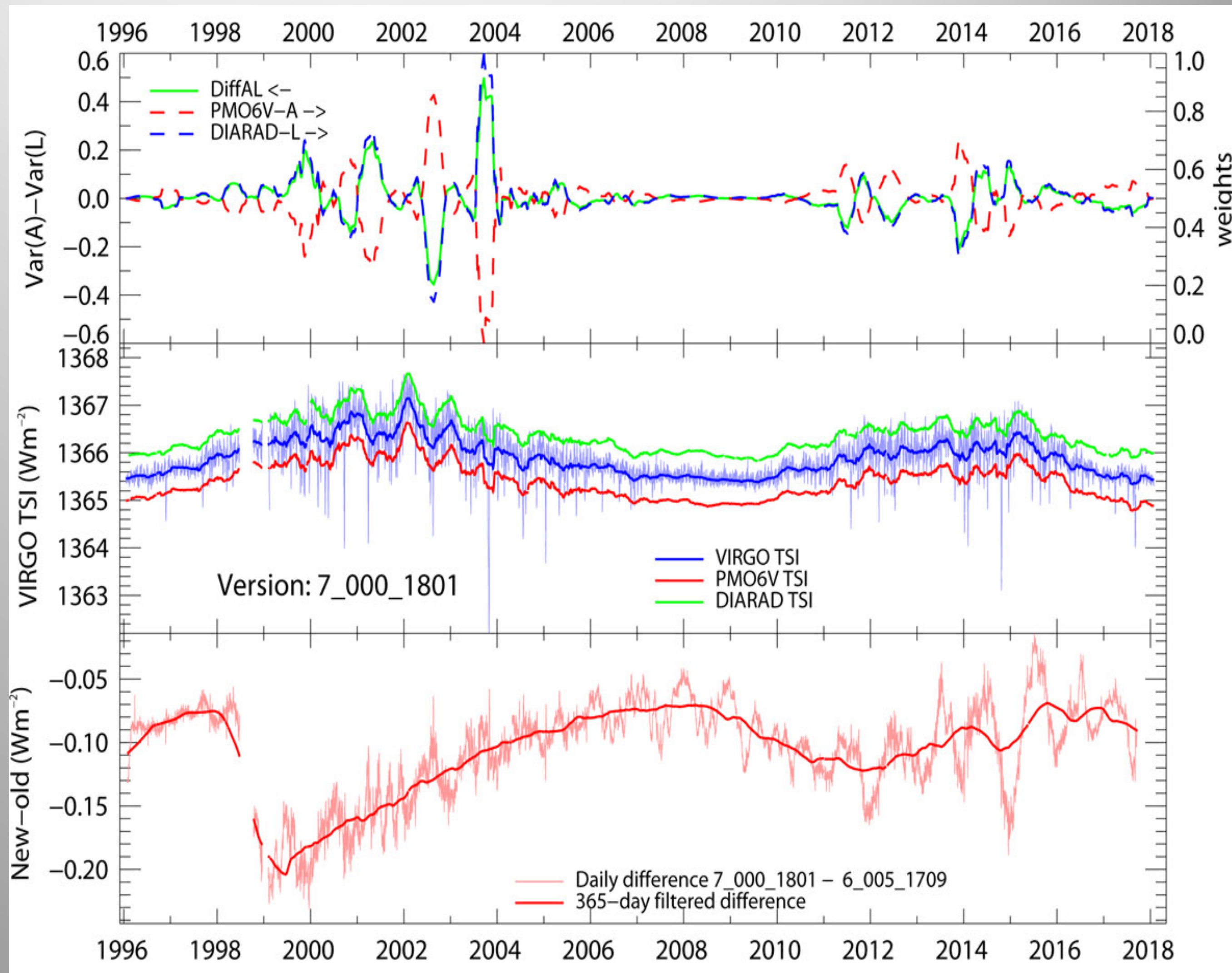
Corrections of PMO6V-A by comparing with PMO6V-B

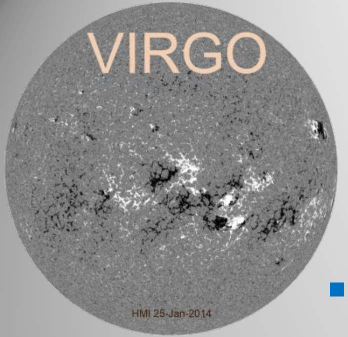
- This is straight forward and we get the results as shown in the plot below.
- The difference over the SOHO vacation is now almost zero indicating the the corrections as a result of the earlier ananlysis are confirmed



Final Results for DIARAD-L and PMO6v_A

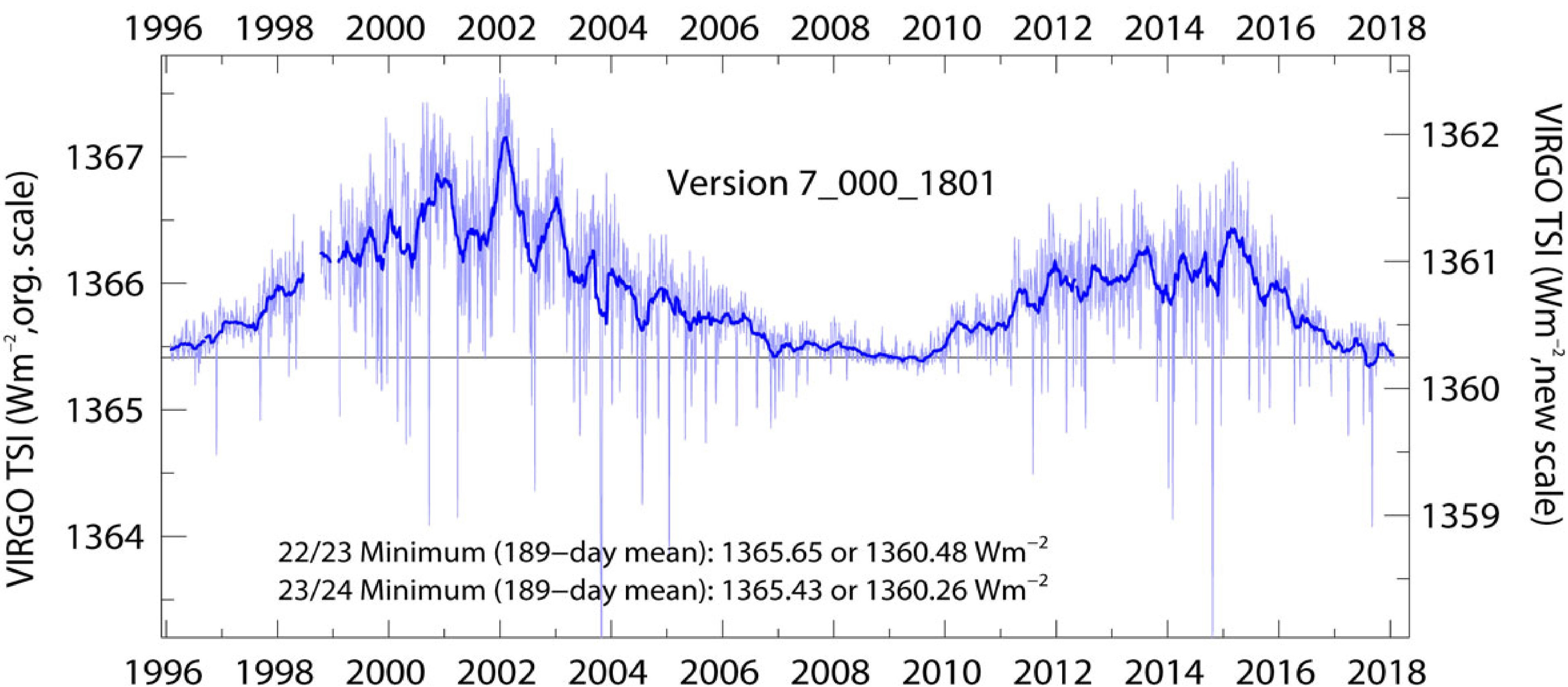
- The top panel shows the weighting of the two time series to the get the average VIRGO TSI
- The middle panel is the final result
- The bottom panel the difference to the last version (1709)
- A major difference is the change of the amplitude of both cycles.
- The change over the SOHO vacations is due to an errenious share of the slips in the older versions

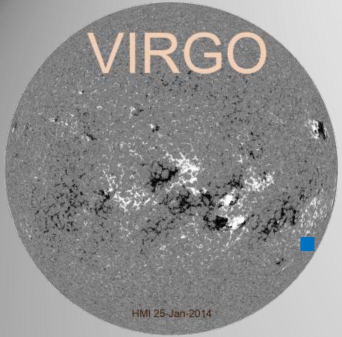




VIRGO TSI version 7.0

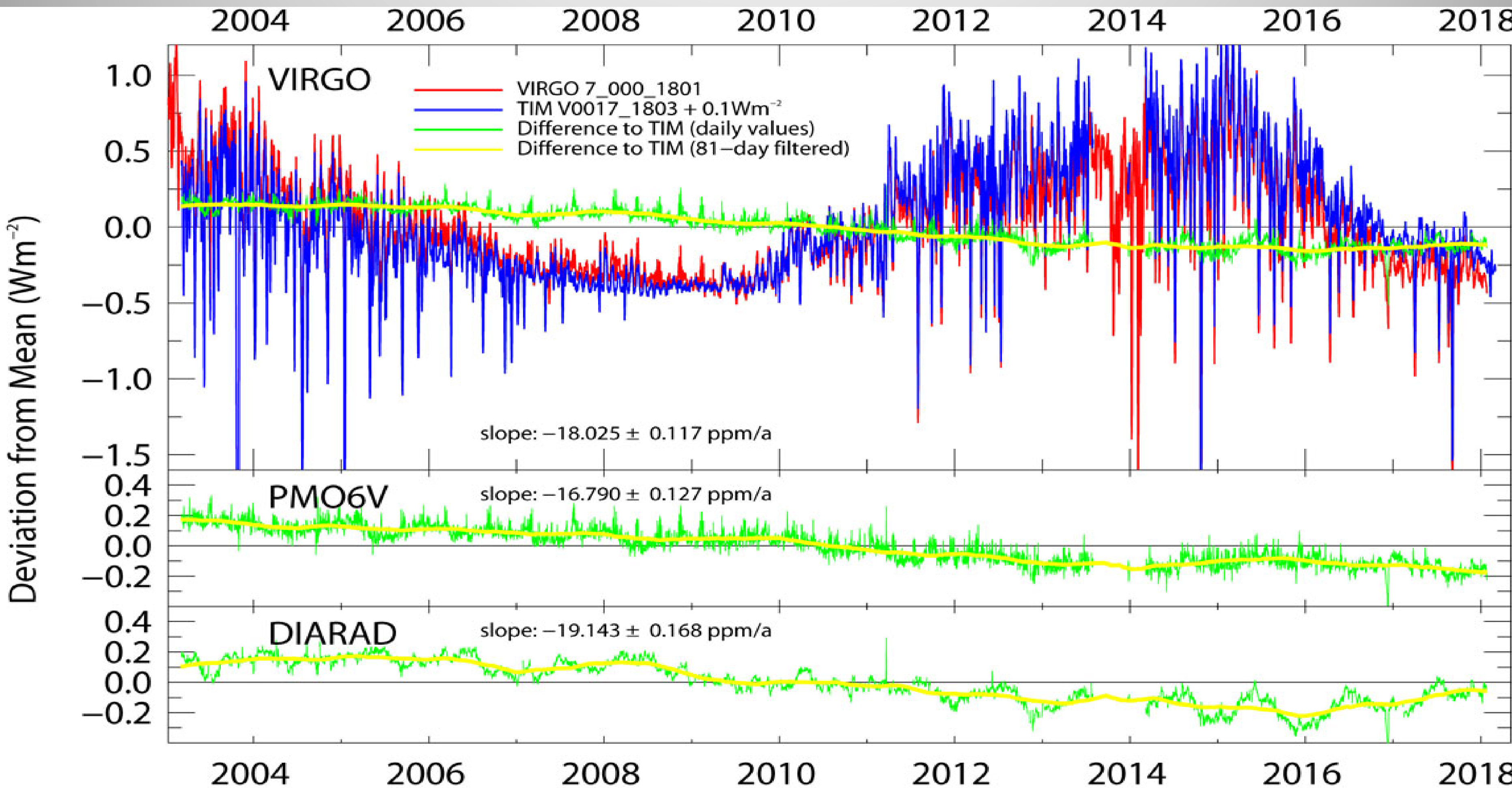
- This is the final VIRGO TSI, both in the ‘old’ and ‘new’ scale (for the scale change see my poster
- The change between the last two minima is of the order of 0.22 Wm^{-2} or about 160 ppm and it is not change from earlier versions

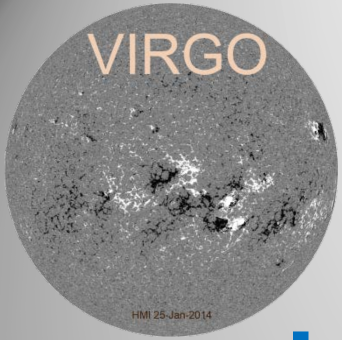




Comparison with TIM

- The trend over the whole period has changed. It changes from small to stronger around 2008 and then turn back up in 2016 (mainly due to DIARAD)





Conclusions

- A 22-year record is a great opportunity to study degradation and other long-term changes of radiometers in space
- It is astounding that a model with exponentials can work over such a long period of time
- The use of two different radiometer types helps to disentangle and quantify changes with more reliabilty. It was an important argument in the proposal, now we can confirm that it ws excelent idea
- I planned to include new level-1 evaluation of the PMO6 radiometers, which will eliminate most the noise – not only during the keyholes. But the long-term aspect was more important and as always it took more time than expected.
- The level-1 evaluation will be done after this meeting – probably within a month. By the end of April there will be the final version of VIRGO TSI available.