Total Solar Irradiance since late 1978

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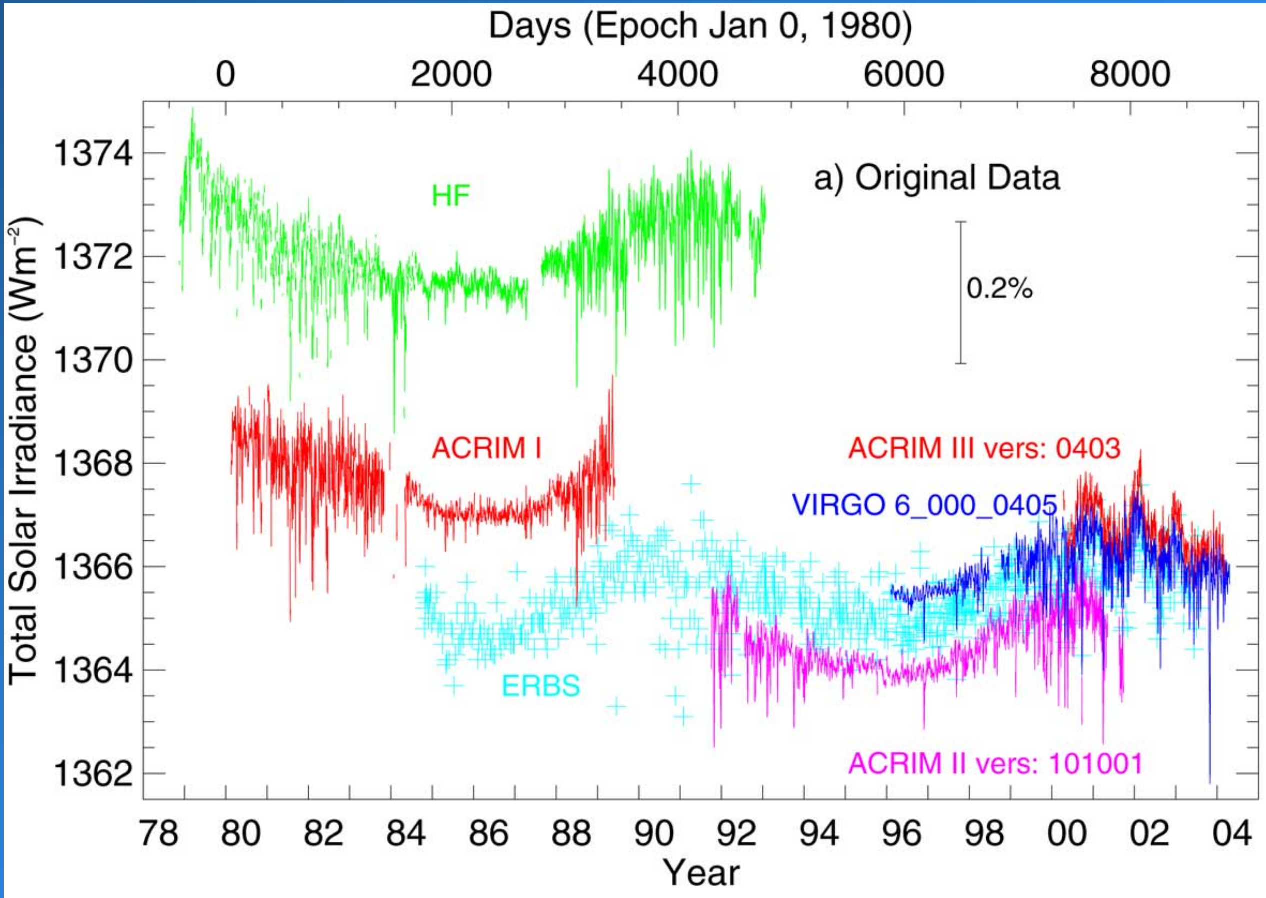
Introduction

- The development of modern ECR with cavities started in the sixties with ACR (Active Cavity Radiometers by R.C. Wilson) to measure the Sun from balloons, rockets and satellites and with PACRAD (Primary Absolute Cavity Radiometer by Jim Kendall) to help space engineers with the measurement of the radiation of solar simulators and their comparison with the real Sun (experiment on the Mercury mission)
- 'Room-Temperature' is meant to contrast 'cryogenic' radiometers operating at liquid-He temperatures. Although the latter have a much lower uncertainty, they cannot be used to measure the solar irradiance on ground. Thus, for measurements in an ambient environment the room temperature radiometers cannot be replaced as such



How do we deal with ‘degradation’

Introduction

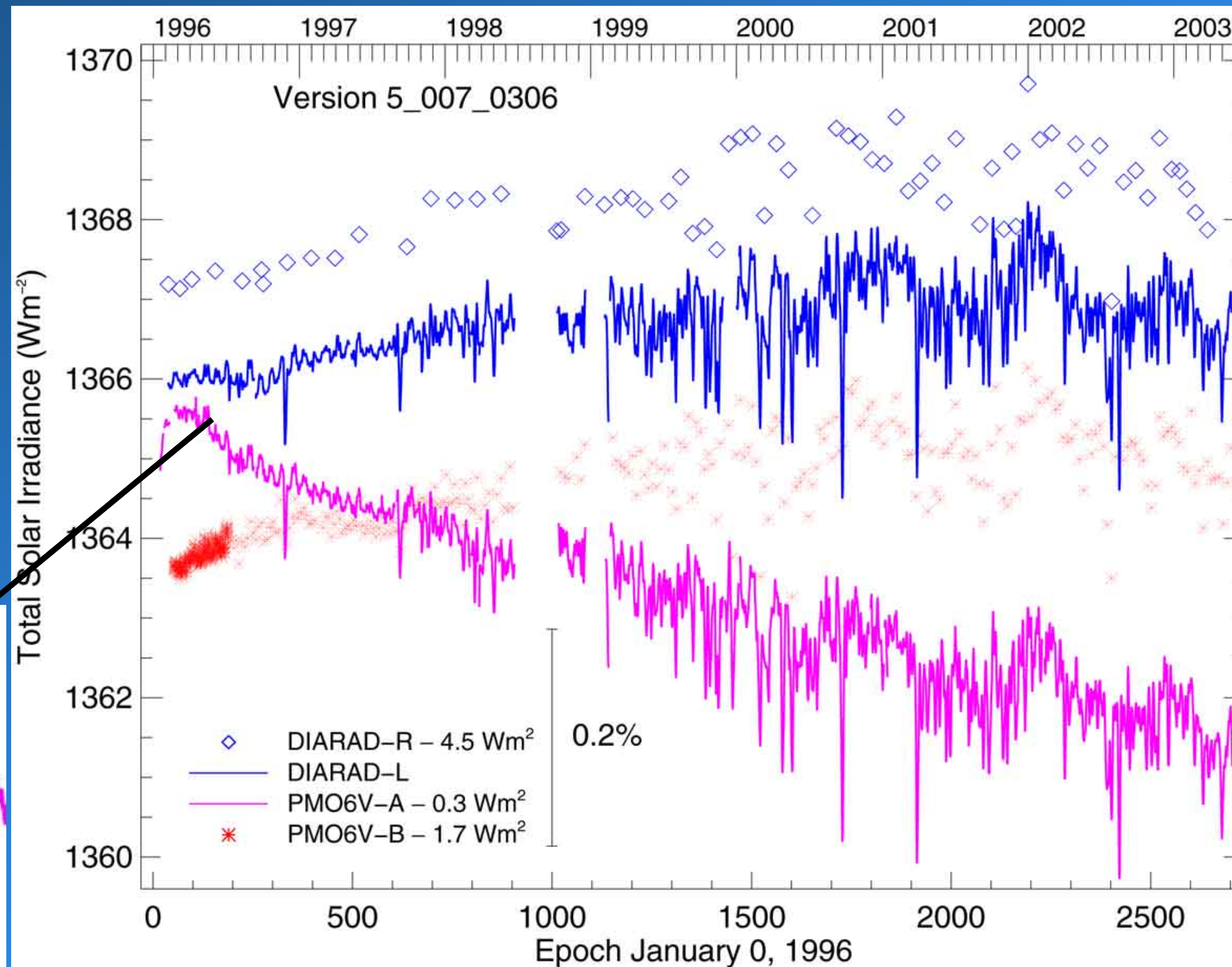
- The uncertainty of the transfer of a room-temperature radiometer to space depends mainly on the accuracy of the knowledge of the change of behaviour from air to vacuum.
- This change can be measured on ground with the sun as source, but the precision is only of the order of ±0.05%.
- The comparison of the two PMO6V radiometers on SOHO have shown that the ratio in space changed by <0.1%, which is just at the limit of the uncertainty and thus not conclusive.

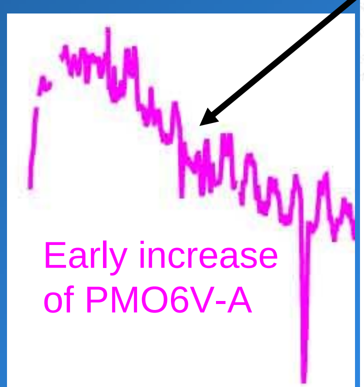
How do we deal with 'degradation': VIRGO

Degradation

A major problem are changes of sensitivity of the radiometers due to the exposure to the strong UV radiation of the Sun and the exposure to the space environment

The VIRGO radiometry will be used as an example how this problem is tackled.





How do we deal with ‘degradation’: VIRGO

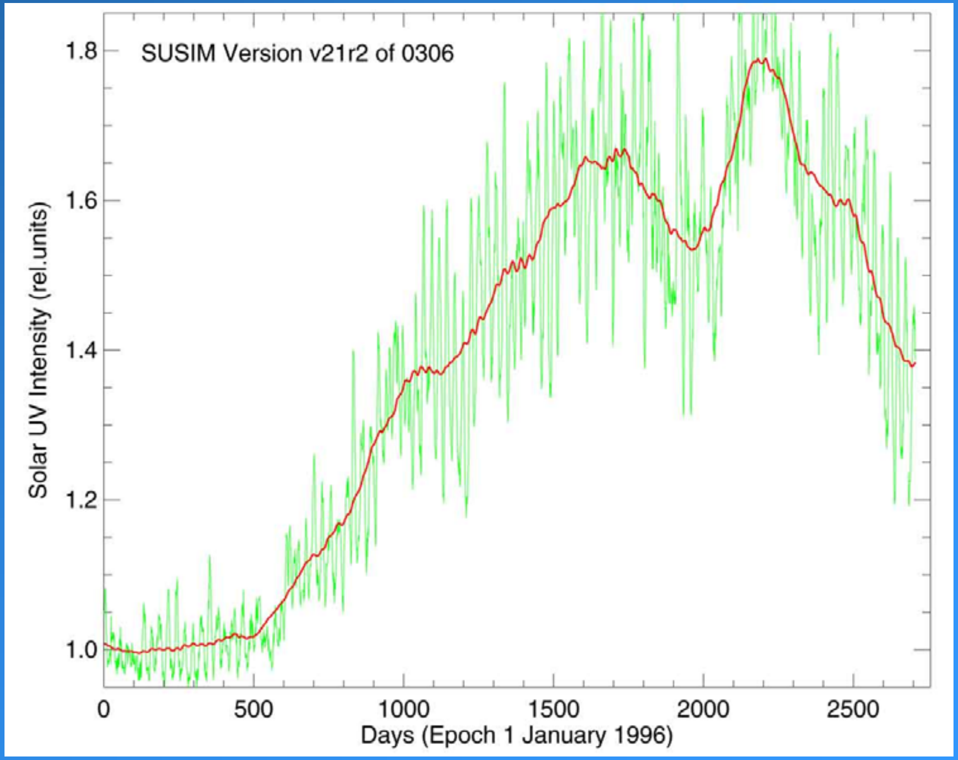
Development of a model for degradation

The changes are expressed as a hyperbolic function (see e.g. Fröhlich and Finsterle, 2001; Fröhlich, 2003) which is the solution of a differential equation describing the ‘siliconizing’ of a quartz window exposed to UV radiation, that is a change of the optical properties and a subsequent decrease of the response to radiation exposure.

The time dependent sensitivity change $\Delta S(t)$ is expressed as

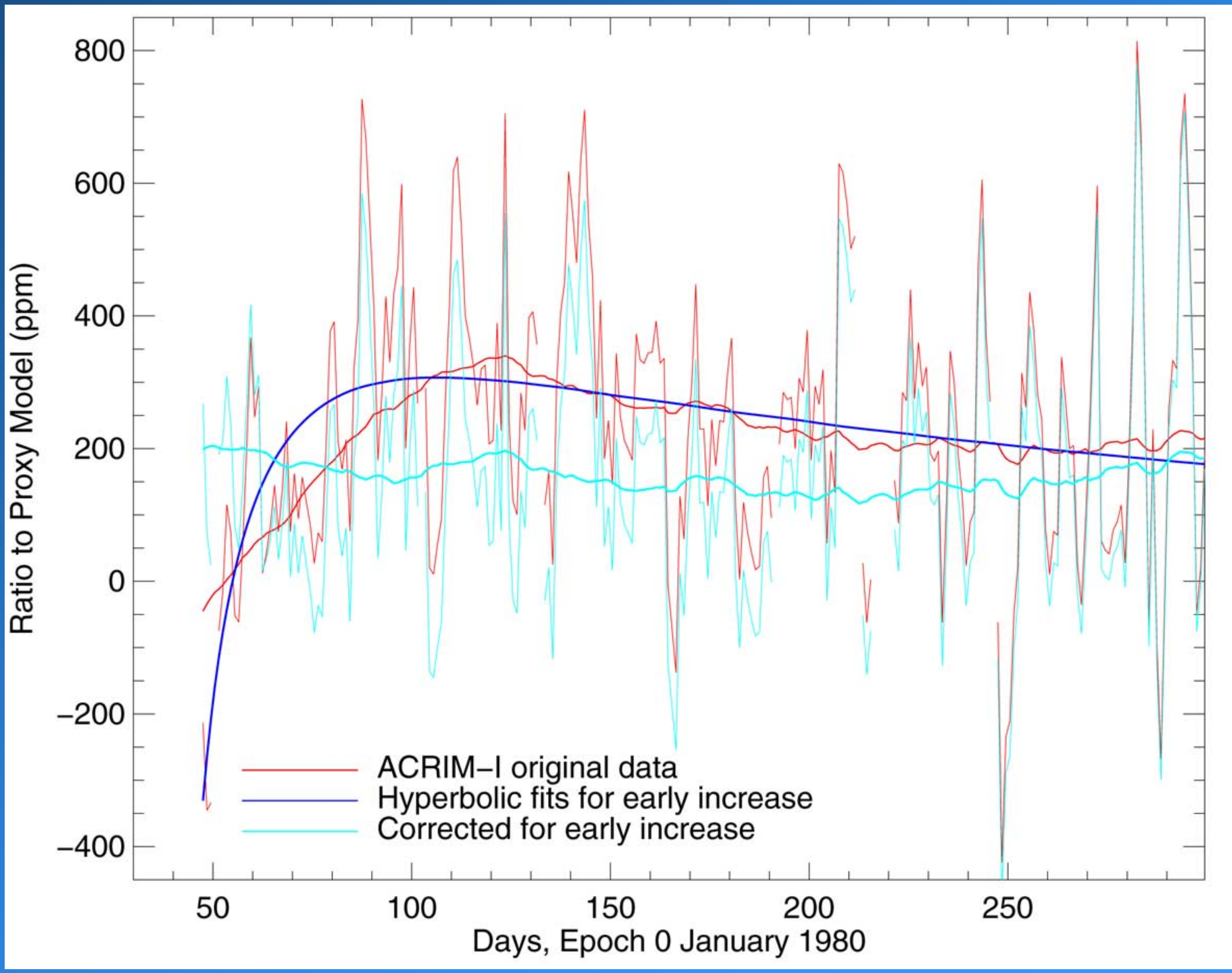
$$\Delta S(t) = a\left[\left(1+\frac{1}{\tau}\int_0^{t_{\mathrm{exp}}}(\lambda M(t)+1)\,dt\right)^{-b}-1\right]$$

with a, τ, b and the scaling λ as adjustable parameters and $M(t)$ the instantaneous UV radiation, normalized to 0 at solar minimum and 1 at solar maximum. The MgII index is used to represent UV radiation and is taken from SUSIM/UARS.



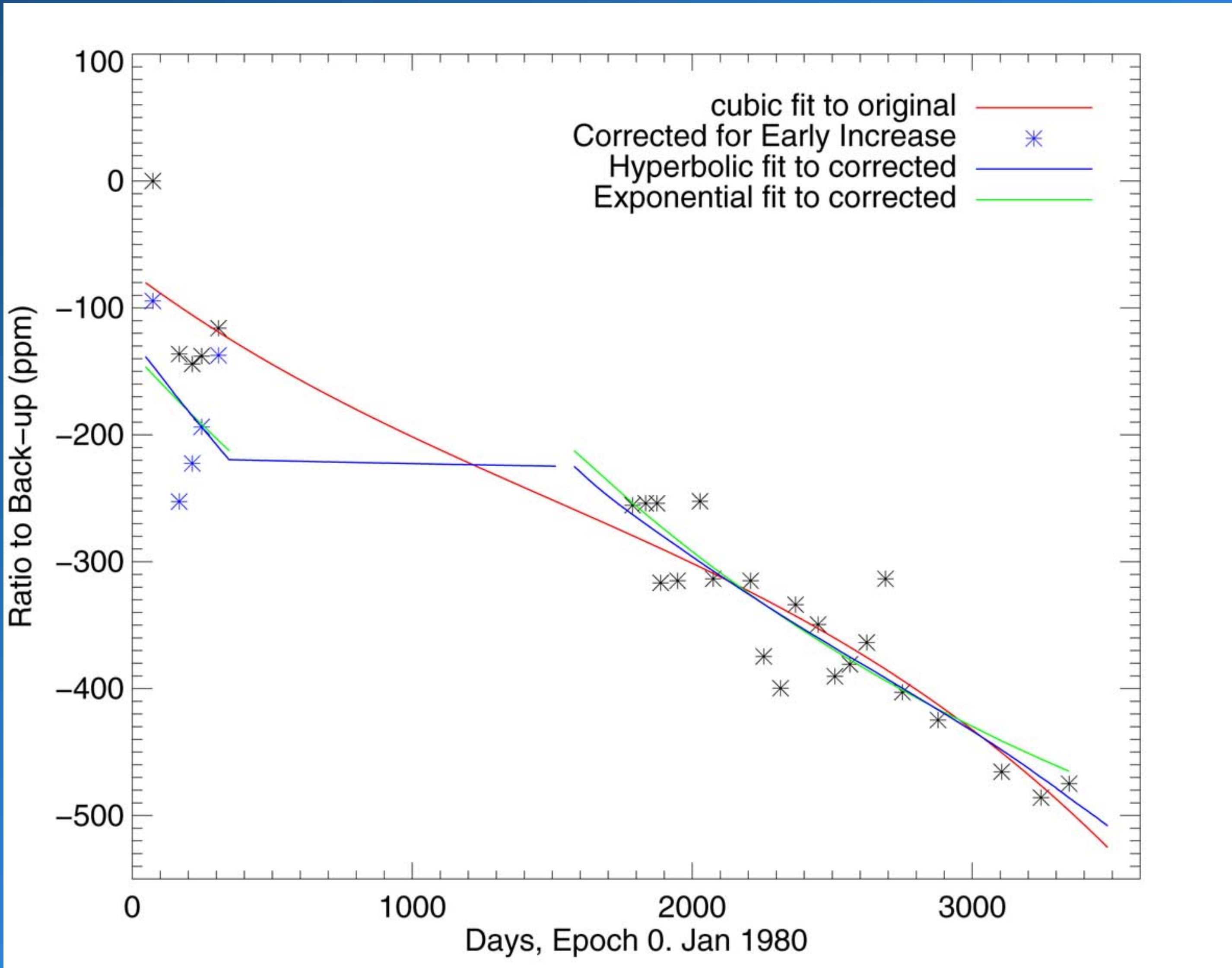
How do we deal with 'degradation': ACRIM-I

Also ACRIM-I shows an early increase which is corrected in the same way as for the PMO6V radiometers. The determined coefficients for the increase and decrease are very similar to the one determined for PMO6V



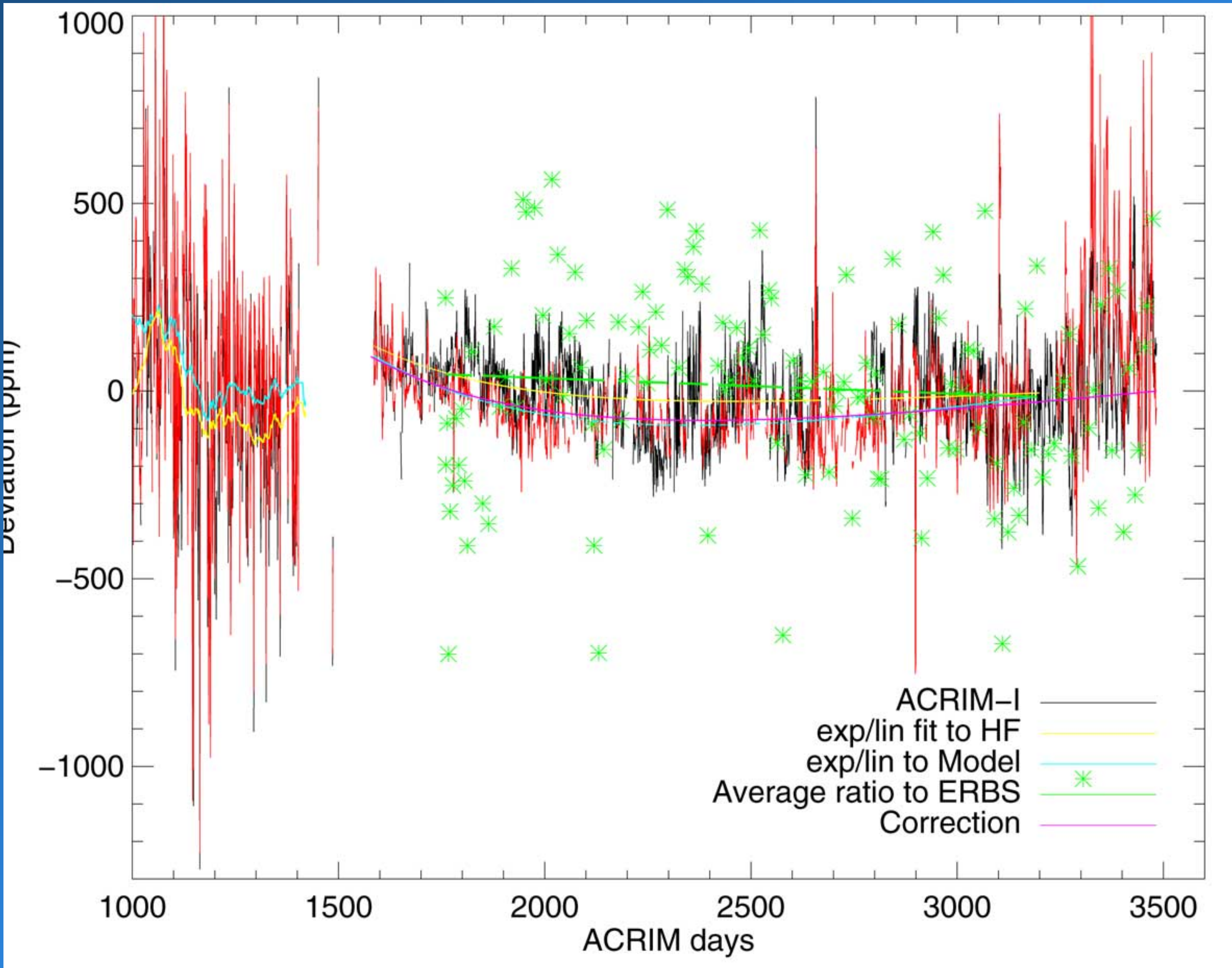
How do we deal with ‘degradation’: ACRIM-I

The long-term changes are determined from comparison with less exposed spare radiometers. The early data have to be corrected for the early increase and all has to be done in exposure time.

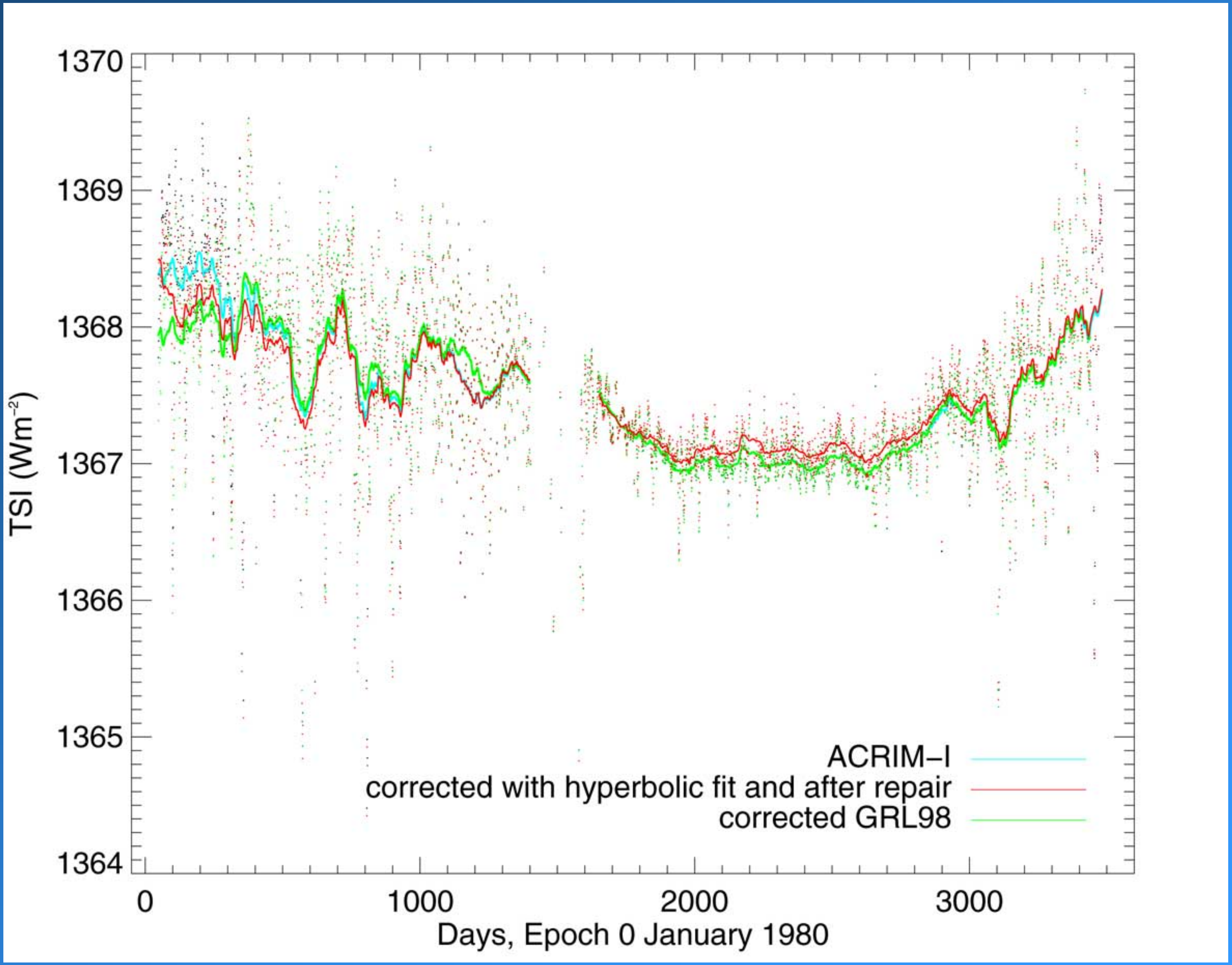


How do we deal with 'degradation': ACRIM-I

After repair of SMM and switch-on of ACRIM-I there seem to be some changes which have not been detected by the comparison with the back-up.



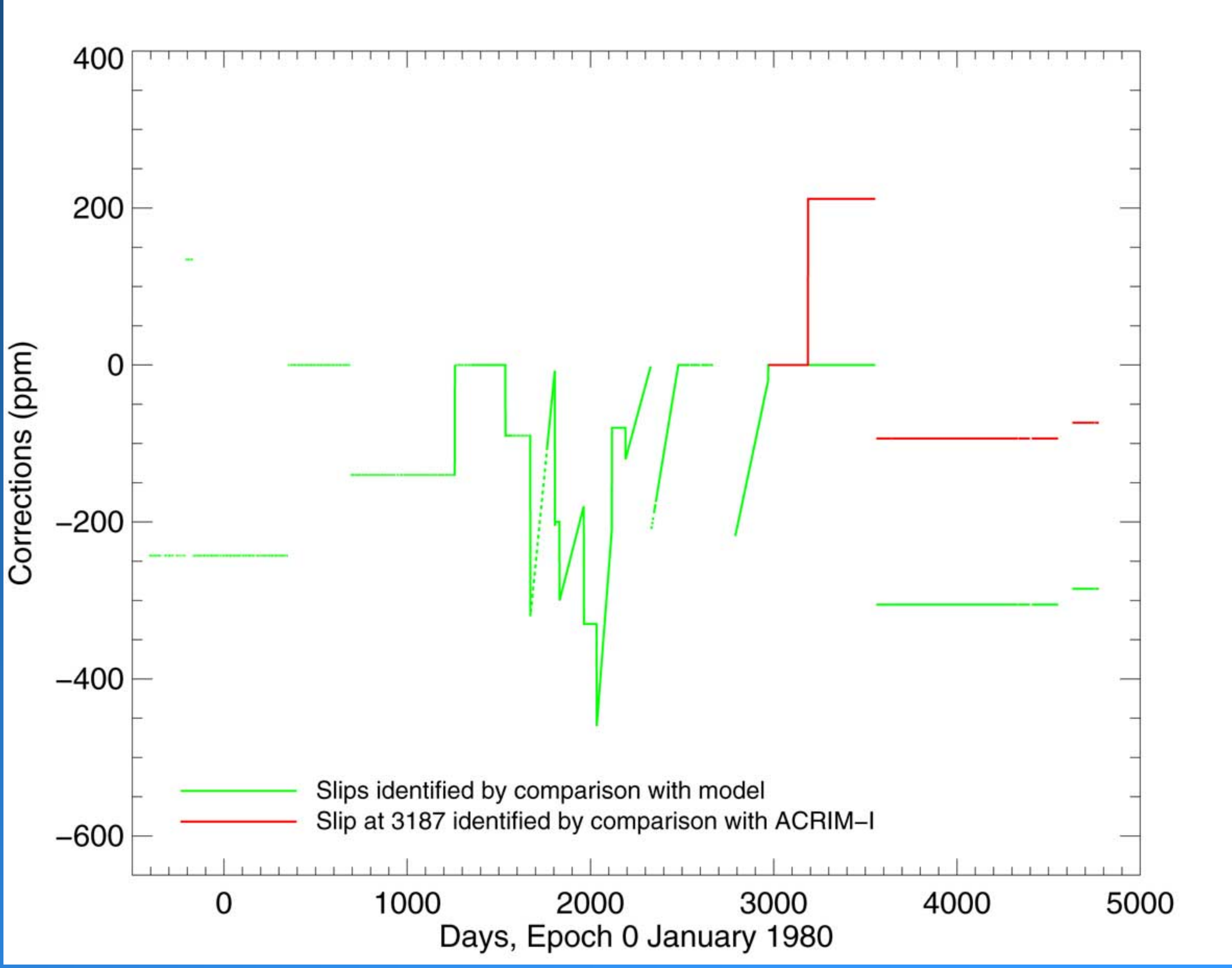
How do we deal with ‘degradation’: ACRIM-I



How do we deal with 'degradation': HF

There are many slips in the HF data set because of the operation of NIMBUS. As it is an Earth viewing satellite the sun is only seen for a few minutes at the southern terminator. The inclination of the optical axes relative to orbital plane (beta angle) is changing and needs corrections from time to time.

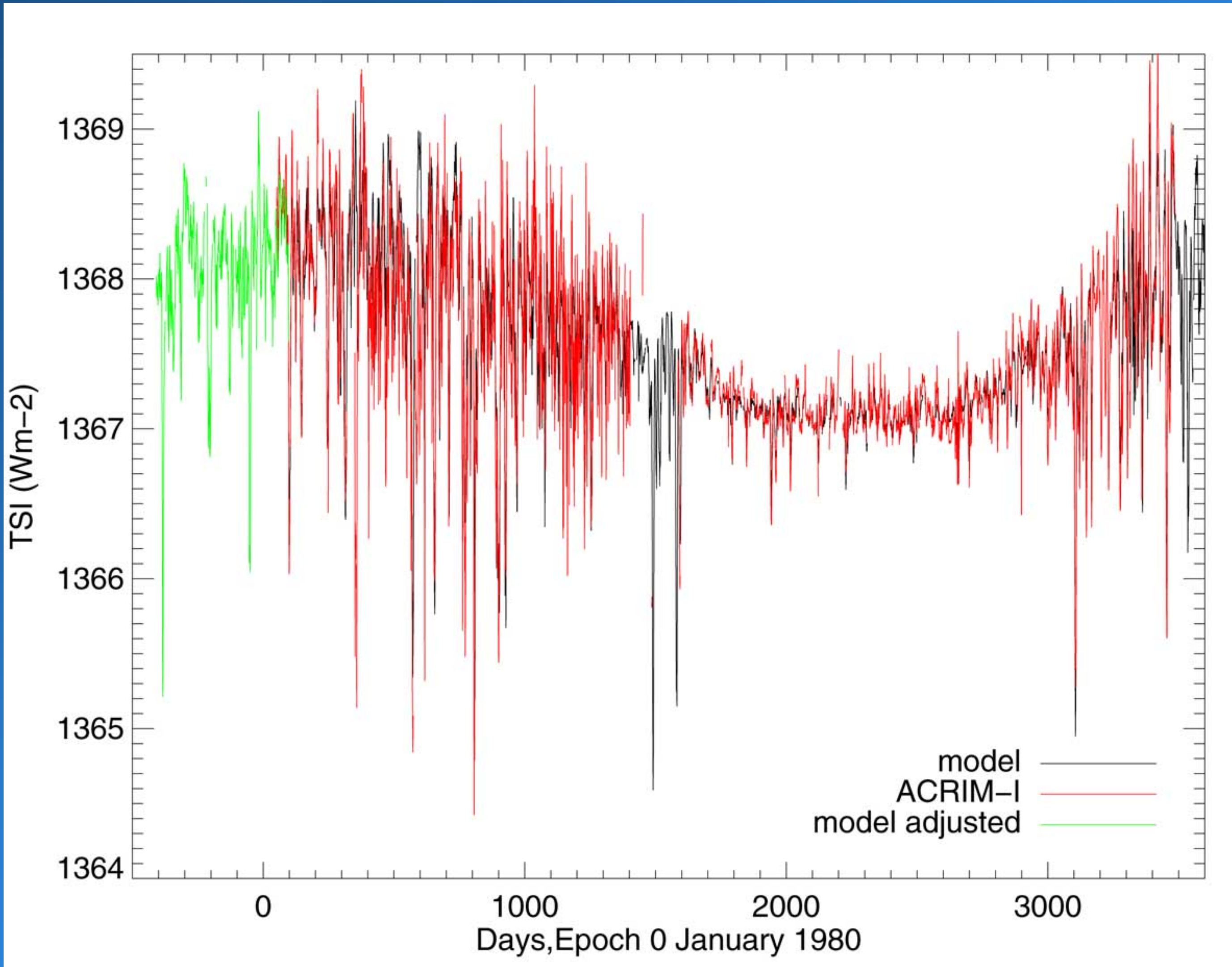
The slips are determined by local comparison with a proxy model



How do we deal with 'degradation': HF

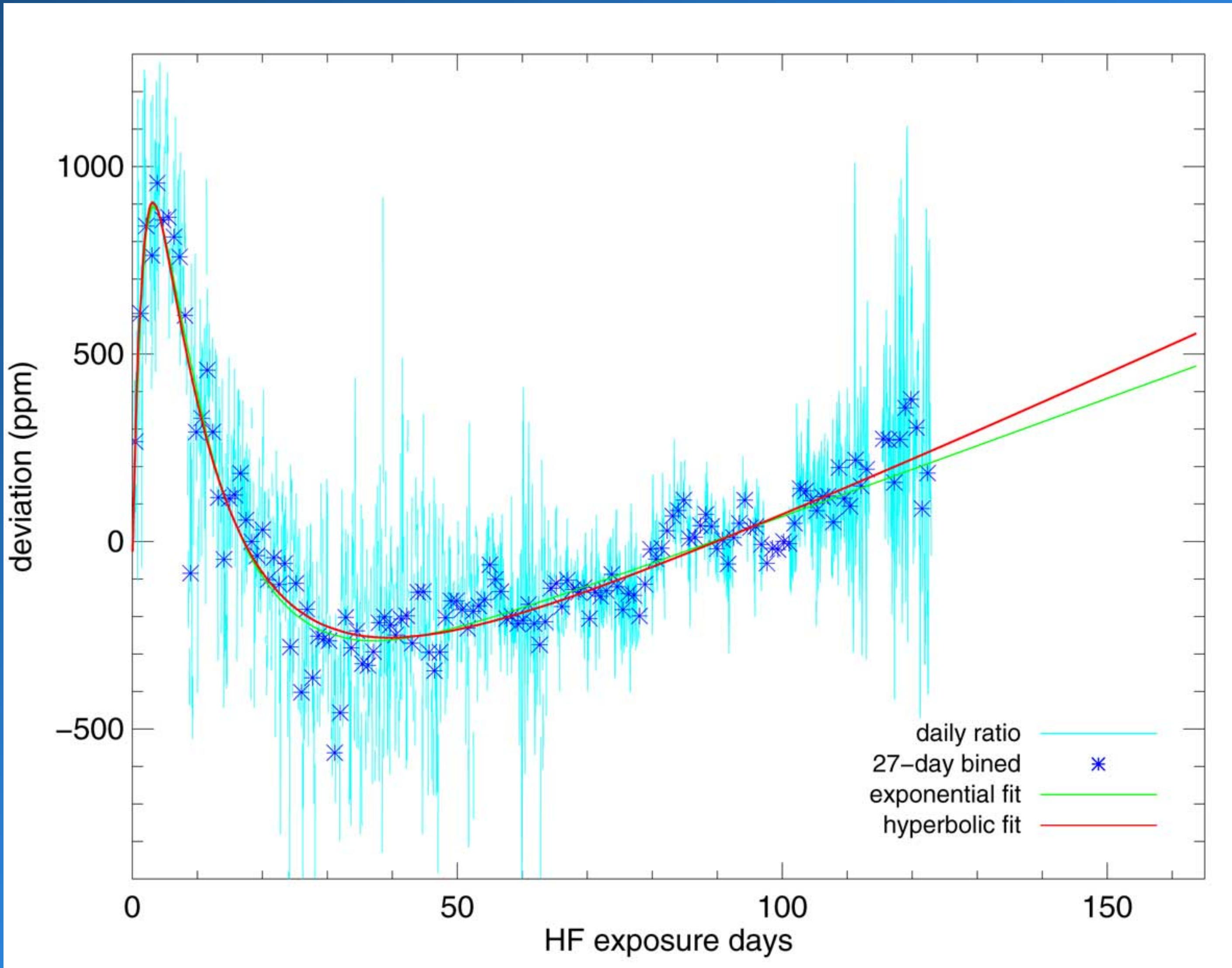
After having corrected the slips we need a reference to determine the long-term changes, especially the early increase.

The ACRIM-I record, extended with the proxy model is used.

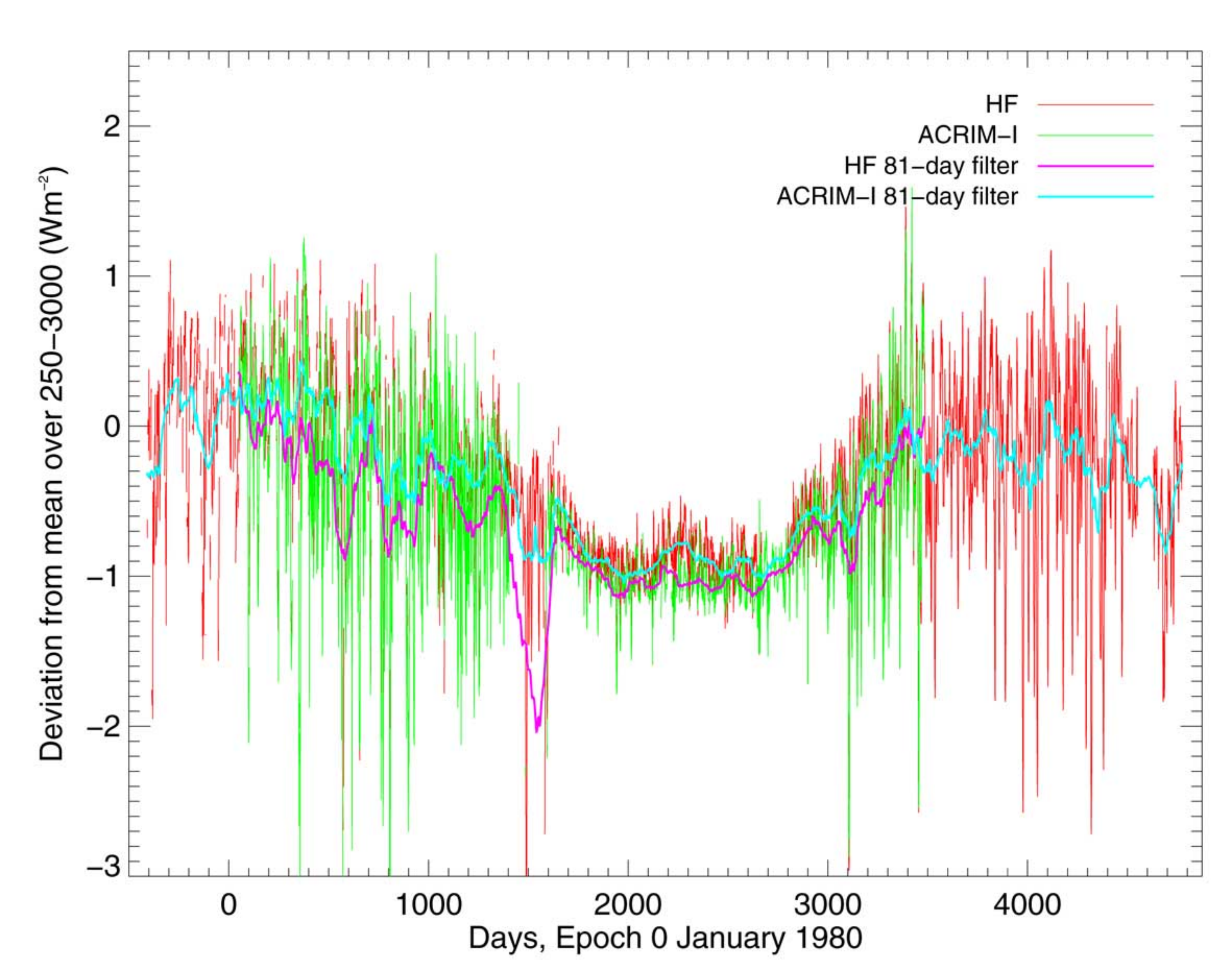


How do we deal with ‘degradation’: HF

The model used for the corrections assume an early increase and a decrease which may include also the long-term degradation. To compensate for the long-term increase of sensitivity we add a straight line.

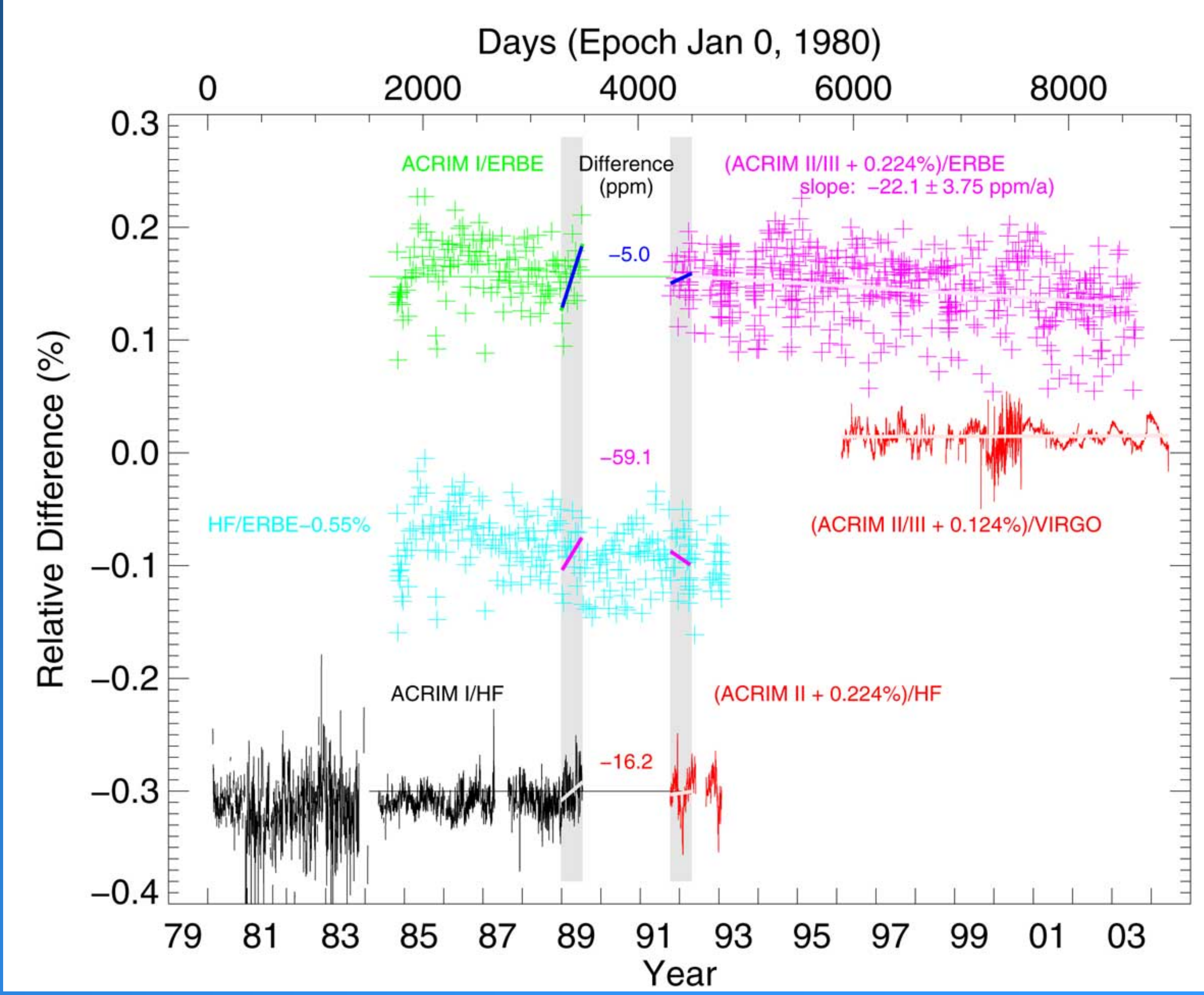


How do we deal with ‘degradation’: HF

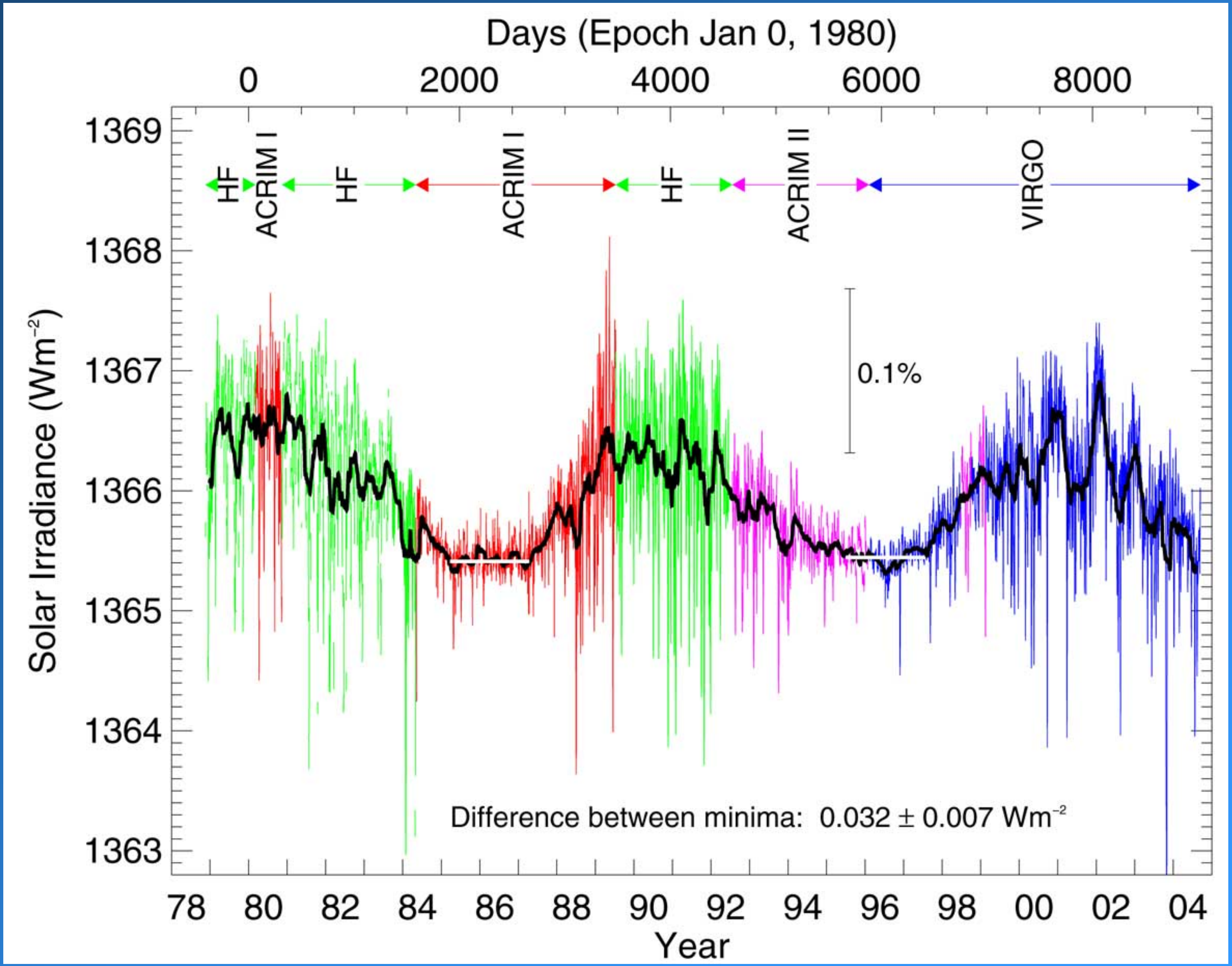


Construction of the composite (1 of 5)

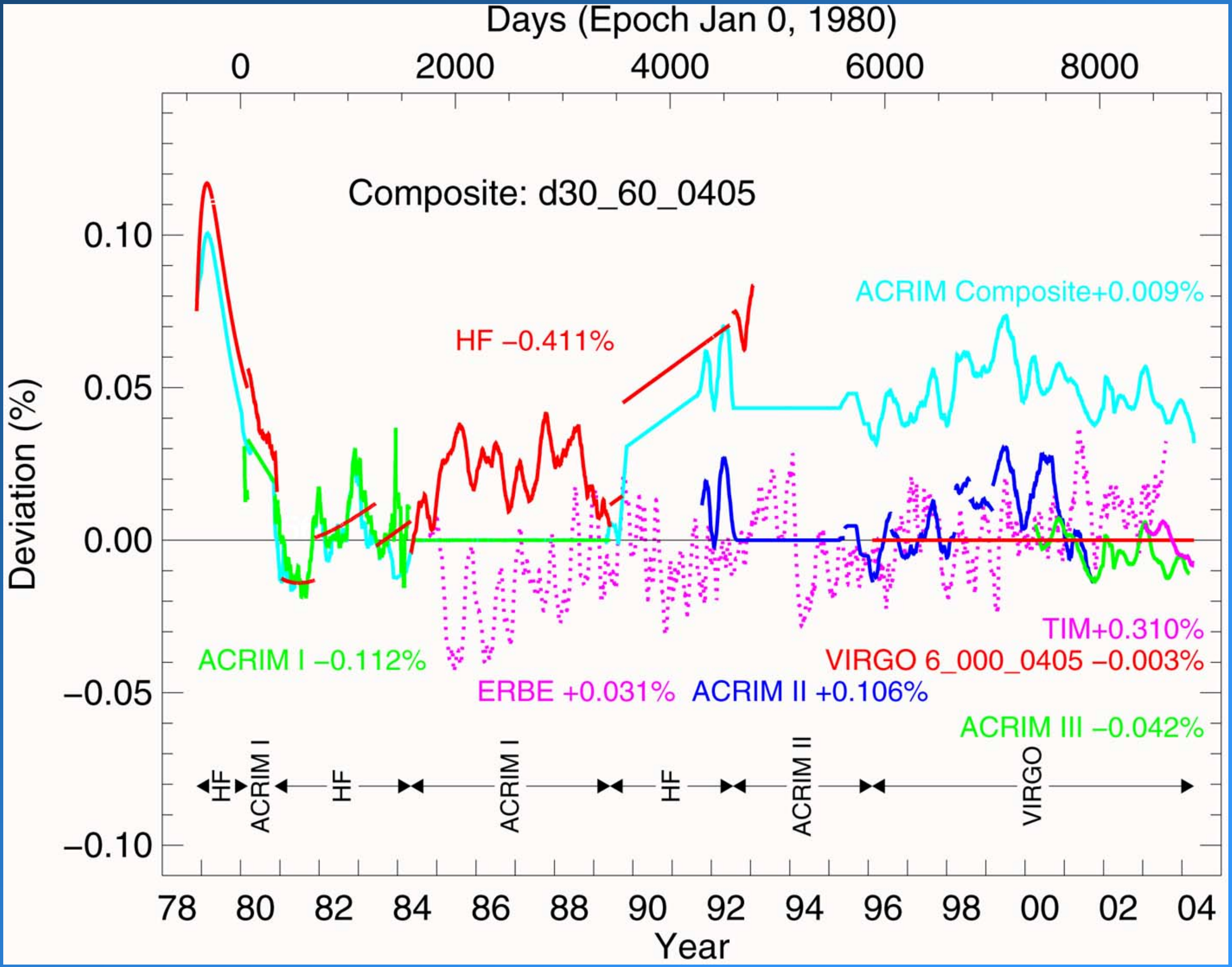
Before we are ready to construct the composite we need to refer ACRIM-II to ACRIM-I which is done by comparison with HF and ERBS.



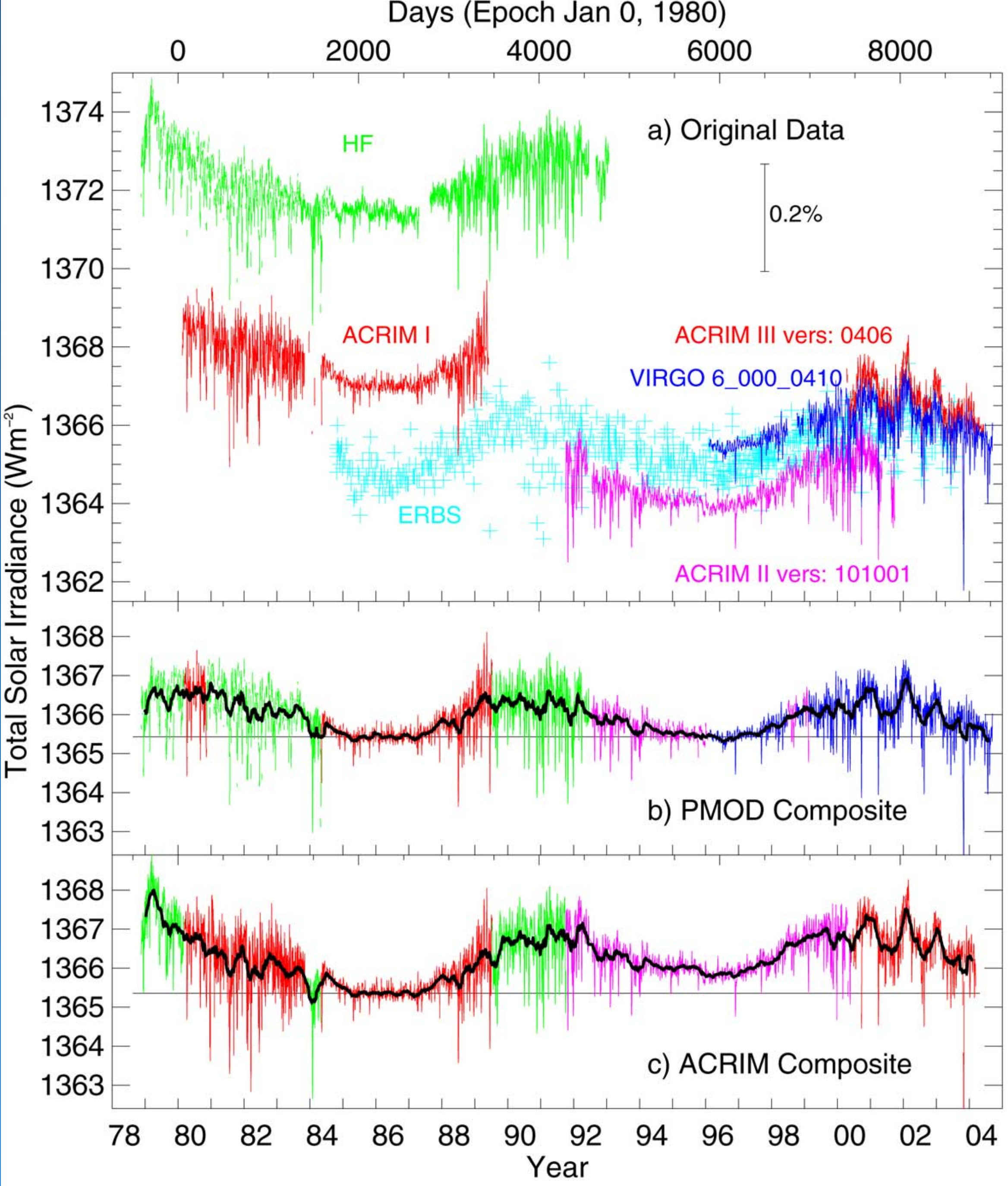
Construction of the composite (2 of 5)



Construction of the composite (3 of 5)



Construction of the composite (4 of 5)

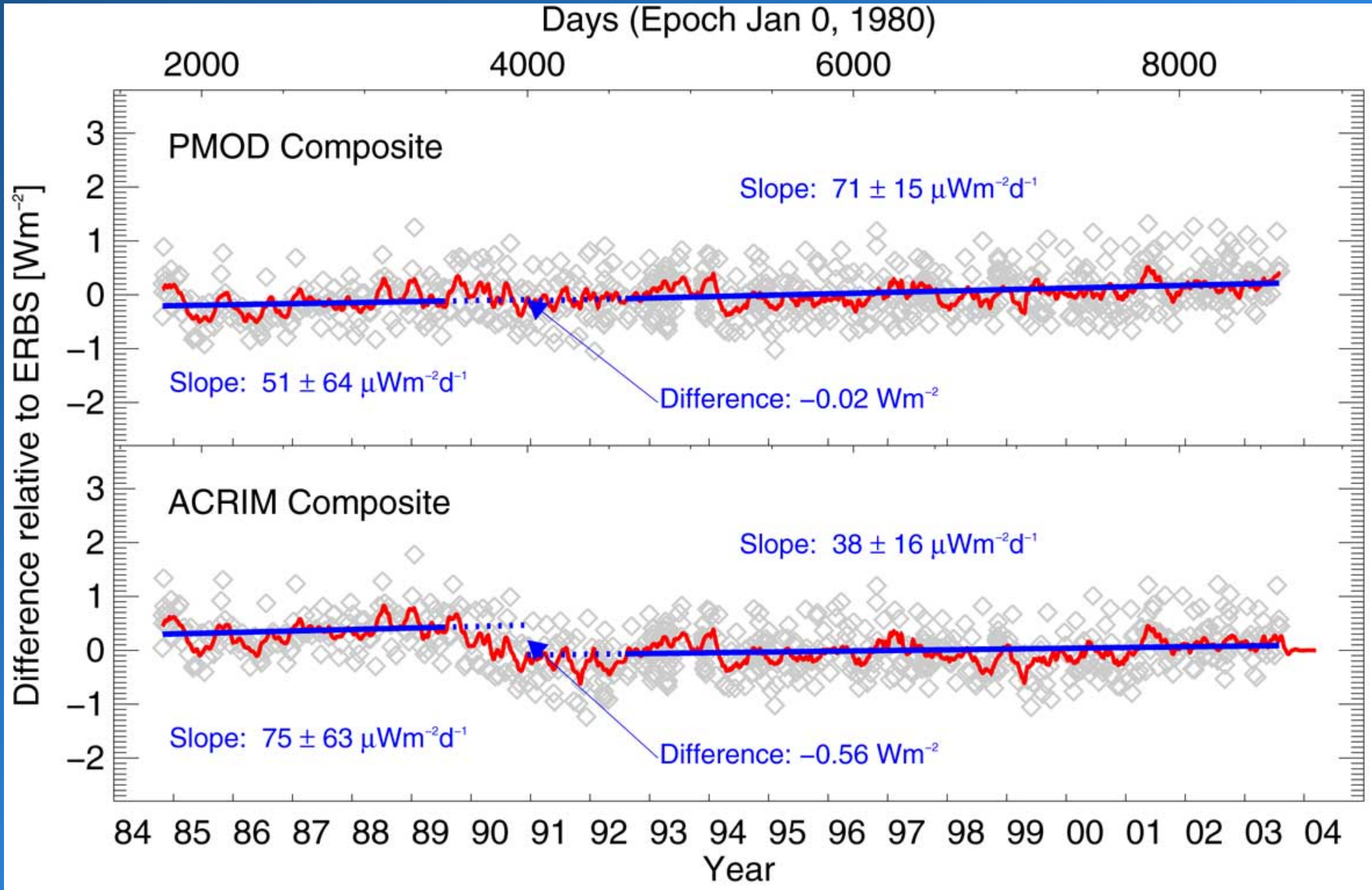


Construction of the composite (5 of 5)

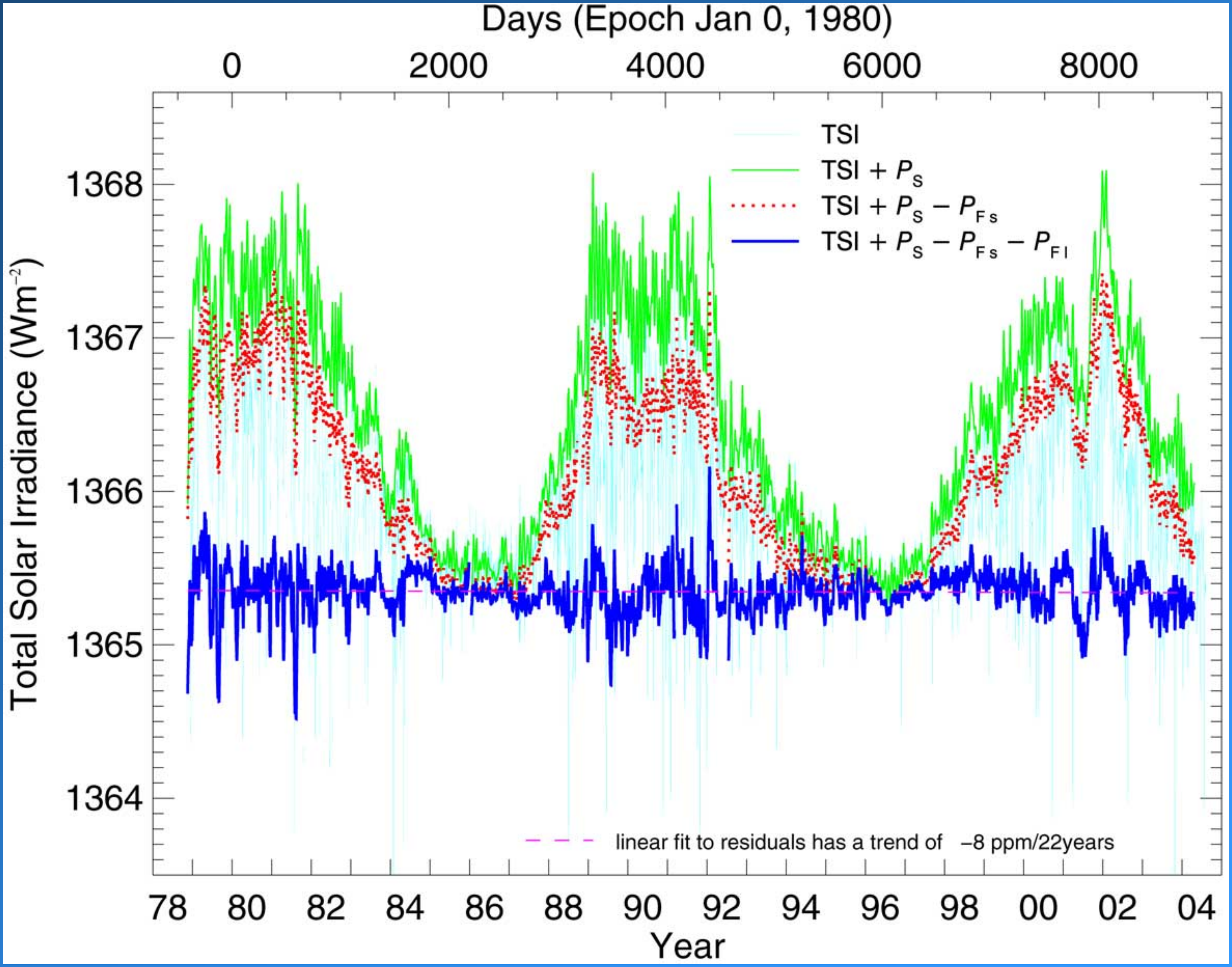
The ACRIM composite obviously neglects the HF correction during the ACRIM gap and thus concludes that the Sun was increasing by 403 ppm between the two minima.

The difference of 403 + 33 ppm can be explained by 376 ± 71 ppm derived from the correction over the corresponding period of time.

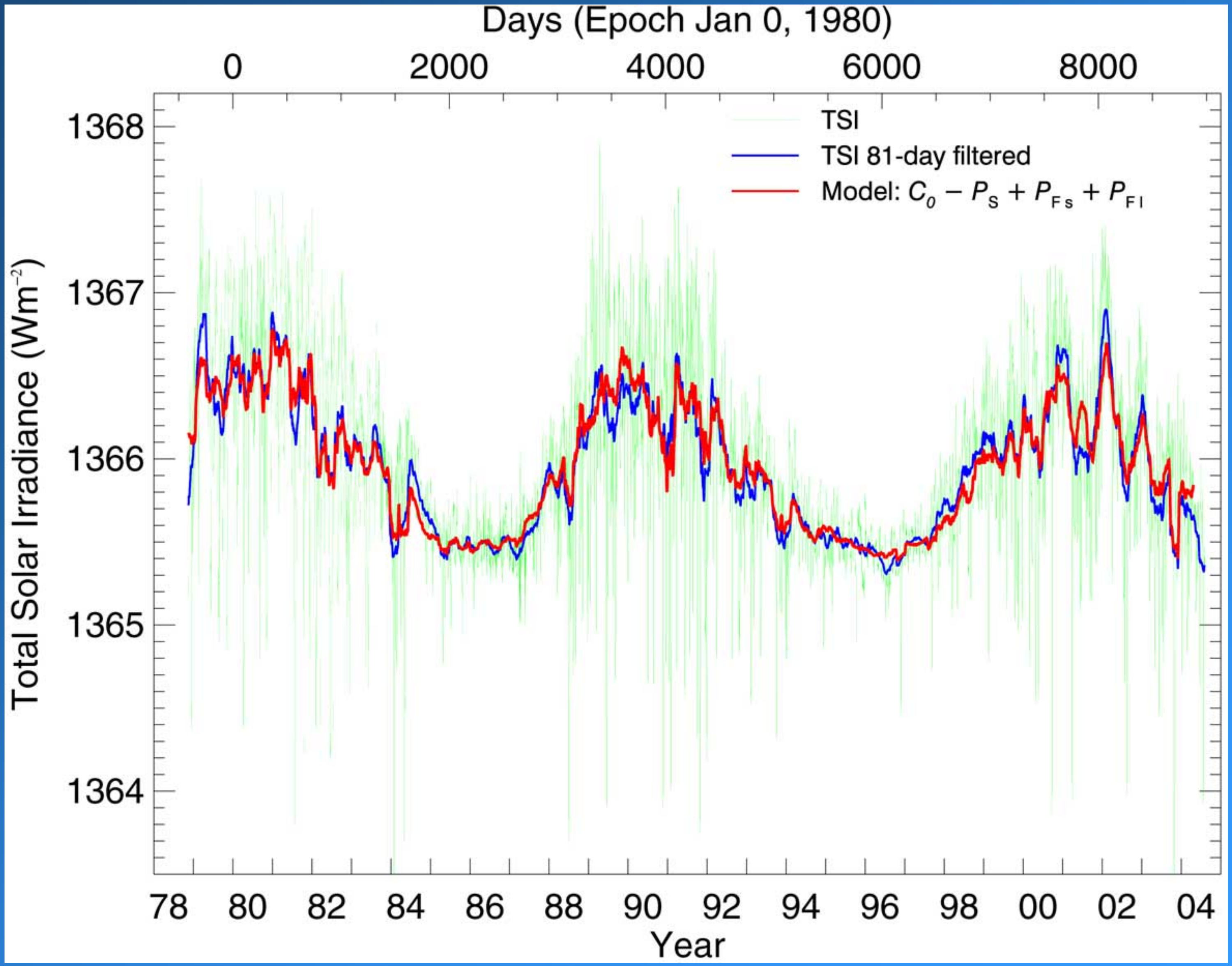
The comparison with ERBE of both composites illustrates this fact even better. Moreover, the positive trend of ERBE can be explained with its early increase. With a total of 2.6 exposure days the total increase becomes 127 ppm/d_{exp}, which compares well with the value of PMO6V-A of 184 ppm/d_{exp} at the beginning of the mission. There seems to be no way to explain the change of ERBE during the ACRIM gap by a degradation as suggested by Willson (2003).



Comparison with Model



Comparison with Model



Conclusions

- The new evaluation of the long-term changes of ACRIM-I and HF/ERB changes the cycle 21 around its maximum.
- The trend between minima changes slightly, but is still not significantly different from zero.
- Comparison with the model calibrated with this composite shows better overall agreement.