Understanding long-term changes in solar irradiance is essential for quantifying the Sun's role in Earth's climate variability. Direct measurements of total solar irradiance (TSI) exist only since 1978 and suffer from cross-calibration issues, leaving long-term trends poorly constrained and making empirical extrapolations of TSI back to pre-satellite times highly uncertain. Reconstructions are therefore needed, but they have been limited by the lack of reliable information on bright magnetic regions (faculae), especially before space-borne magnetograms became available in 1974.

We address this by extending the world's most advanced semi-empirical physics-based Spectral And Total Irradiance Reconstructions (SATIRE-S; Yeo et al. 2014) model developed at Max-Planck Institute for Solar System Research (MPS) with new data sources. In addition to space-based magnetograms, we now incorporate direct measurements from Mt Wilson Observatory and magnetograms reconstructed from high-quality Ca II K archives (Meudon, Rome/PSPT, San Fernando; Figure 1). Recent advances in calibration and stability assessment have enabled these Ca II K data (Chatzistergos et al. 2018, 2019, 2020) — long underused — to provide information on the solar surface magnetic field.

Our reconstruction (currently from 1974 onwards) substantially reduces long-term uncertainties while being independent of how direct TSI composites are compiled. The model reproduces observed TSI with very high fidelity (correlation of 0.98 with TSIS1-TIM), is fully consistent with the Montillet et al. (2022) (Figure 2) and ROB composites (0.87 and 0.96), and also agrees strongly with spectral irradiance composites in Lyman-α and Mg II lines (0.96 and 0.97).

We find that TSI decreased slightly (-0.22 ± 0.17 W m^{-2}) between the 1976 and 2019 solar minima. Our results also resolve the ACRIM-gap controversy, which had suggested a spurious ~0.5 W m^{-2} TSI rise between the 1986 and 1996 minima. Both Meudon and Mt Wilson data, covering this interval, show no such increase; our reconstruction yields only a negligible, statistically insignificant change, confirming that the gap arose from uncorrected instrumental artefacts in Nimbus7-ERB data.

By integrating Ca II K–derived magnetograms, SATIRE-S now provides the most consistent, physics-based irradiance reconstruction over the last 50 years. The next step is to exploit the century-long Ca II K archives to extend reconstructions back to 1892 when these observations started, offering a clearer view of solar forcing on climate across the telescopic era.

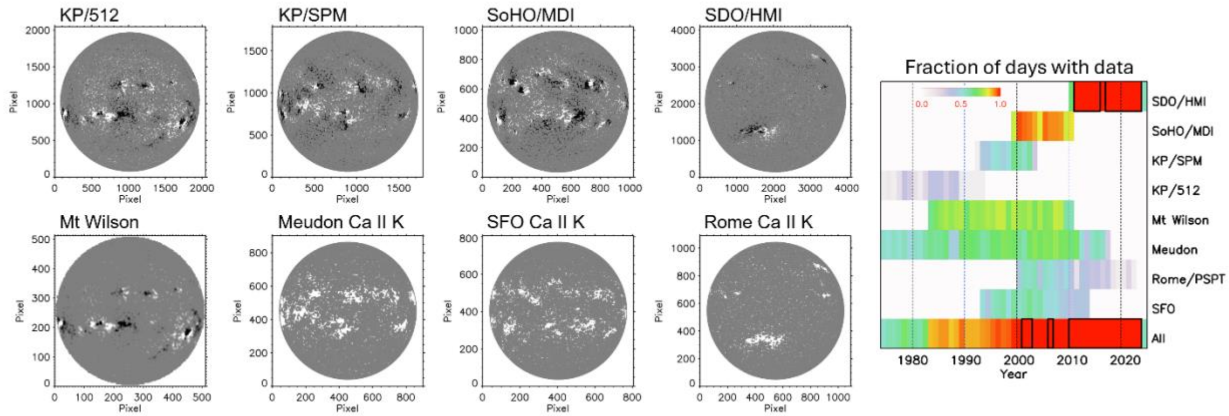

Figure 1Left: Magnetograms used for our irradiance reconstruction with SATIRE-S. Right: temporal coverage of the magnetogram archives (measured or restored from Ca II K observations).

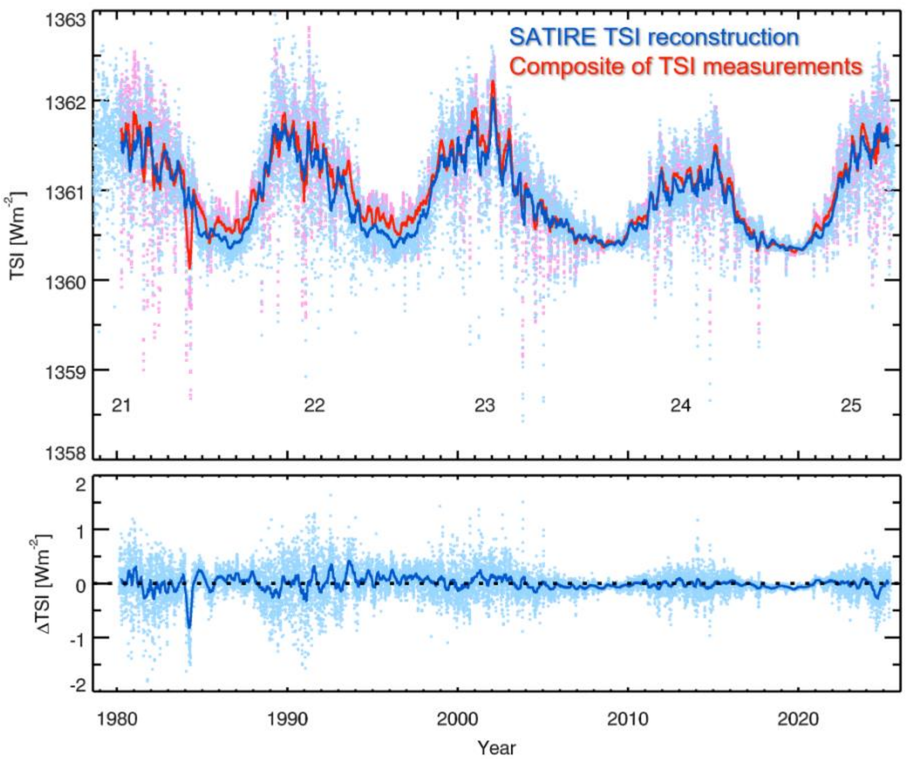

Figure 2: Reconstructed TSI with SATIRE-S by combining all magnetogram sources (bright and light blue for daily and 81-day running means) compared to the composite of direct TSI measurements by Montillet et al. 2022 (bright and light red for daily and 81-day running means). Bottom: Difference between our TSI reconstruction and the composite of direct TSI measurements by Montillet et al. 2022 (bright and light blue for daily and 81-day running means).