



Publication Year	2021
Acceptance in OA	2023-05-30T10:34:28Z
Title	Reconstructing solar irradiance from historical Ca II K observations. I. Method and its validation
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Publisher's version (DOI)	10.1051/0004-6361/202141516
Handle	http://hdl.handle.net/20.500.12386/34221
Journal	ASTRONOMY & ASTROPHYSICS
Volume	656

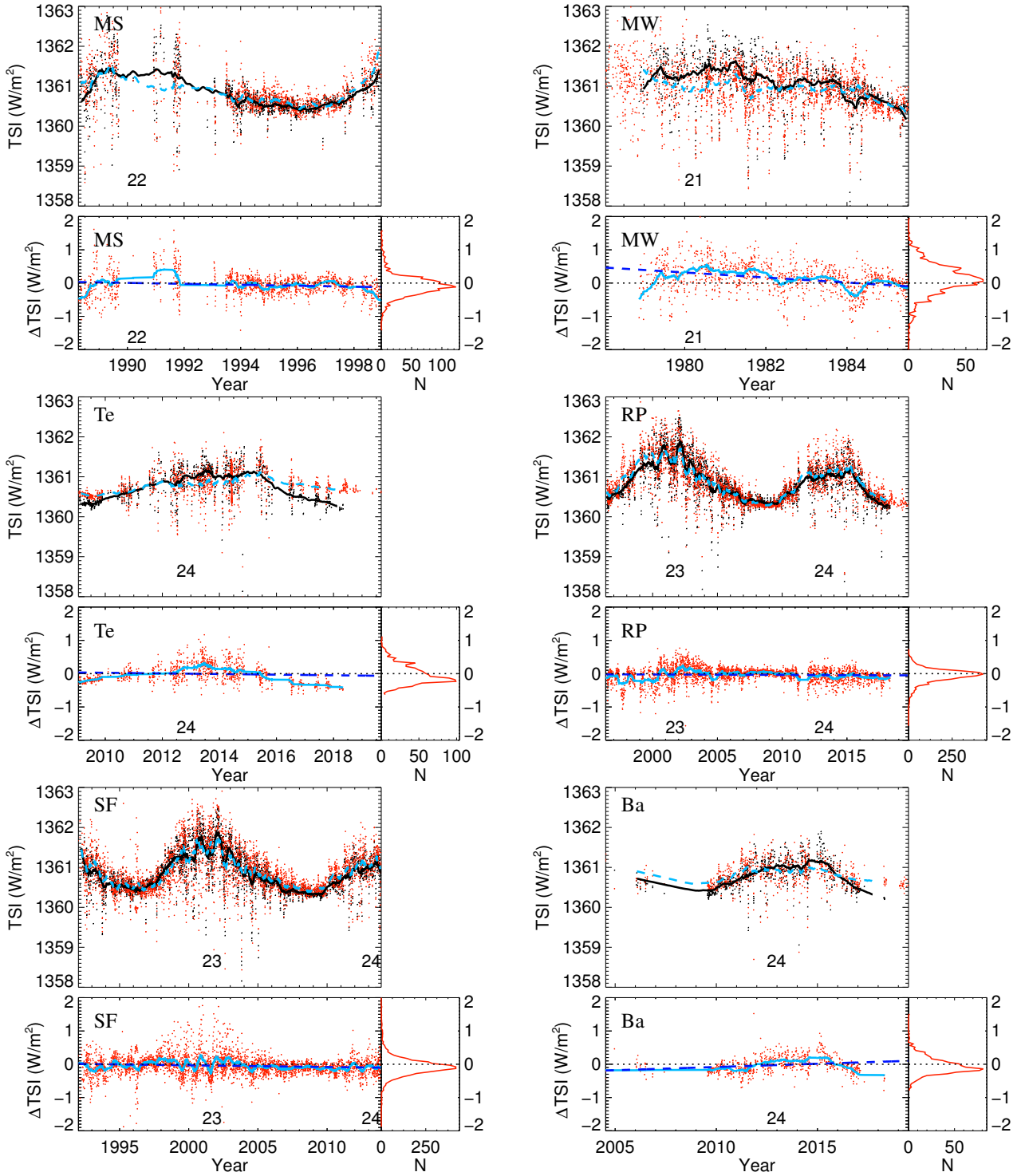


Fig. 11. Upper part of each panel: TSI reconstructions from Ca II K observations using the reconstructed TSI series from MD1 Ca II K data as the reference. Daily values from the MS, MW, Te, RP, SF, and Ba datasets are shown as red dots and the corresponding 81-day running means as dashed blue lines. For comparison, the PMOD irradiance composite series is overplotted (black dots for daily values and the solid black line for the 81-day running means), which was used as the reference for the reconstructed series from MD1 Ca II K data. The running means have been computed considering only days on which both the reconstructions and the PMOD series were available. Lower left part of each panel: difference between the PMOD composite and the reconstructed TSI (red dots for daily values and solid light blue for 81-day running means). The dashed blue line is a linear fit to the residuals. The horizontal black dotted line marks the zero difference. Lower right part of each panel: distribution of the residuals in bins of 0.05 Wm^{-2} . The numbers in the bottom part of each panel indicate the solar cycle number, which are placed roughly at the maximum of each cycle.

We used the images from the Mount Wilson (MW) and Meudon (MD1) archives to reconstruct the TSI over the period after 1978, when we can compare the outcome to direct TSI mea-

surements. We showed that inconsistencies within the archives can distort the results. However, if the inconsistencies are identified, then such data can still be used to recover irradiance

variations sufficiently accurately. Thus, identifying and potentially accounting for such inconsistencies and discontinuities will be the main challenge for reconstructions of irradiance from historical archives. Once such issues are better understood and taken into account for the available archives processed by Chatzistergos et al. (2020c), we will use them for the reconstruction of irradiance over the 20th century.

In this paper we focused on presenting results for TSI; however the model also produces the spectrally resolved solar irradiance (solar spectral irradiance, SSI) over 115–160 000 nm. Future work aiming at the reconstruction of the past irradiance variations from historical and modern Ca II K data using the method described in this paper will include both TSI and SSI.

Finally, we used the TSI reconstruction from the MD1 archive (which were photographic prior to 2002 and CCD-based afterwards) as a reference for reconstructions from other archives. We found that the quality of the reconstructions remained comparable to that when the PMOD TSI was used as a reference. This is extremely important, considering that many historical datasets do not overlap with direct irradiance measurements and thus optimising the free parameter would not be possible otherwise.

In summary, we have shown that historical Ca II K data are a viable source of information on the facular and network contribution to solar irradiance variations. The availability of such data for over a century will allow irradiance variations to be reconstructed based on independent data sources for sunspots and faculae for a considerably longer period of time than has been possible so far.

Acknowledgements. The authors thank the observers at the Baikal, Big Bear, Brussels, Calern, Kanzelhöhe, Mauna Loa, Mees, Meudon, Mt Wilson, Rome, San Fernando, and Teide sites. We thank Isabelle Buale for all her efforts to digitise the Meudon photographic archive. We also thank the anonymous referee for encouraging and constructive suggestions that helped us to improve the presentation of our work. T. C. acknowledges funding from the European Union's Horizon 2020 research and Innovation program under grant agreement No 824135 (SOLARNET). This work was supported by the Italian MIUR-PRIN grant 2017 "Circumterrestrial Environment: Impact of Sun–Earth Interaction" (grant 2017APKP7T), by the German Federal Ministry of Education and Research (Project No. 01LG1909C), and by the BK21 plus program through the National Research Foundation (NRF) funded by the Ministry of Education of Korea. This research has made use of NASA's Astrophysics Data System.

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Appendix A: Comparison between reconstructed TSI with RP data and various TSI series

Figure A.1 and A.2 show the difference between our reconstructed TSI with RP data and the various respective reference TSI series. The reconstructed TSI agrees quite well with the various TSI reference series. The trend of the residuals is generally flat or marginally decreasing, although for SORCE/TIM and the four empirical models (EMPIRE, NN-SIM, NRLTSI and PSUM), it is slightly increasing. We note that PSUM used

exactly the same Ca II K data for their (empirical) reconstruction. The trend is somewhat stronger when we compare to SORCE/TIM, but this could also be, at least partly, due to the shorter period covered by this record. The marginally decreasing (increasing) trend means that our reconstructed TSI shows a marginally stronger (weaker) decline with time than the TSI series employed for comparison. Given that the differences are very small, all results appear consistent with each other. Only the ACRIM case is clearly different, with a strong decreasing trend in the residuals.

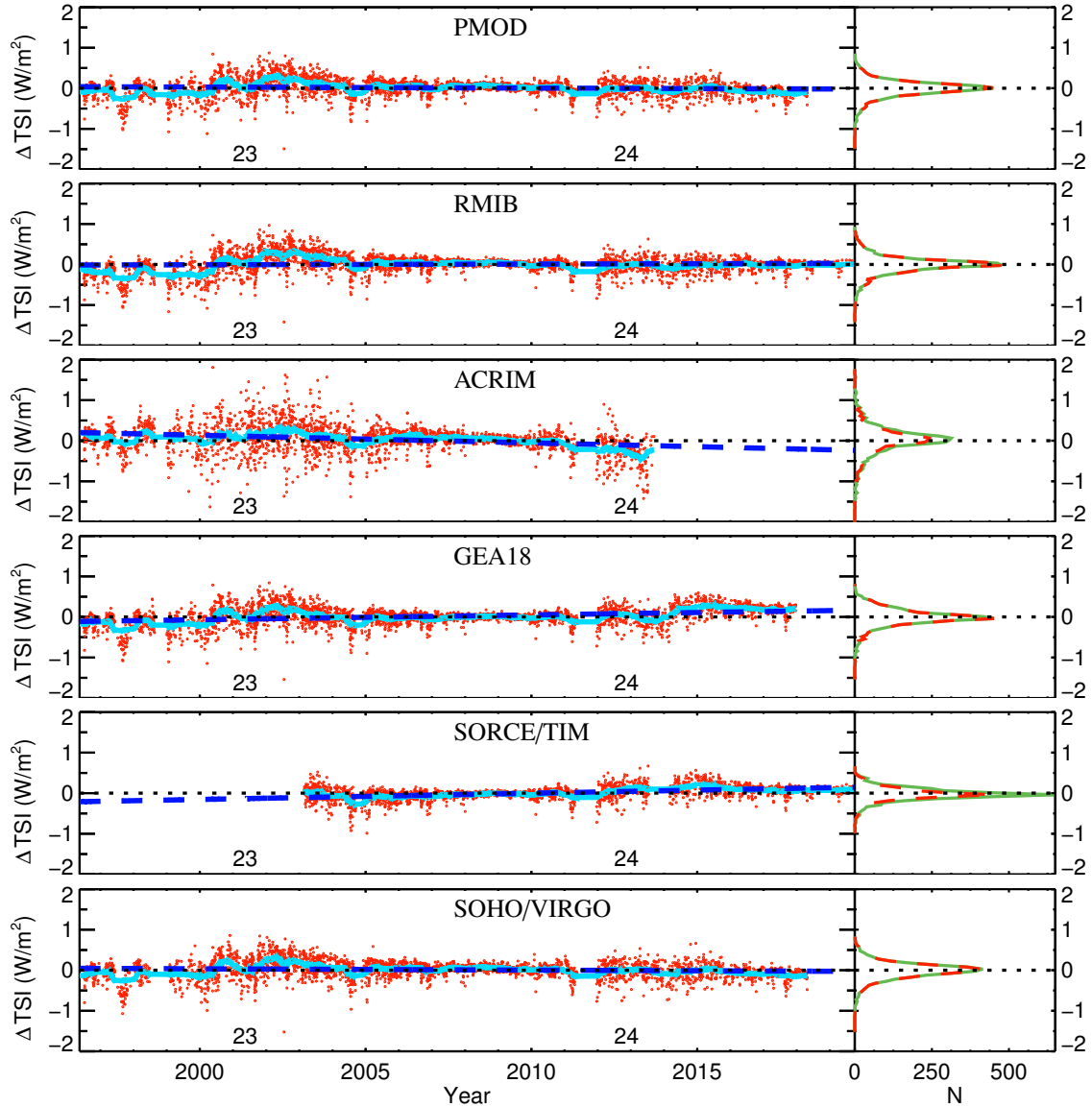


Fig. A.1. *Left:* Difference between the various TSI reference series and the TSI calculated from RP Ca II K data (red circles for daily values and light blue curve for 81-day running mean values) using the respective TSI reference series as a function of time. The TSI reference series used are PMOD, RMIB, ACRIM, GEA18, SORCE/TIM, and SOHO/VIRGO. Also shown is a linear fit to the residuals (dark blue dashed line). The horizontal dotted black line denotes the zero level difference. The numbers in the lower part of the panels denote the solar cycle number. *Right:* Distributions of the residuals in bins of 0.05 Wm^{-2} for the series shown in the left panels (red dashed). Also shown (in green) are the distributions normalised to the same number of days, namely that in the PMOD record.