Improving Solar Spectral Irradiance Calibrations Through Analysis of TSIS-1 SIM Measurement Artifacts

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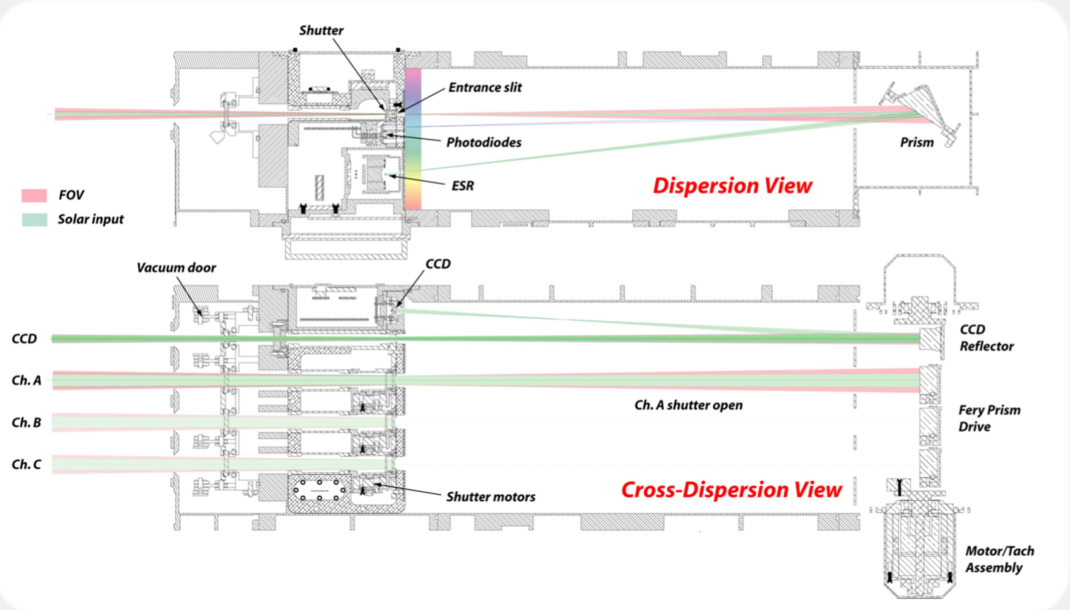
SIM Instrument Overview

The Spectral Irradiance Monitor (SIM) instrument onboard the Total and Spectral Solar Irradiance Sensor (TSIS-1) mission measures solar spectral irradiance (SSI) from 200 nm to 2400 nm using:

- Three channels to monitor instrument degradation each with a Féry prism for dispersion
- Three photodiode detectors:
  - Ultraviolet (UV: 200 nm – 311.5 nm)
  - Visible (Vis: 311.5 nm – 950 nm)
  - Infrared (IR: 950 nm – 1620 nm)
- An absolute electrical substitution radiometer (ESR: 200 – 2400 nm)



TSIS-1 SIM produces higher accuracy and lower noise measurements than its predecessor SORCE SIM

SIM Spectral Irradiance Artifact

The higher accuracy of TSIS-1 SIM emphasizes measurement artifacts that may not have been apparent in SORCE SIM

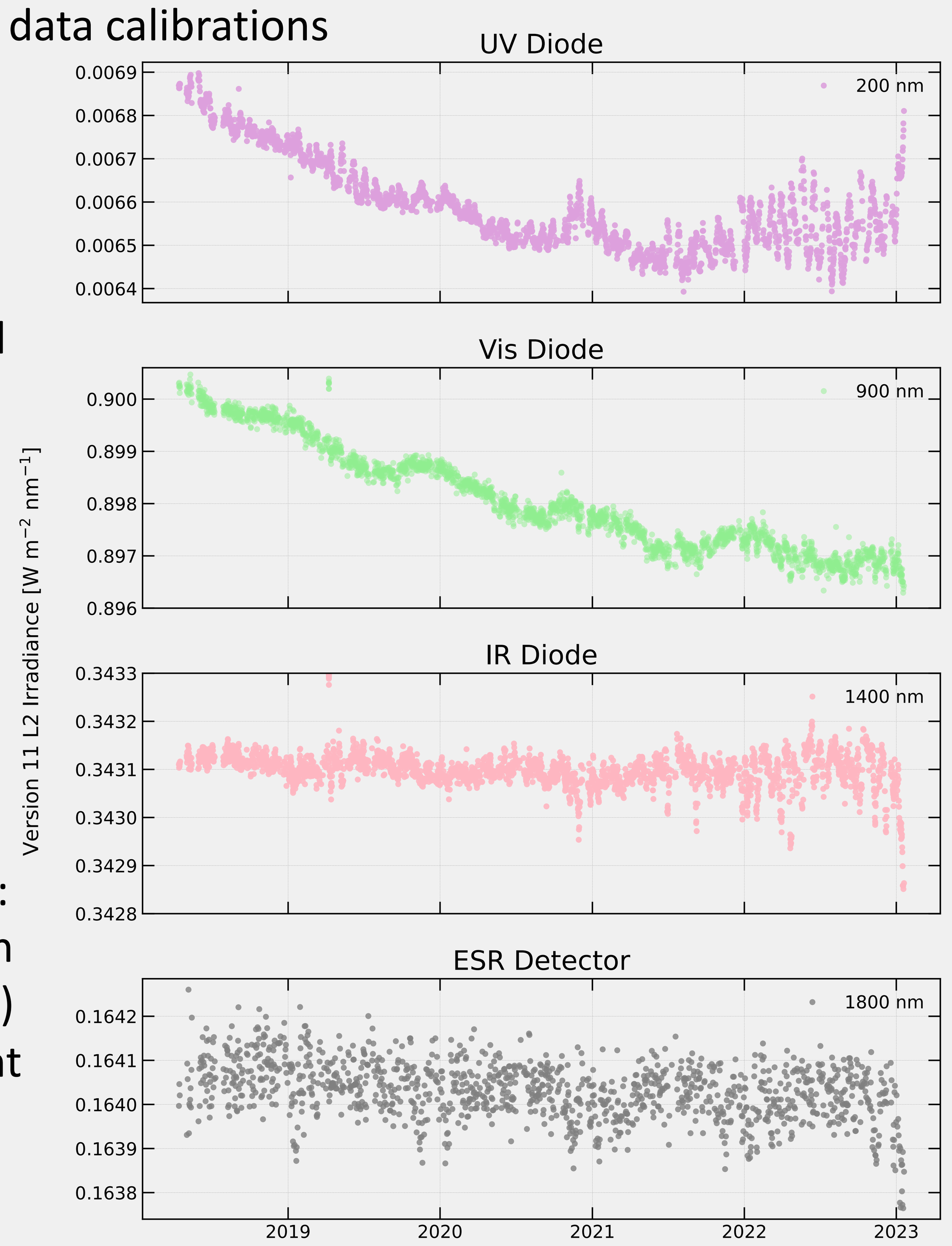
Artifacts in the data provide an opportunity to better characterize the instrument and improve the data calibrations

As noted in the Version 10 Release Notes, a known artifact in the TSIS-1 SIM spectral irradiances is the presence of an annual signal

- The annual signal is most prevalent at wavelengths longward of ~700 nm
- Impacts the data quality and the degradation corrections

The annual signal could result from errors in several calibration methods such as:

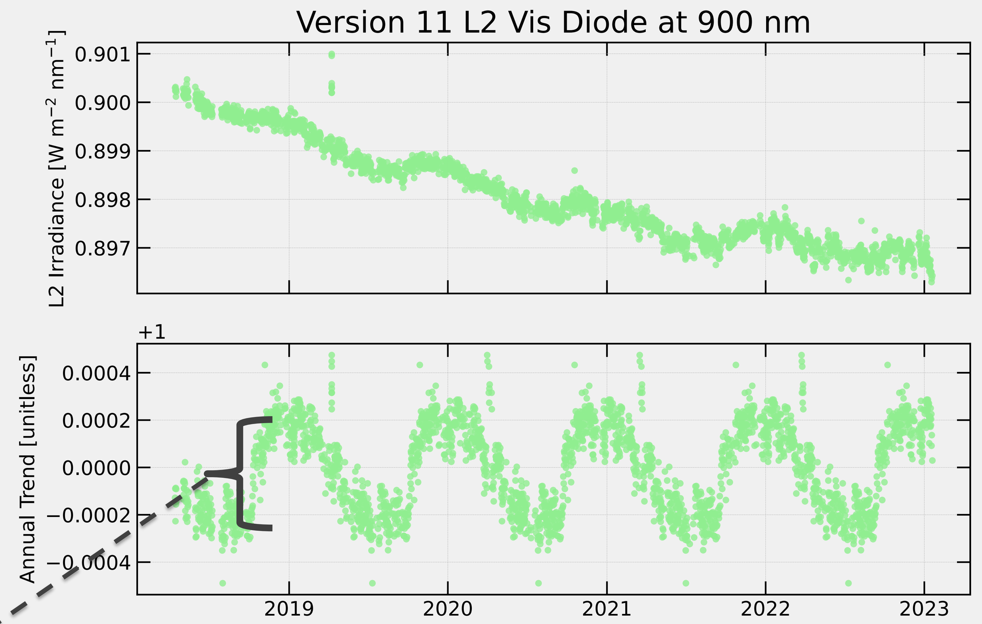
- The diffraction calculation (including limb darkening)
- The wavelength alignment procedure
- Temperature-dependent instrument responsivities

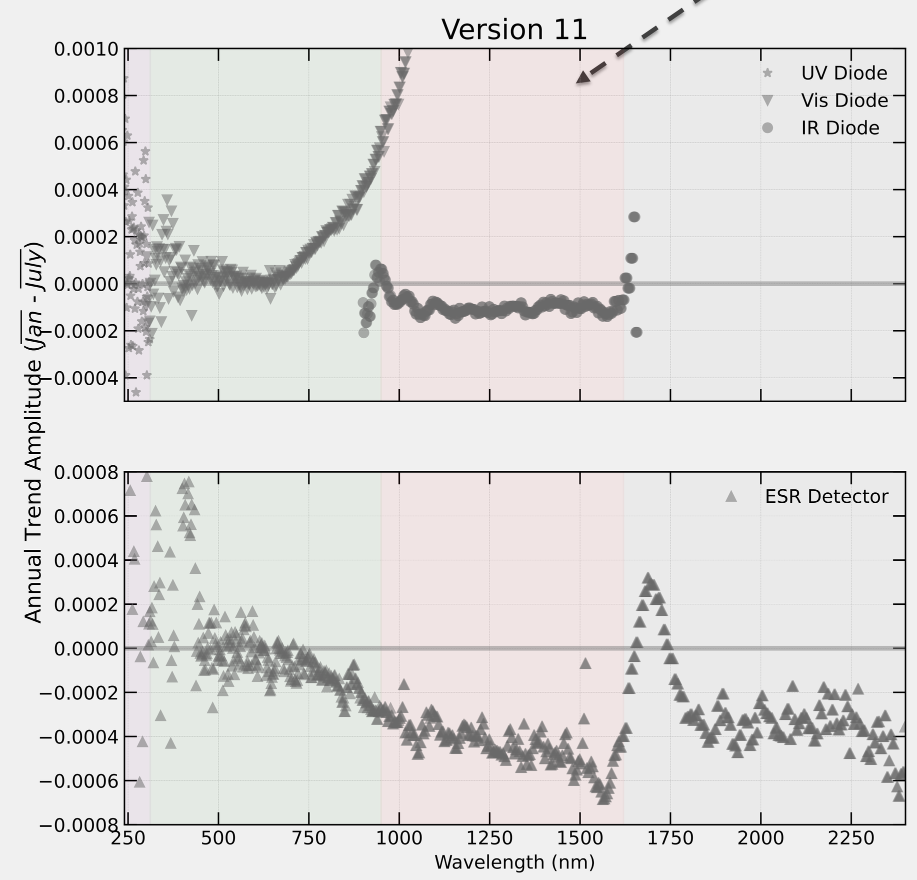


Determining the Source of the Annual Signal

METHODOLOGY

- Use Version 11 L2 SIM data to isolate the annual trends in the UV, Vis, IR, and ESR measurements separately (i.e., not using L3 degradation-corrected data)
- Characterize the amplitude of the annual signal at each wavelength using a detrending algorithm (Python statsmodel package)



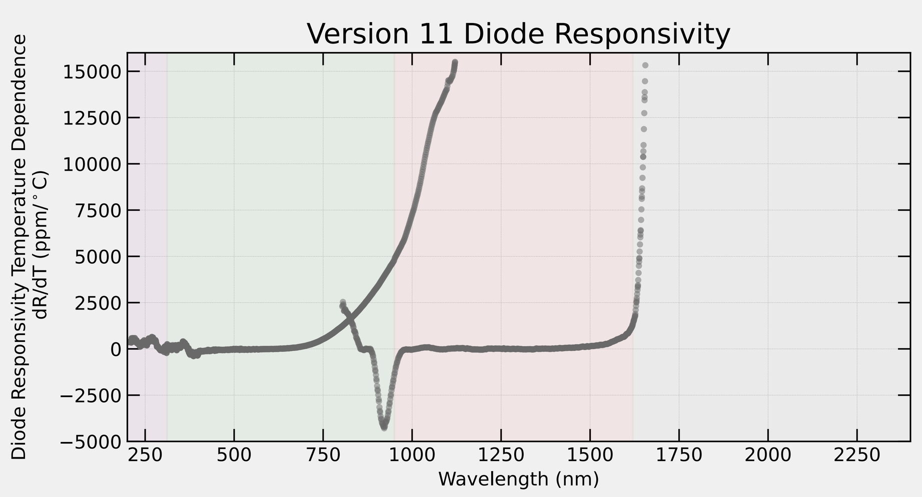


As shown (left), the amplitude of the annual signal is uniquely wavelength-dependent for measurements from the three photodiodes (top) and the ESR (bottom).

- The amplitude in the Vis and IR photodiode measurements closely resembles the diode responsivity temperature dependence (dR/dT), indicating a potential error in this calibration
- The amplitude in the ESR measurements increases with wavelength, suggesting a possible error in the diffraction correction

DIODE RESPONSIVITY TEMPERATURE DEPENDENCE (dR/dT)

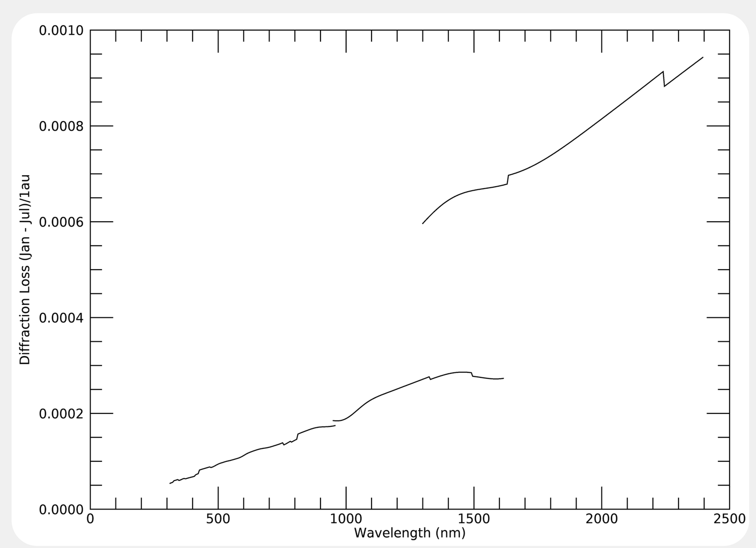
Since the photodiode temperature has a strong annual variability, errors in dR/dT calibration could manifest as an annual signal in the photodiode measurements



We tested the effect of changes in the dR/dT calibration values on the amplitude of the annual signal

- The dR/dT calibration is used to correct for the diode responsivity to convert from diode Amps to Watts
- The dR/dT values are also used in an intermediate step to perform the wavelength alignment for each scan

DIFFRACTION CORRECTION



Given the larger dispersion angle off the prism for the ESR, errors in the diffraction calculation will be:

- Larger in the ESR than the photodiode measurements
- Larger in the IR photodiode measurements than in the UV or Vis

We tested the impact of adding the true solar radius in the diffraction calculation where it was previously using an average radius

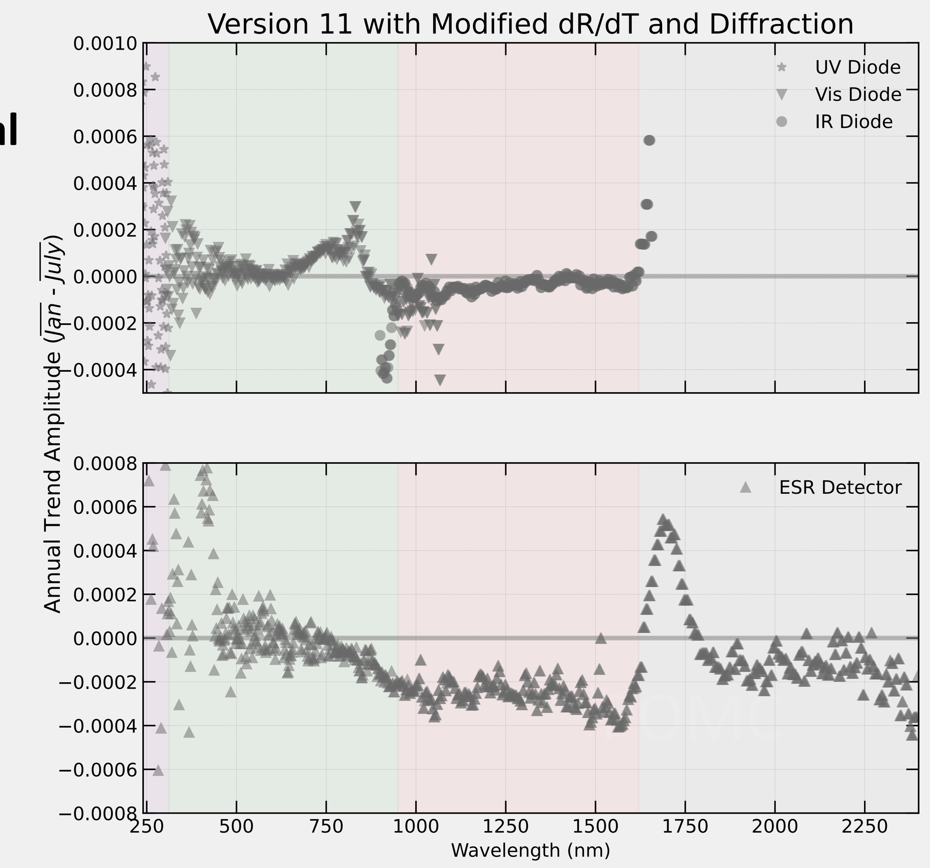
Results

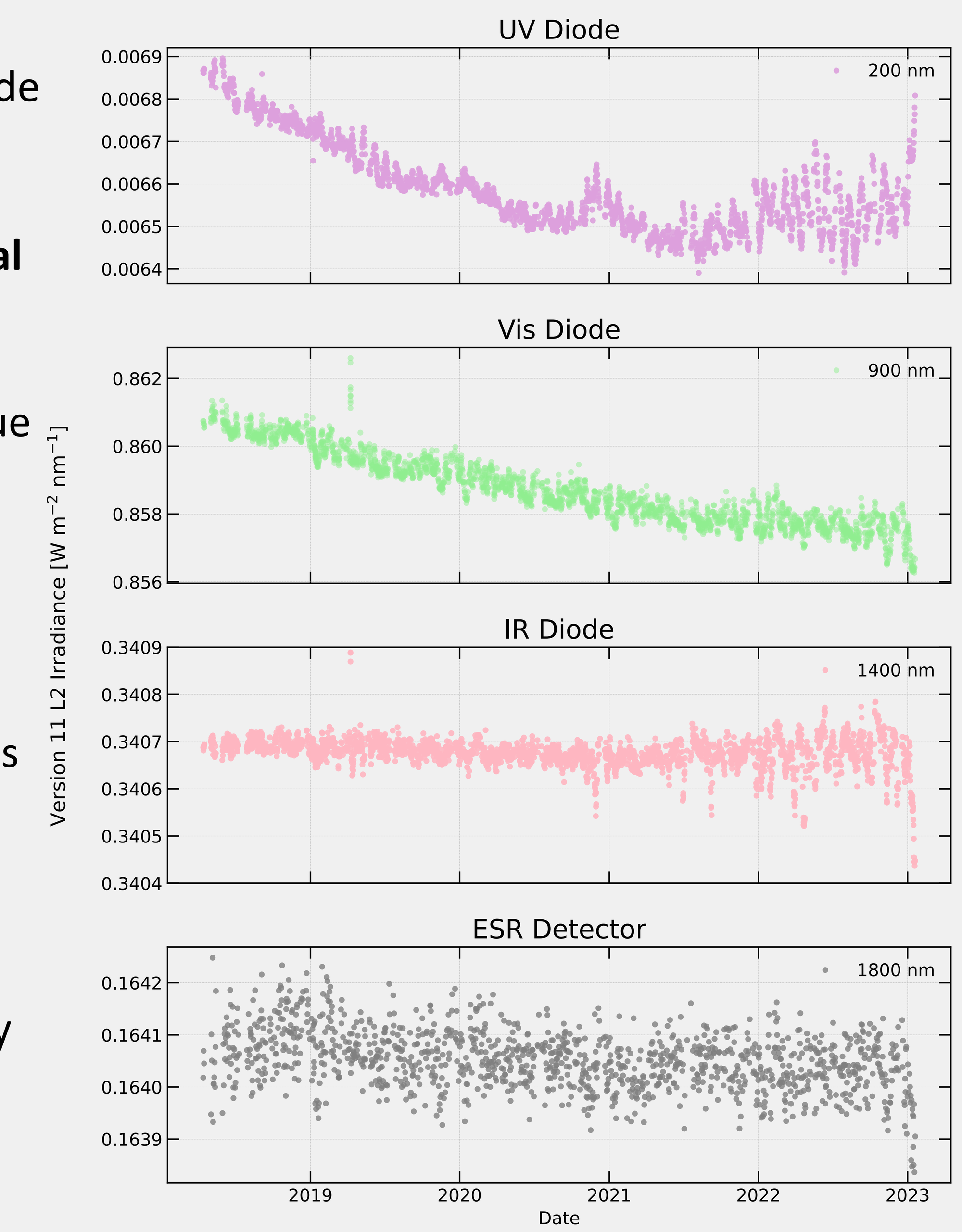
Residual errors in the dR/dT calibration values causes annual signals in the photodiode measurements

- Modifying the dR/dT calibration values for the Vis photodiode measurements greatly reduced the annual signal at all wavelengths longward of ~700 nm
- The modified dR/dT values were derived from the pre-flight calibration measurements, which will need to be refined to remove the residual annual signals remaining in the photodiode measurements

Improving the diffraction correction reduces the annual signals for long wavelengths

- The diffraction correction was updated to use the true solar size instead of an average solar size
- This change reduced the annual amplitude in the IR and ESR measurements by ~50% for most wavelengths
- While reduced, the annual signals in the ESR measurements remain, particularly from ~1500–1800 nm, and are currently thought to be due to the lack of accurate wavelength-alignment for ESR measurements





Conclusions and Future Work

We have determined the dominant sources of the annual signal artifact in the TSIS-1 SIM data, finding it to be due in part to errors in dR/dT calibration values and a simplification used in the diffraction calculation

Future work includes:

- Rederiving dR/dT to ensure accuracy and reduce the remaining annual signal in the photodiode measurements
- Investigating the remaining annual signal from ~1500 – 1800 nm, including exploring methods for wavelength alignment for the ESR scans
- Apply corrections in new data version release, which will be made available at https://lasp.colorado.edu/tsis/data/