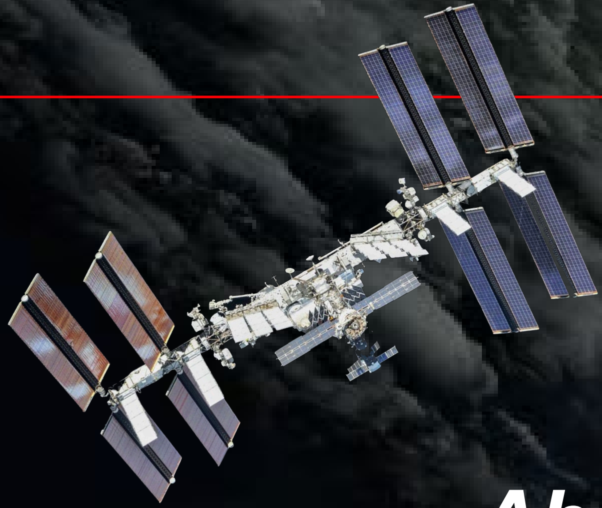

SORCE/TSIS Overlap Analysis

Absolute Scale Comparison, Stability Estimates, and Cycle 23/24/25 Record Construction

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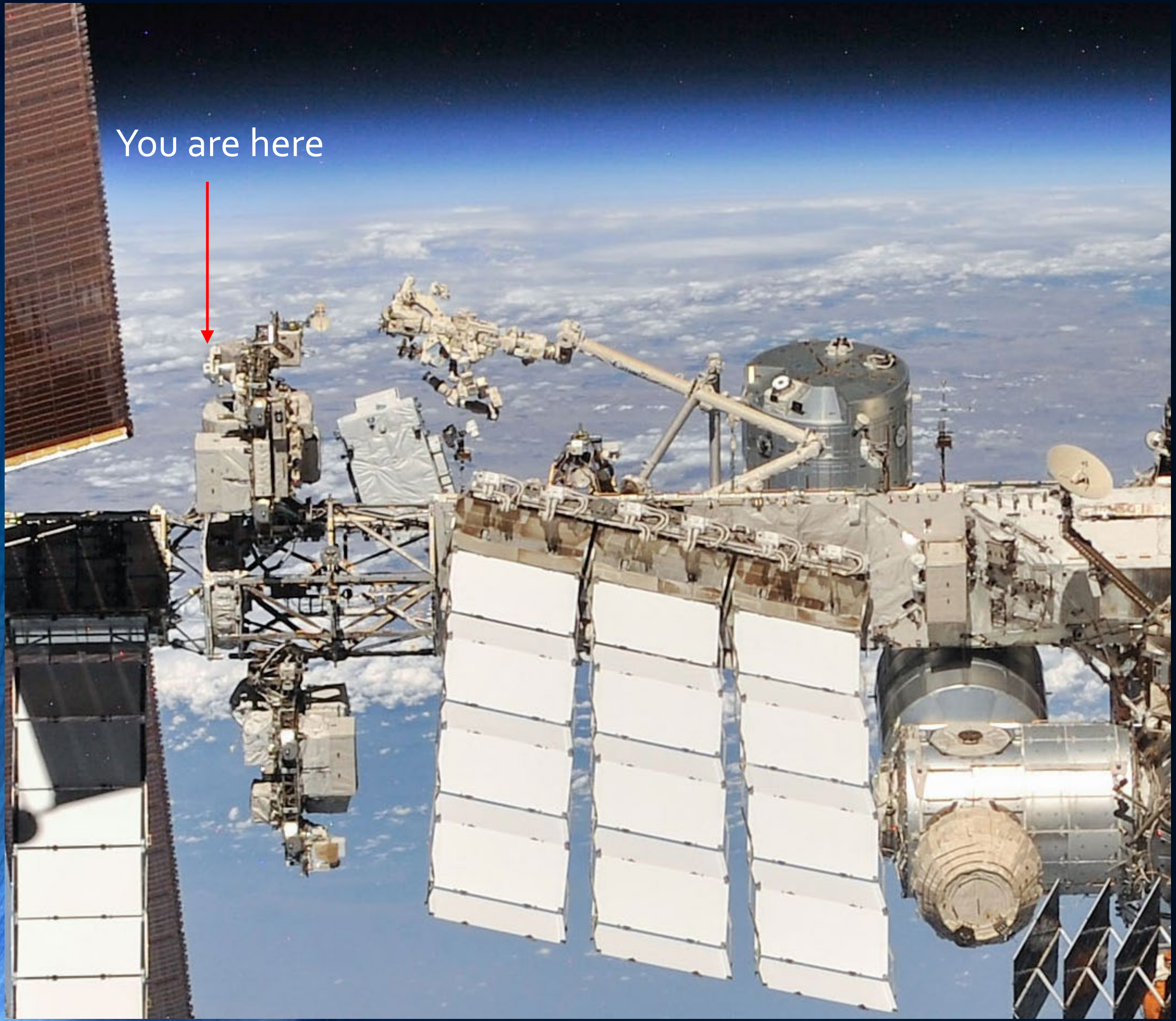
SIST - Study Goals

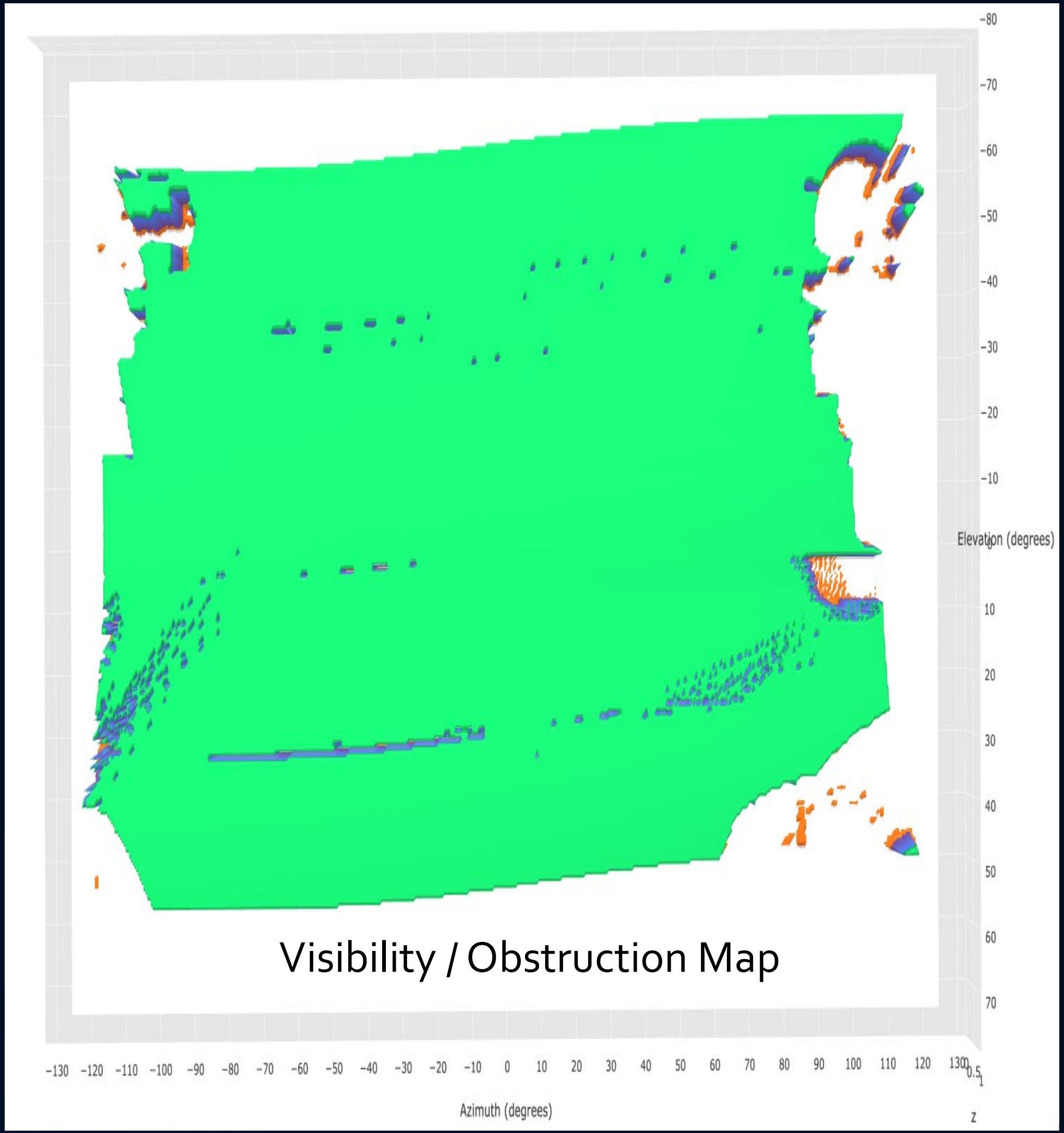
1. Based on the high-quality SI traceable calibrations adapted for the TSIS SIM instrument, produce a Solar Cycle 24 (SC24) **solar minimum spectrum** analogous to the **WHI** SC23 minimum spectrum. Recalibrate the SORCE instruments and refine the absolute scale of the SC23 observations based on the low uncertainty of the pre-flight calibration, common instrument configuration, and concurrent observations between TSIS and SORCE SIM/SOLSTICE.

2. With >1.5 year of overlap between SORCE and TSIS, conduct an in-depth analysis of the stability of these instruments to determine their long-term relative drift.

3. Produce a unified SC23-24 full spectral irradiance data set with derived observational uncertainties and estimates of drift that will span the 2003-2019 time period.

TSIS on the ISS





SORCE SIM Absolute Scale Correction – Justification

- SORCE SIM never had a full end-to-end ground calibration before launch. Absolute irradiances were adjusted to the best solar reference spectra available at the time: ATLAS-3 from the SOLSPEC instrument (Harder et al., Sol Phys. 2010)
- TSIS SIM was launched with an absolute scale calibration traceable to NIST standards with an overall uncertainty of ~0.1-0.3% - about a factor of 10x improvement over available calibration capabilities at the time of the SORCE preflight calibration (2001-2003)
- SORCE/TSIS overlap period started in March of 2018 and will continue in until SORCE decommissioning in February of 2020
    - On-orbit overlap period occurs during an extended and very quiescent Solar Cycle 24 minimum period

Instrument design/operation improvement in TSIS

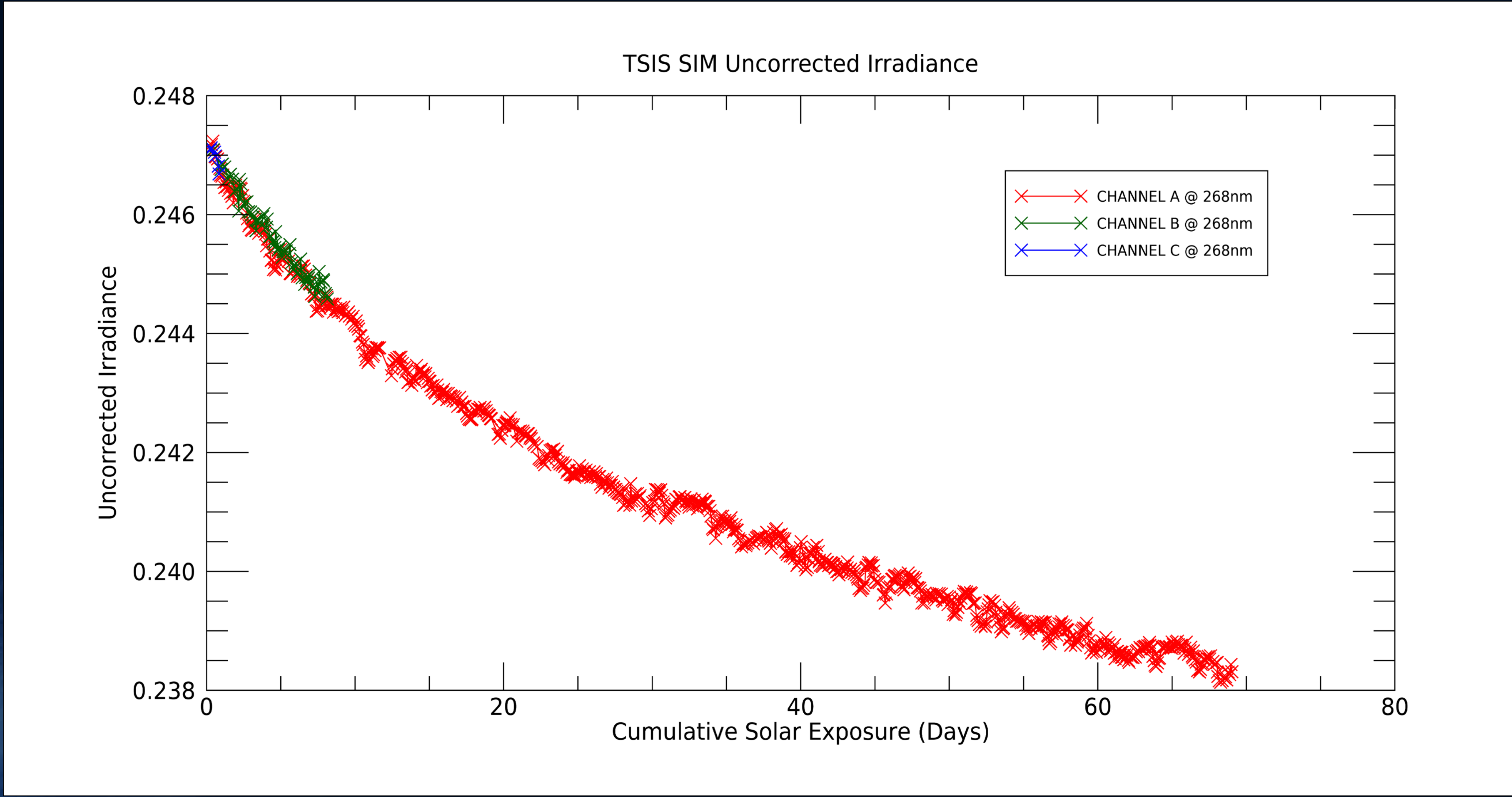
- Lessons learned from SORCE and applied to TSIS
  - Advanced high vacuum / ultra clean instrument chamber design to limit hydrocarbon contamination of prism glass – leading cause of degradation in satellite-borne spectrometers.
  - Three spectrometer redundancy instead of 2 allows for improved corrections for both the daily working channel and the monthly correction channel.
    - Instrument operations follow strict non-varying rates of solar exposure.
  - Significantly improved low-noise performance of the ESR and the focal plane photodiodes.
    - reduced capacitance of the ESR bolometer greatly improves open-loop gain thereby improving detector sensitivity.
    - TSIS SIM photodiodes employ ~20 bit ADC compared to ~13 bit ADC's on SORCE – a factor of 128
  - Improved stray light rejections and off-axis pointing corrections

Instrument Degradation

Two main sources of instrument degradation

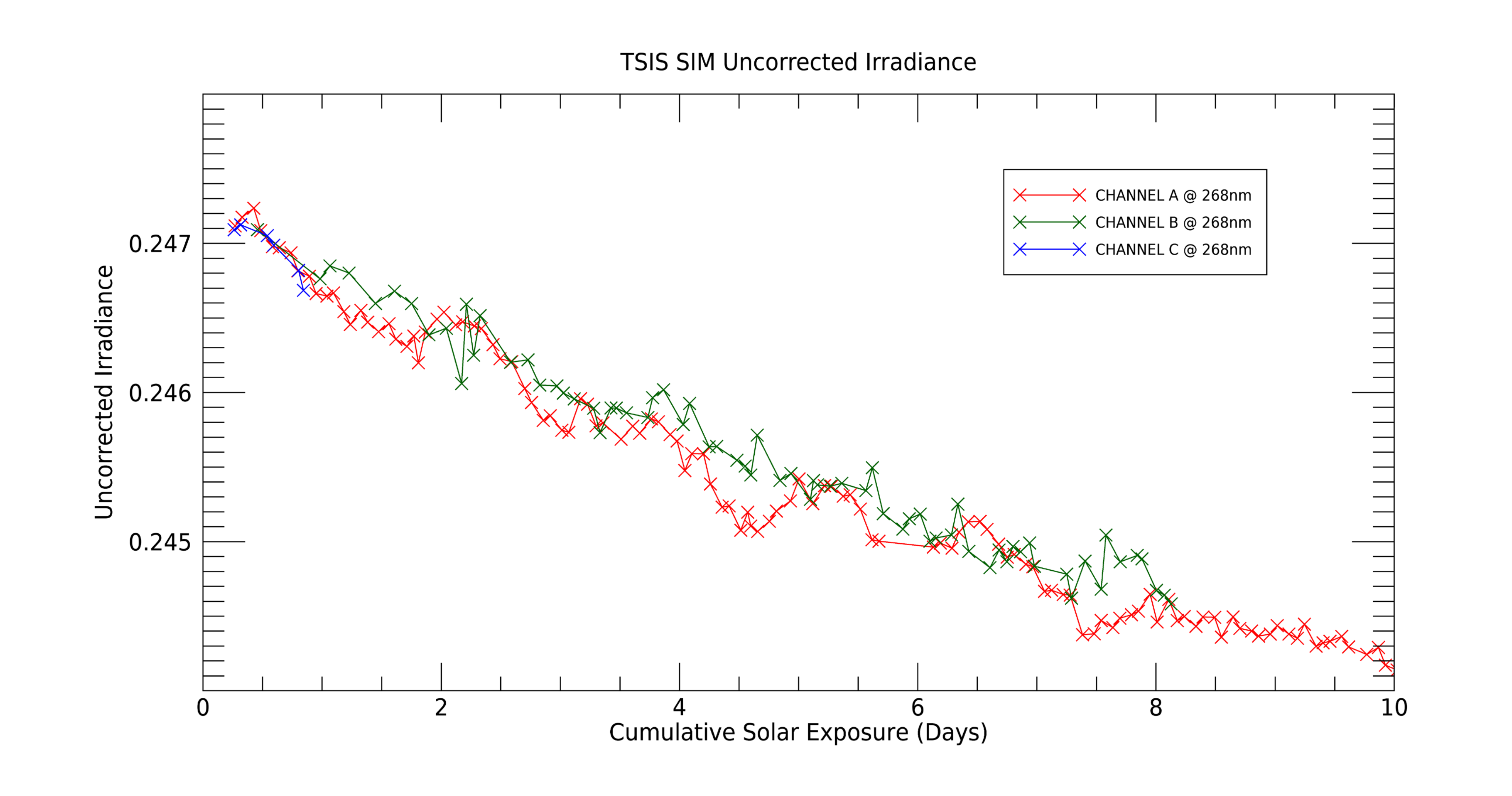
1. Photodiodes degrade in space with high energy particles bombardment
   - Electrical Substitution Radiometer (ESR) is radiation hard and is used as reference measurement
2. Solar UV radiation polymerize hydrocarbons on the surface of the prism reducing its transmission
   - Prism degradation is expected to be directly related to amount of solar exposure
   - Separate channels take measurements at different cadence
   - SORCE has 2 identical channels, TSIS has 3 (channel-C exposed every 6 months for very slow degradation)

TSIS SIM Uncorrected Irradiance at 268.0nm vs Cumulative Solar Exposure



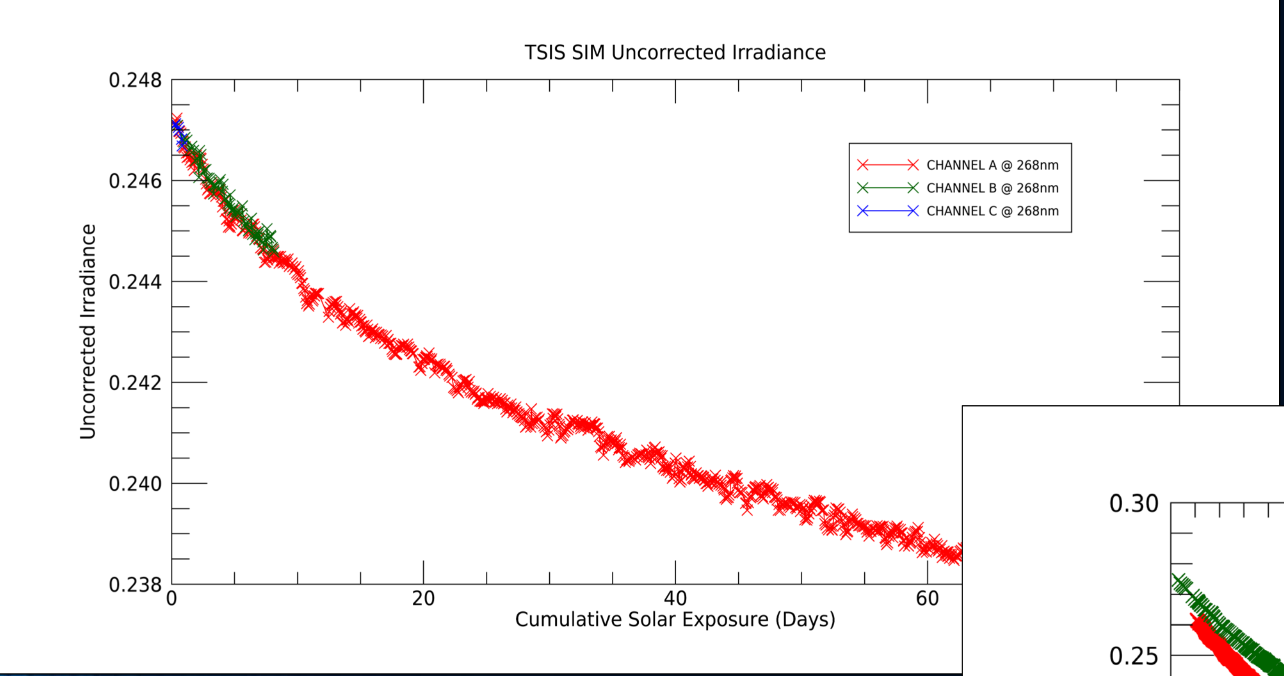
TSIS Data from quiet Sun period 2018-03-14 to 2019-12-26

TSIS SIM Uncorrected Irradiance at 268.0nm vs Cumulative Solar Exposure



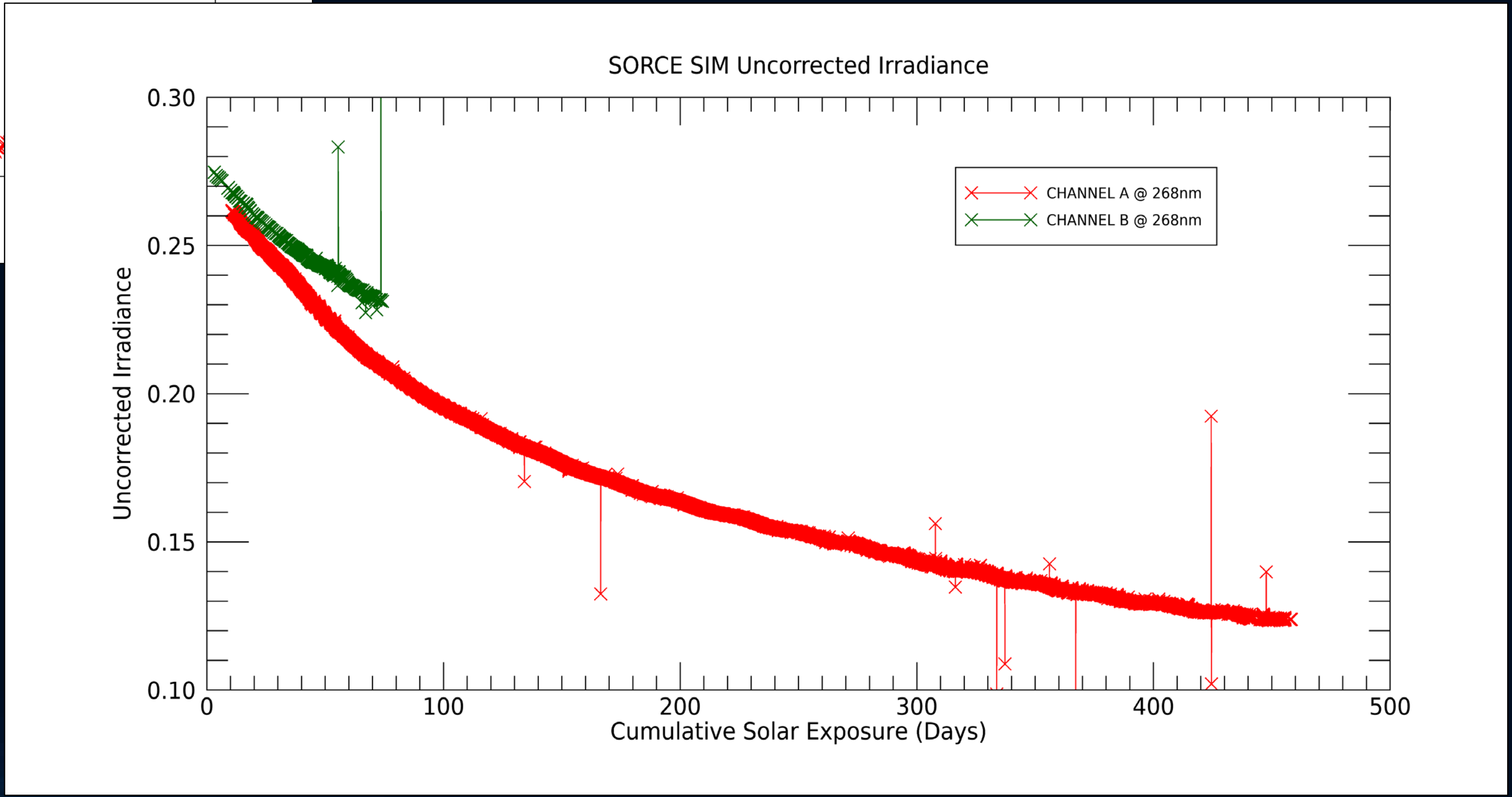
Degradation model assumes the prism degradation is a function of the Cumulative Solar Exposure: Channels A, B and C should follow the same trend

TSIS SIM & SORCE SIM Uncorrected Irradiance at 268.0nm vs Cumulative Solar Exposure

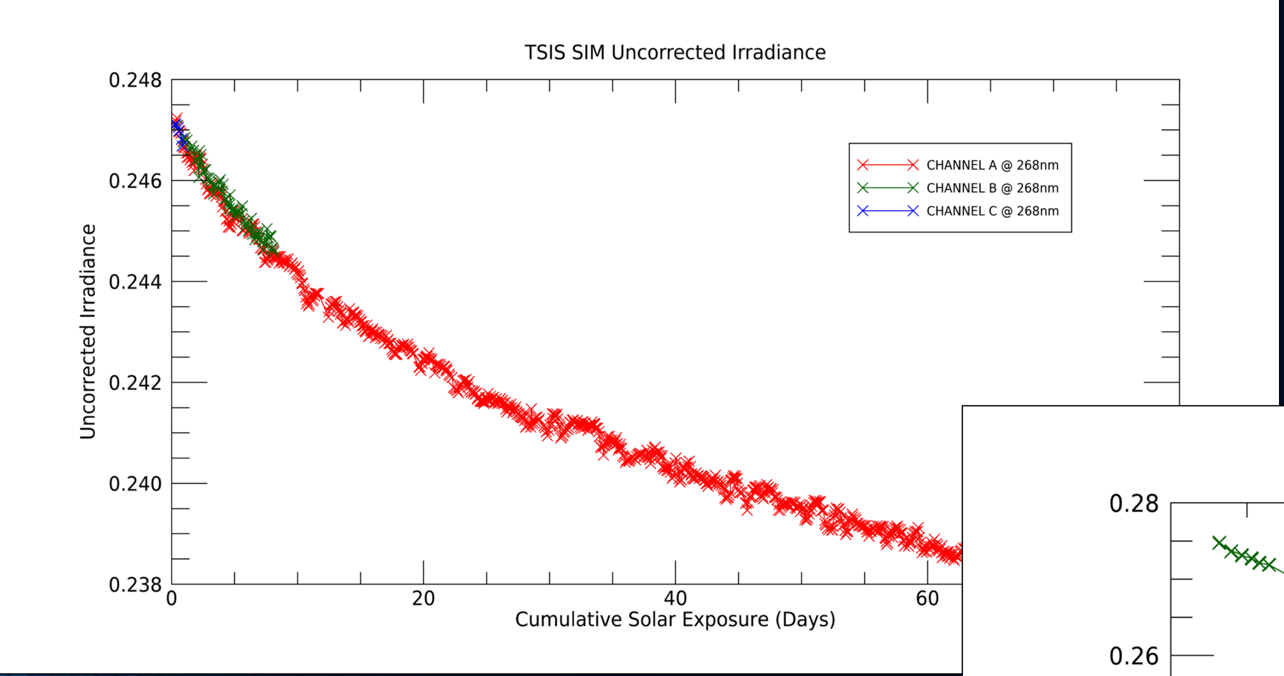


SORCE Uncorrected Irradiance show a clear difference in trends over the mission (Solar Cycle variations are folded in the data plotted below)

TSIS Data from quiet Sun period 2018-03-14 to 2019-12-26



TSIS SIM & SORCE SIM Uncorrected Irradiance at 268.onm vs Cumulative Solar Exposure



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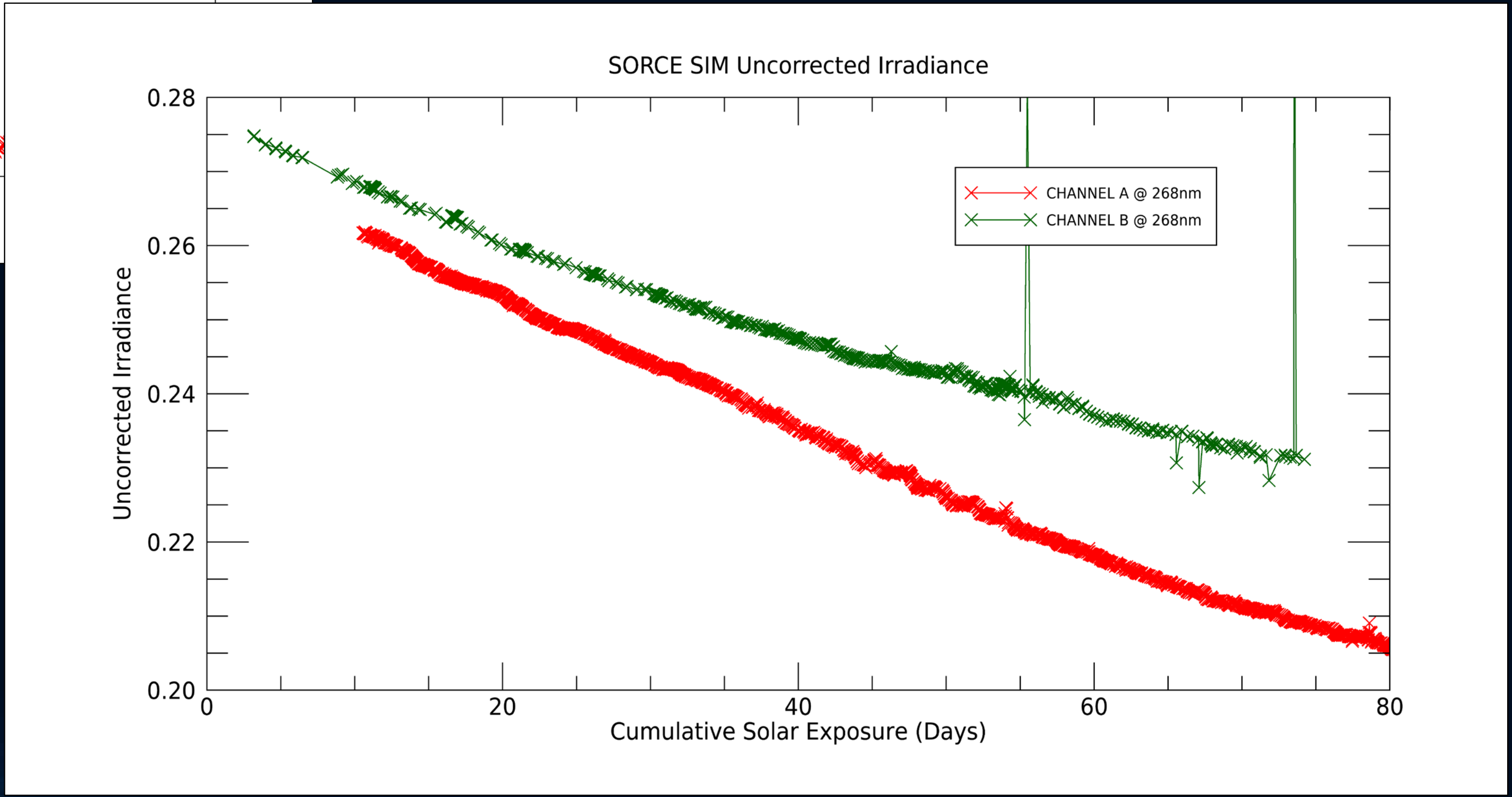
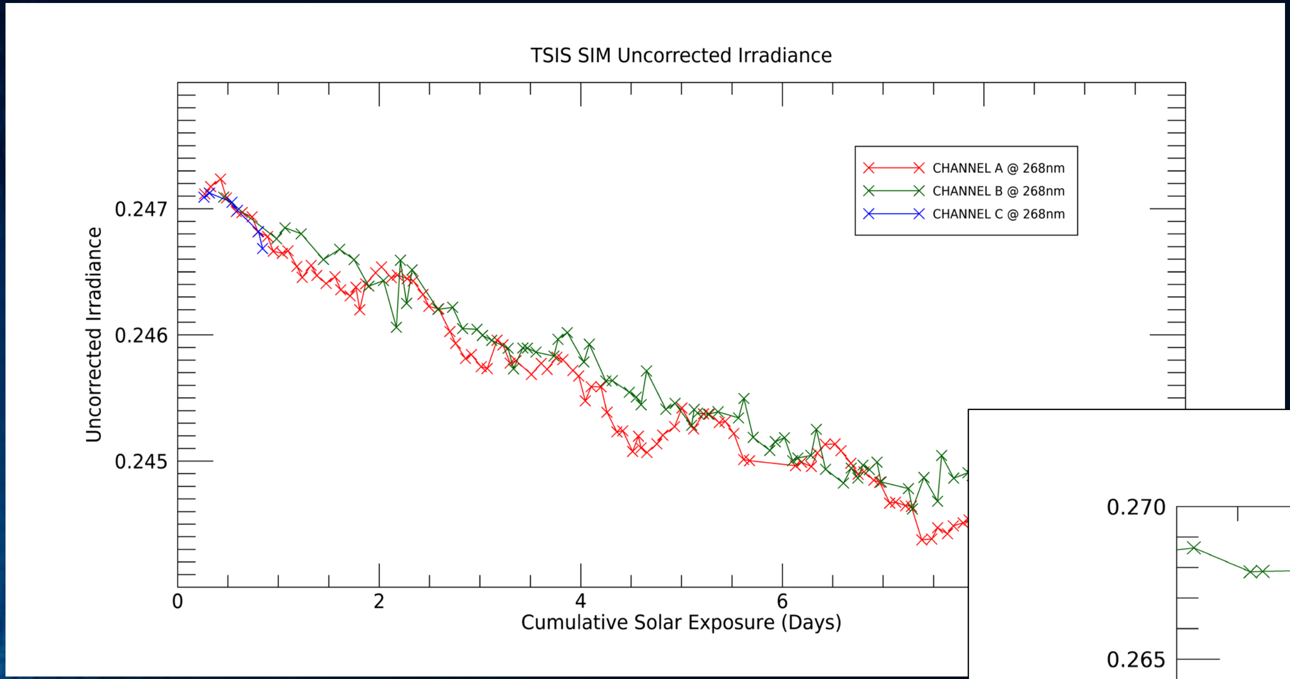
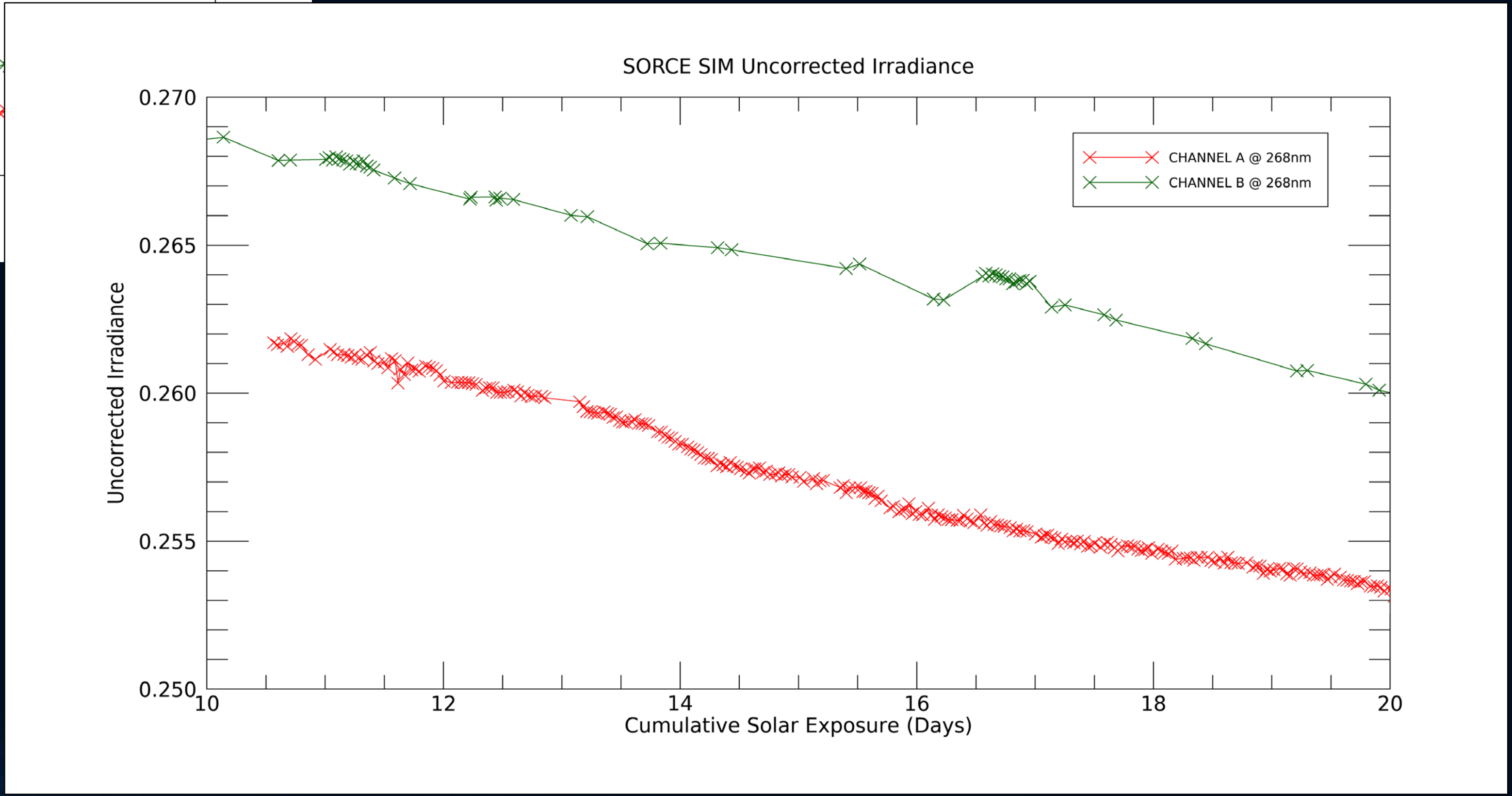


TSIS SIM & SORCE SIM Uncorrected Irradiance at 268.0nm vs Cumulative Solar Exposure



Over the first 10 days of cumulative solar exposure, the trends appear similar …



A longer TSIS dataset will better show the trends between all 3 channels …

TSIS Corrected Irradiances

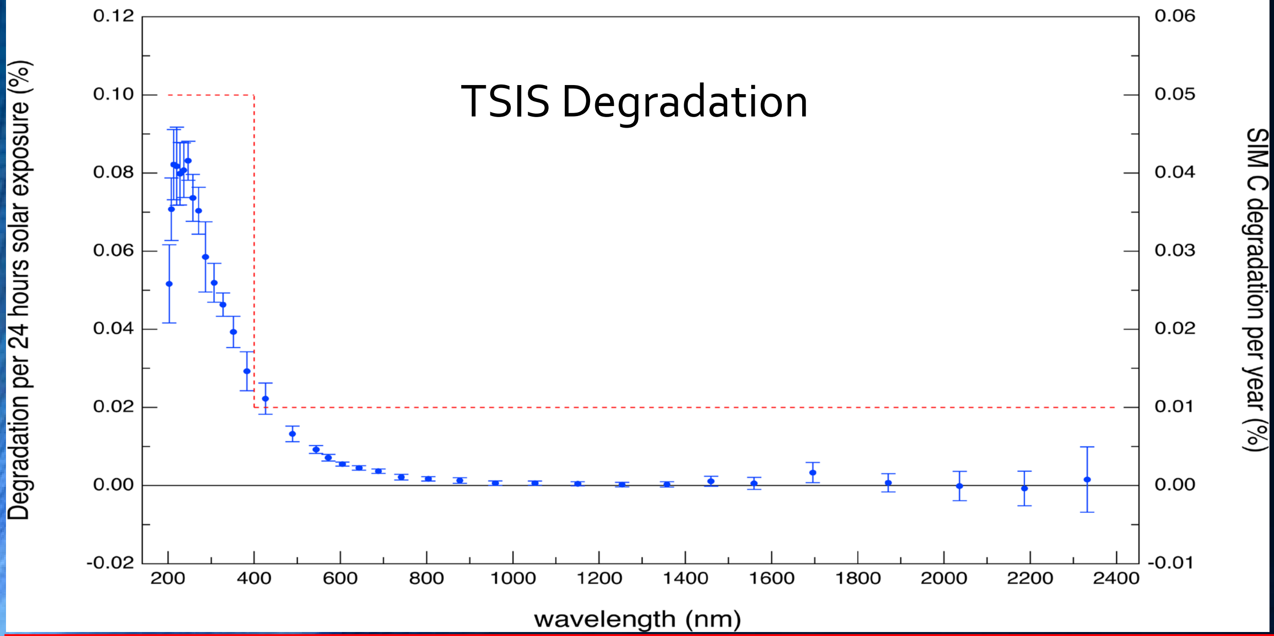
Plots show representative UV to near IR wavelengths and the results of the SIM A degradation corrections based on SIM channel B & C stability corrections.

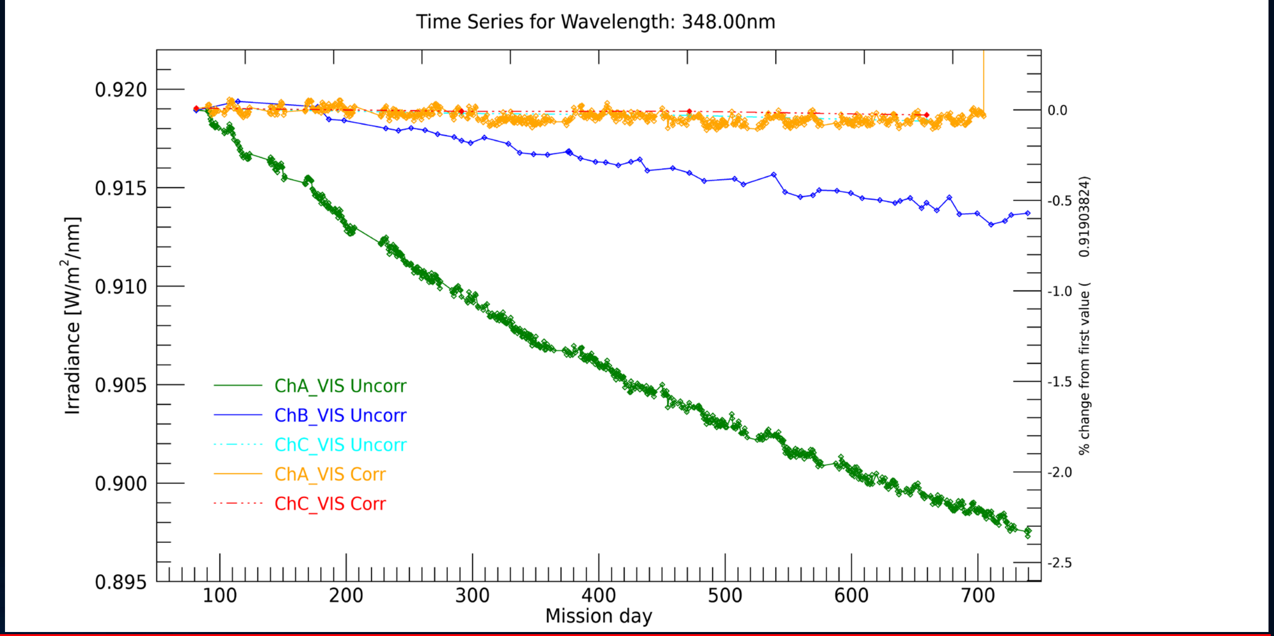
Right axis on each plot shows the relative level of change (in %) between corrected and uncorrected irradiances

As of ***TSIS Mission Day 740*** (Dec. 23, 2019), SIM A had ~69 days of cumulative solar exposure. The degradation is the following (SORCE-SIMA is in red for SD=563 with 69 days of exposure):

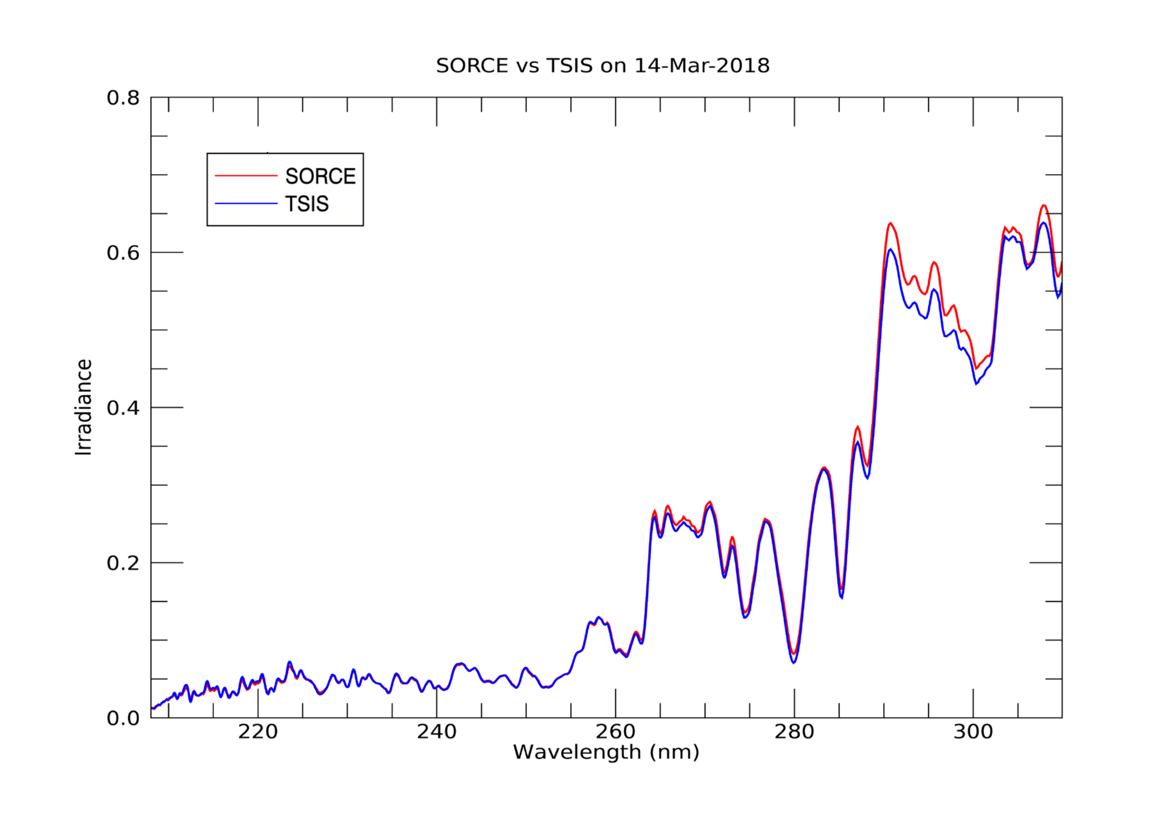
- 239 nm – 4% (23%)
- 280 nm – 3% (19%)
- 348 nm – 2% (6%)
- 676 nm – 0.2% (0.34%)
- 703 nm – 0.15% (0.29%)
- 965 nm – < 0.05% (0.19%)

The final corrected irradiances are shown in Yellow



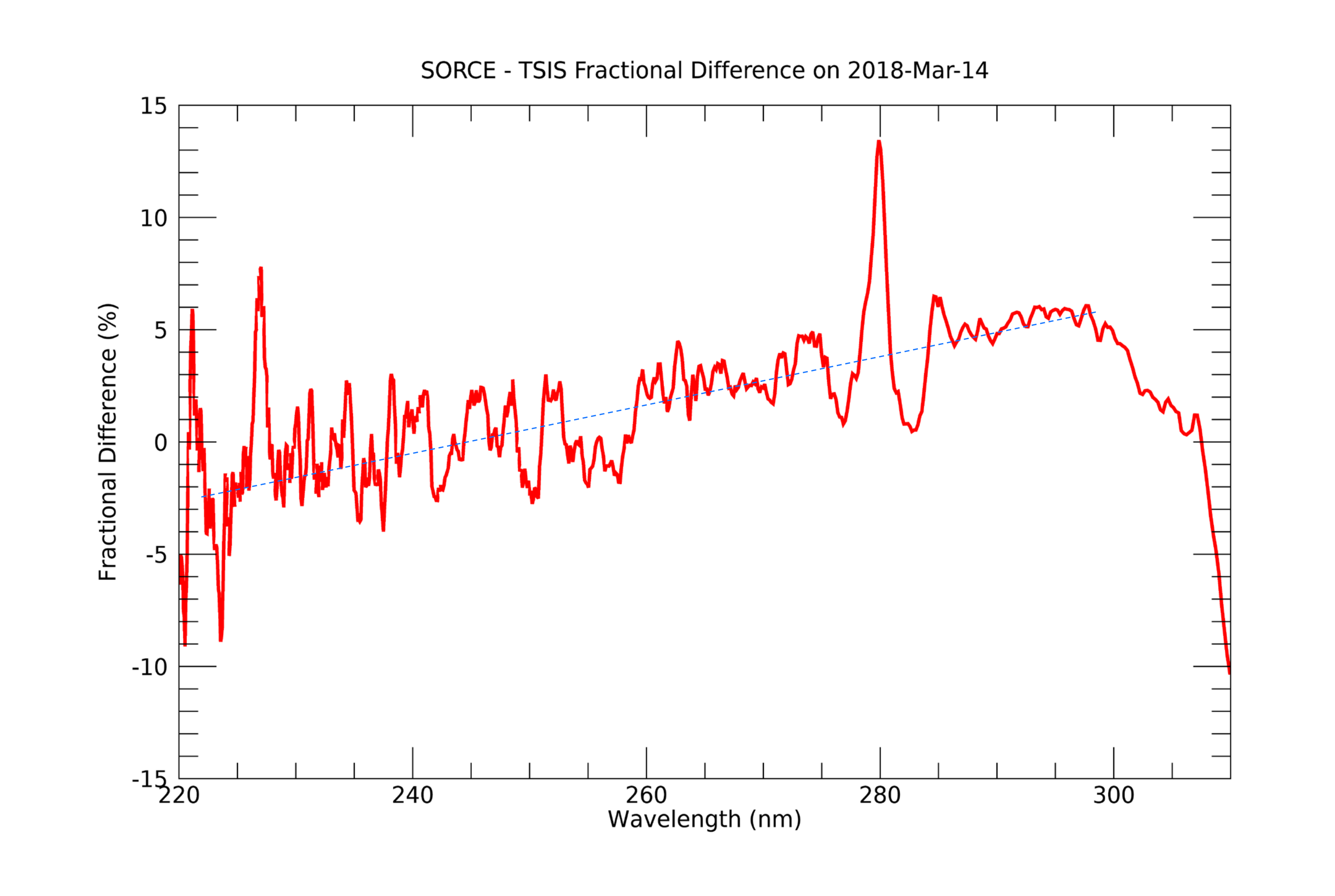


TSIS SIM vs SORCE SIM

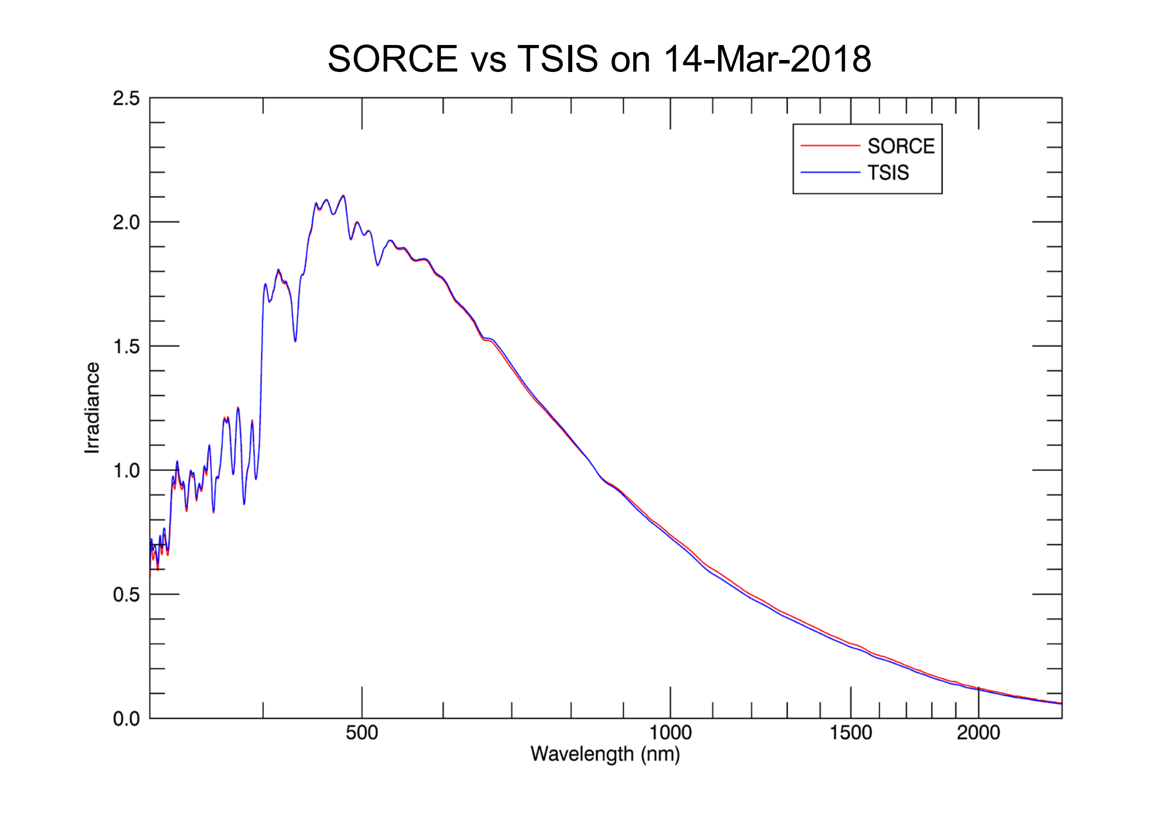


SORCE/TSIS on TSIS First Light (2018-03-14)

- Uncorrected scattered light in SORCE is believed to cause effect at 227nm and 280nm
- General slope is attributed to cumulative errors in the degradation correction

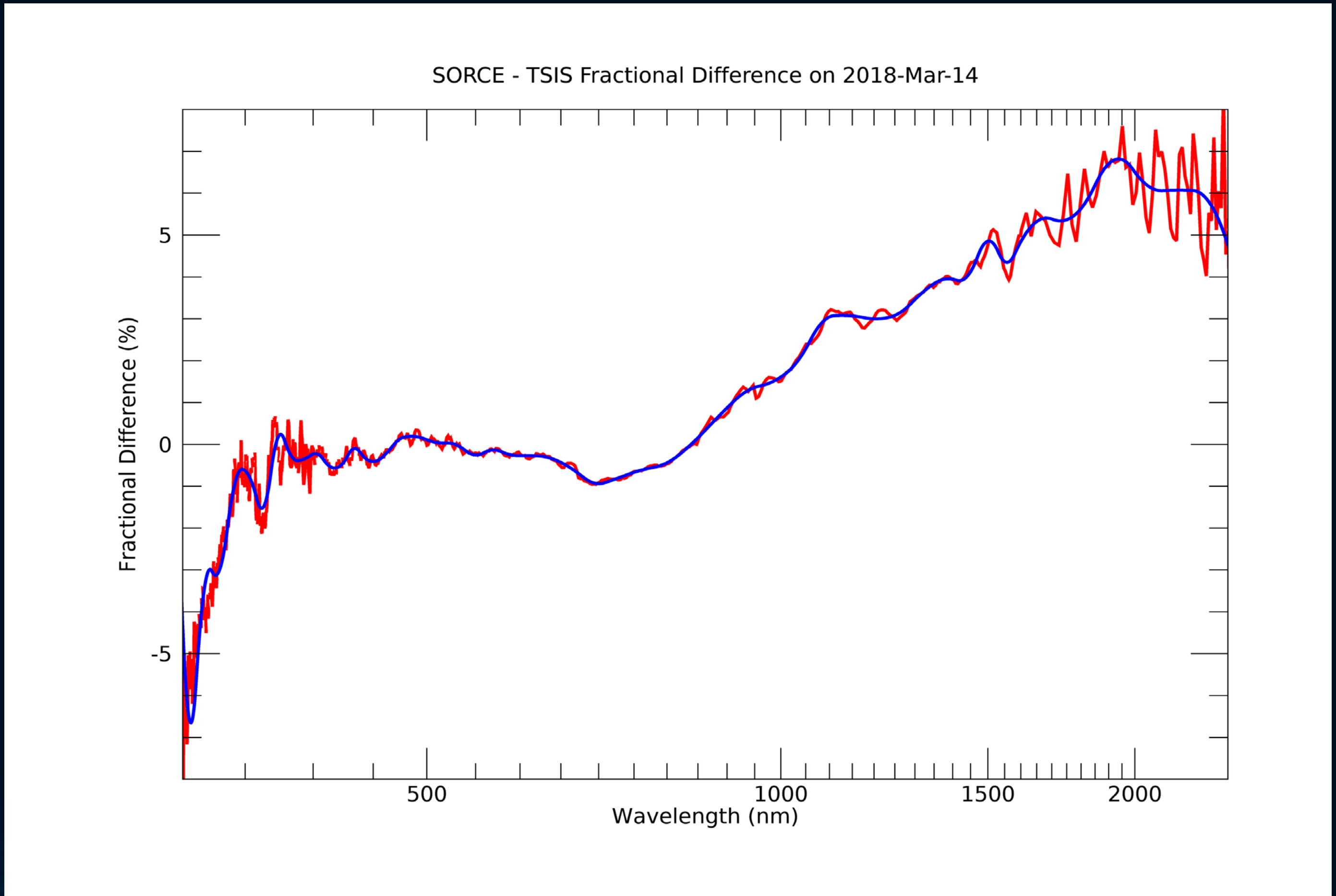


TSIS SIM vs SORCE SIM

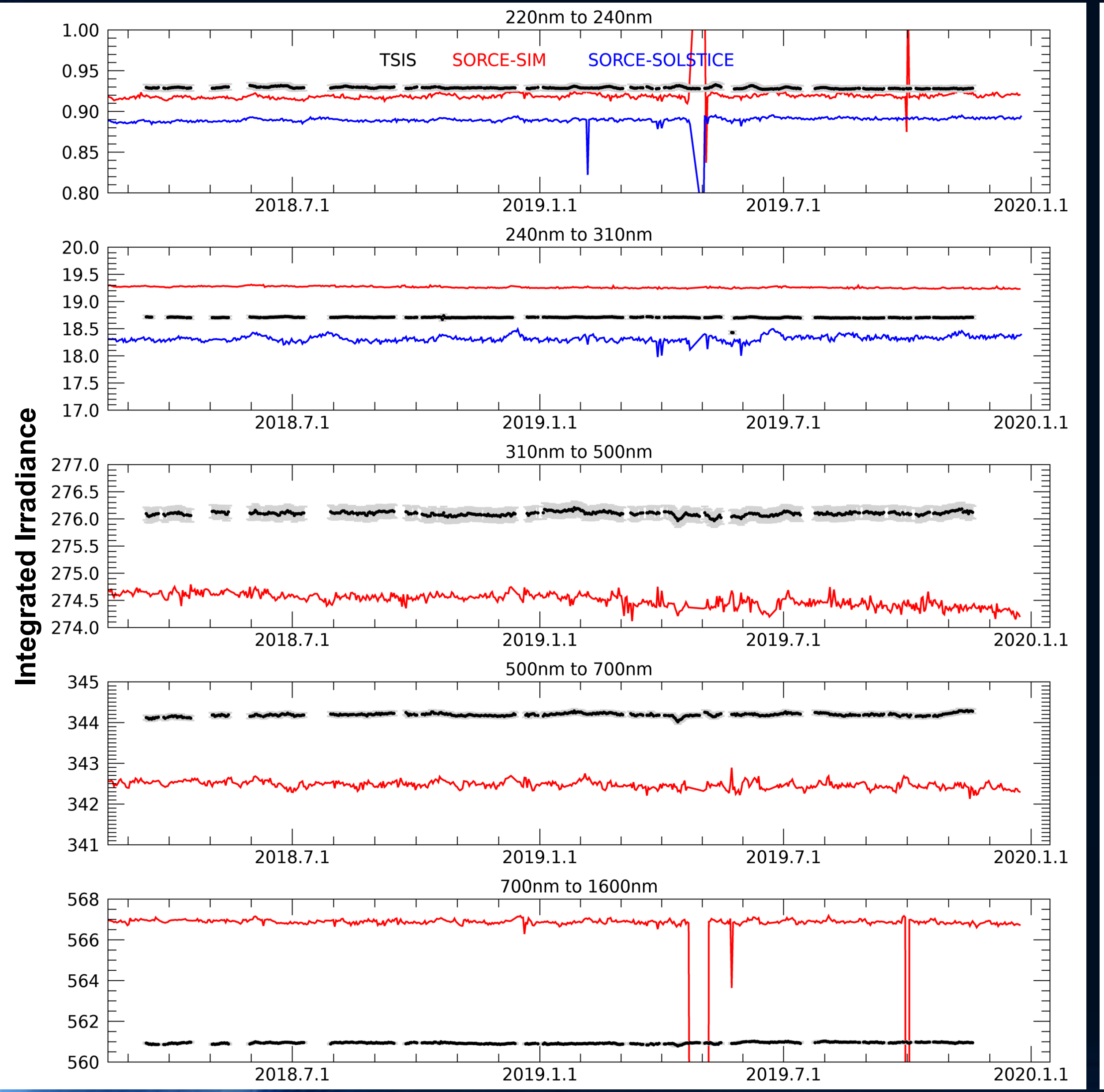


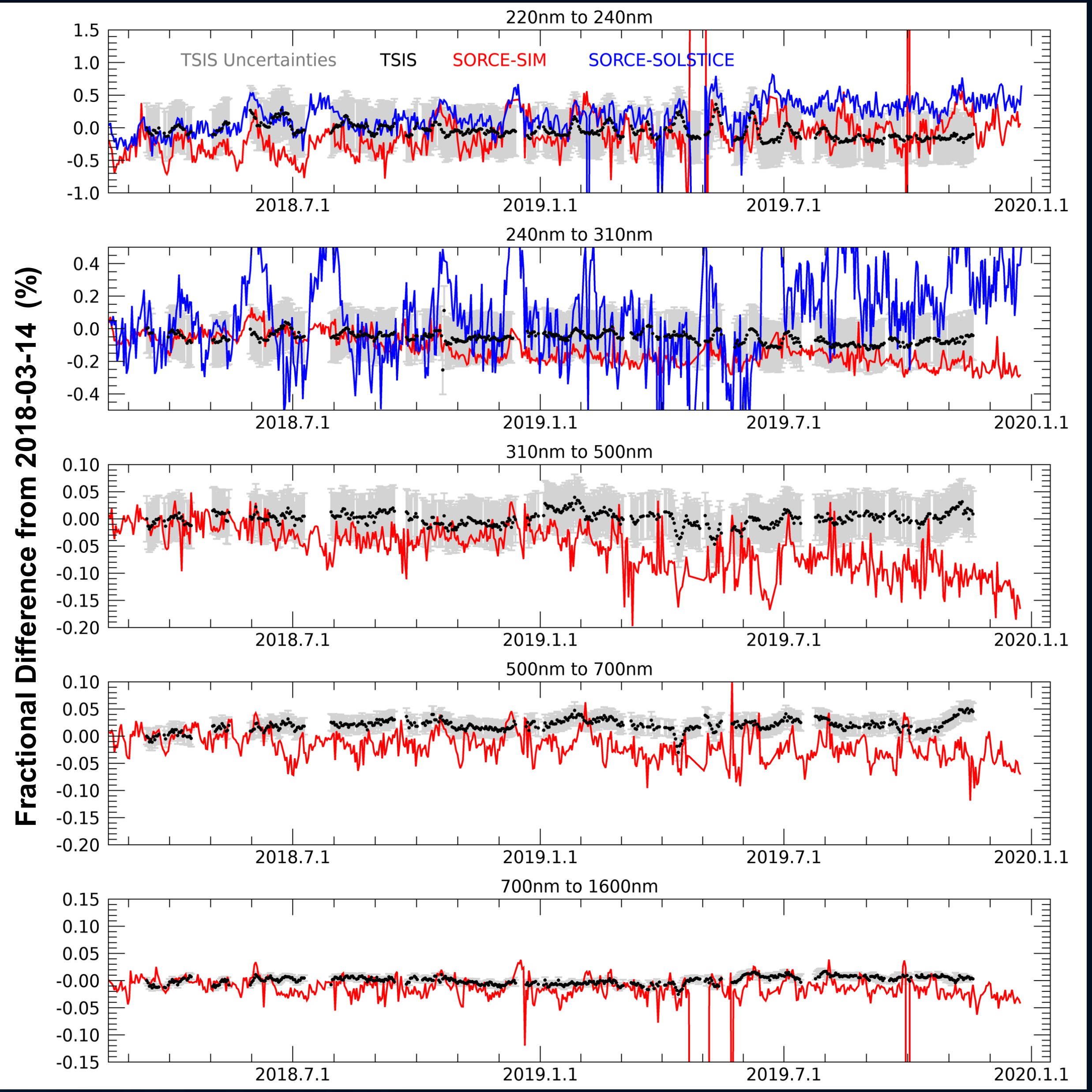
SORCE/TSIS on TSIS First Light (2018-03-14)

- SORCE overestimates the IR > 1000 nm (as does ATLAS3)
- Next SORCE data release will fold in TSIS absolute measurements on First Light



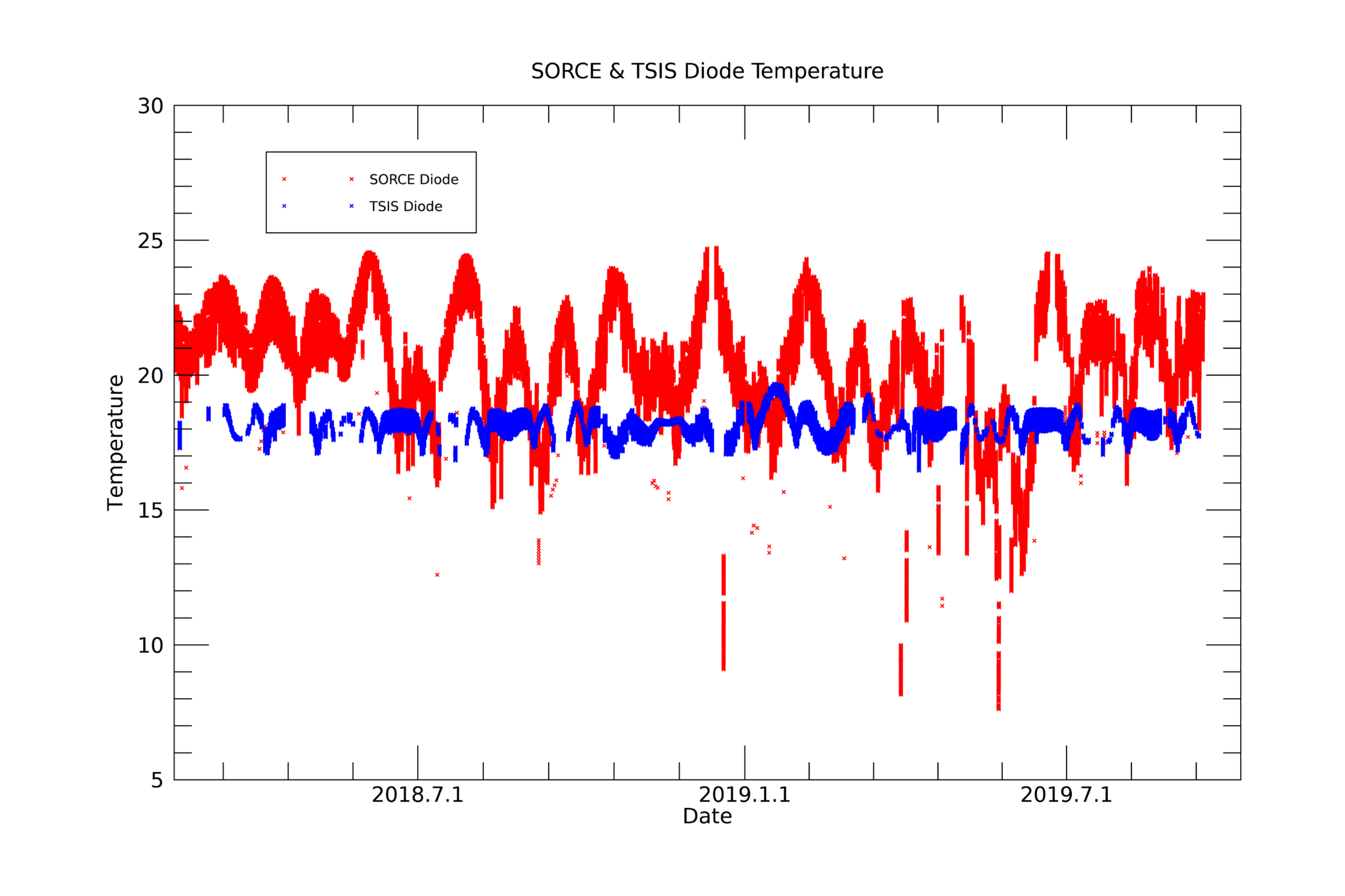
TSIS SIM vs SORCE SIM & SOLSTICE



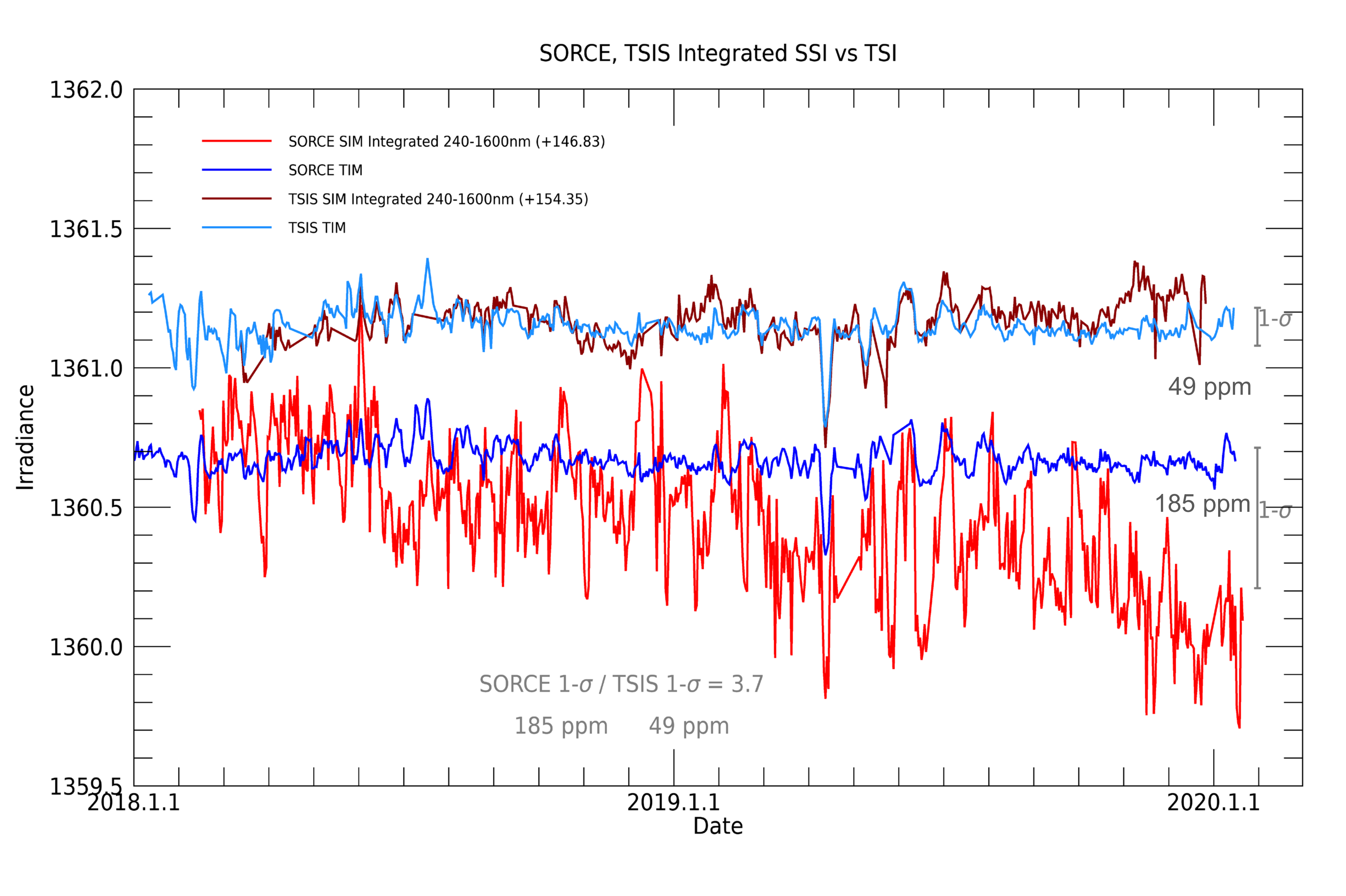


TSIS & SORCE Temperatures

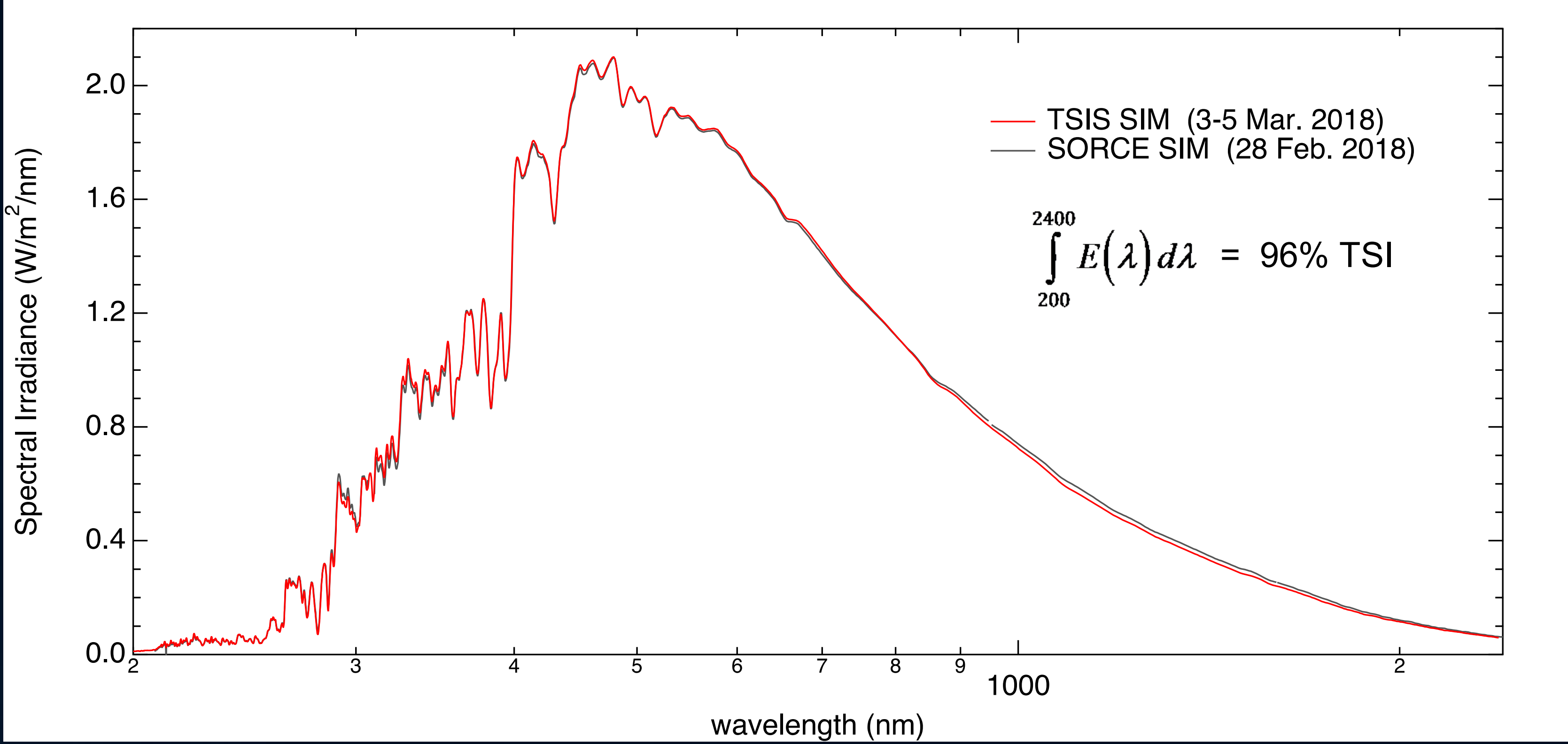
- Since Day-Only-Operations, SORCE SIM temperatures fluctuates significantly.
- Small residual temperature effects can be seen in the SORCE data



TSIS SIM vs SORCE SIM & TSI



SSI Reference Spectra



Spectrum	205-2390 (W/m^2)	+ 52 (W/m^2)*	TIM TSI (W/m^2)	Diff (W/m^2)	% Diff.
ATLAS3	1333	1386	1361	+ 25	+ 1.81
SIRS-WHI	1323	1375	1361	+ 14	+ 1.02
SOLAR-ISS	1321	1373	1361	+ 12	+ 0.87
✓ **TSIS SIM**	**1307.6**	**1359.6**	**1360.6**	**- 1**	**- 0.08**

← 1994 (ATLAS3)
2008 S_{min} (SIRS-WHI, SOLAR-ISS)
← 2018 S_{min} (TSIS SIM)

*Integrated SSI contribution outside 205-2390 nm (±0.1% variability uncertainty)