Solar Spectral Irradiance Measurements from the TSIS-1 SIM: Data continuity and comparisons to other records

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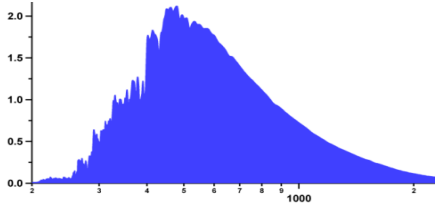
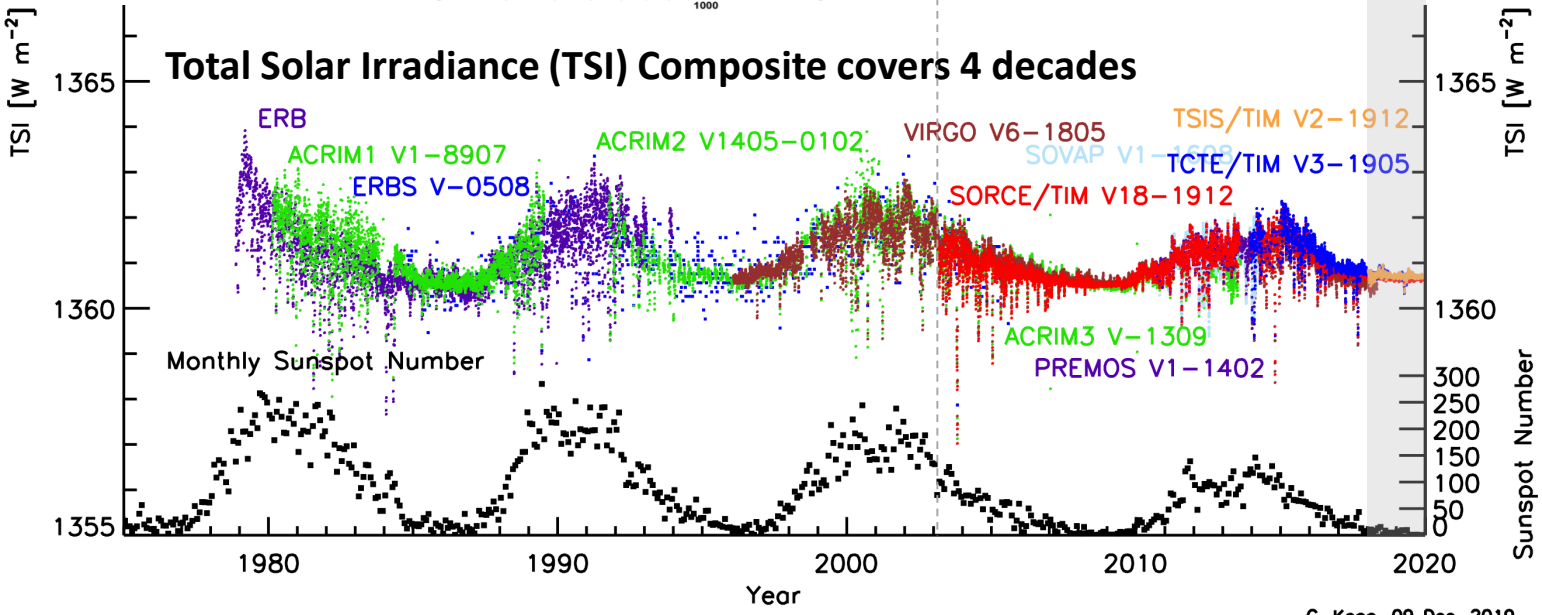
Solar Irradiance Data Record

Continuous Solar Spectral Irradiance (SSI) Record covers < 2 decades





G. Kopp, 09 Dec. 2019

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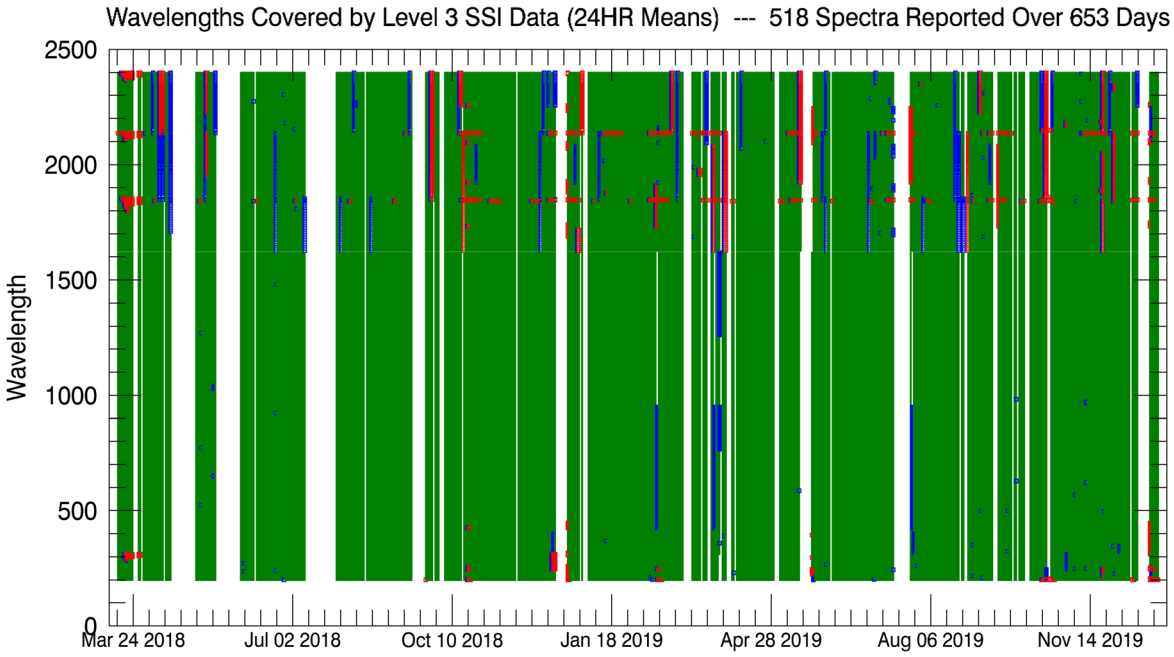
TSIS SSI Data Completeness & Exposure

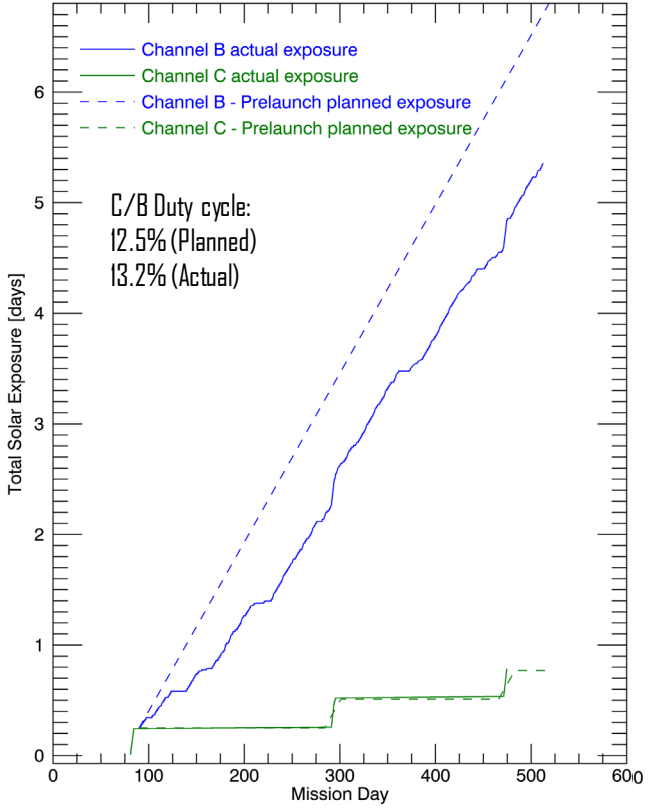


~80% daily scan completeness

Good data -- Quality flag = 0

Back filled data from previous day -- Quality flag = 2

Missing data -- Reported as irradiance = 0 quality flag = 1



http://lasp.colorado.edu/home/tsis/data/ssi-data

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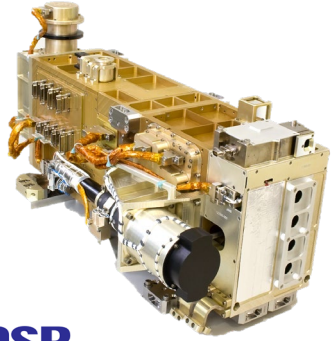
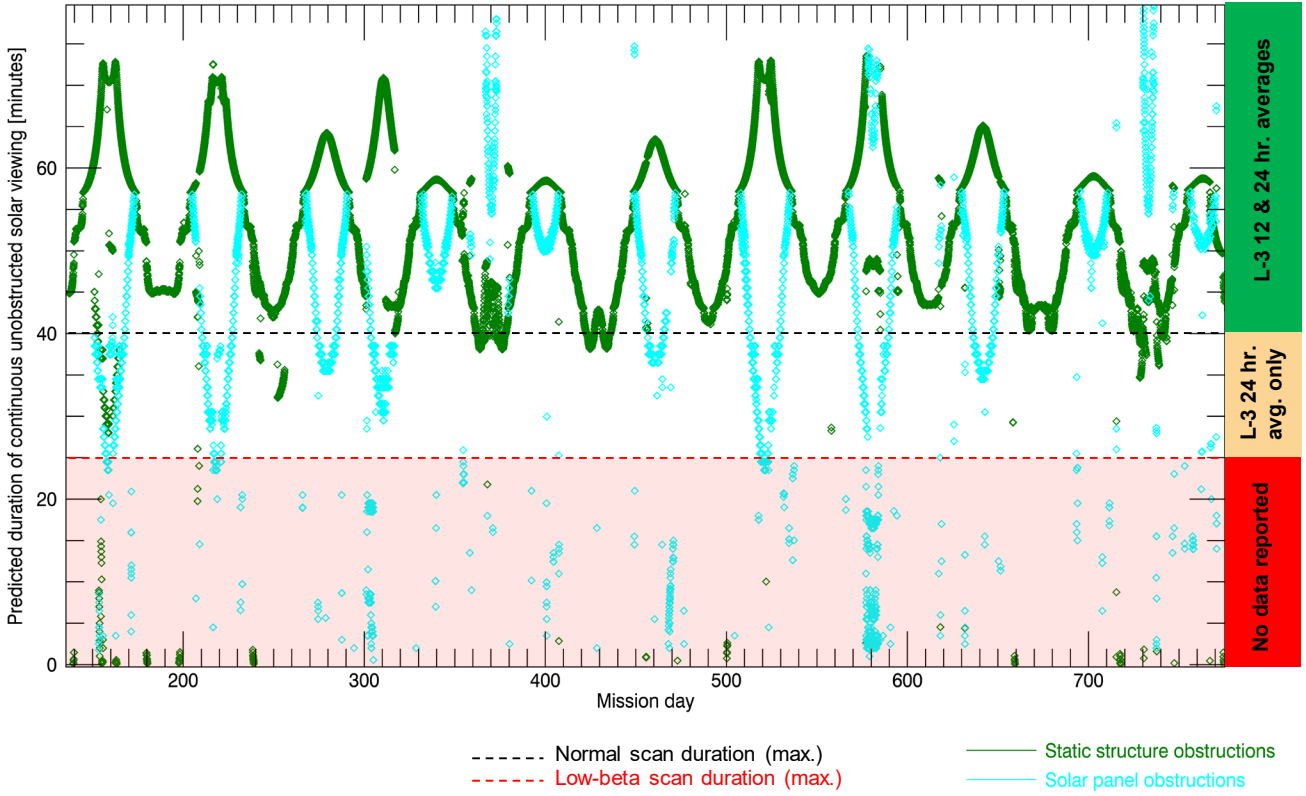
ISS structure impacts on science





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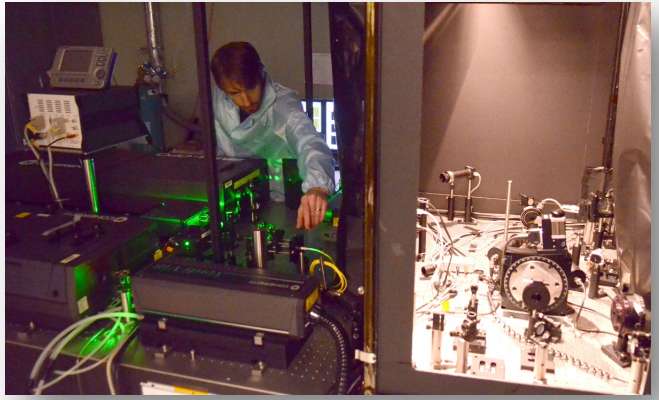
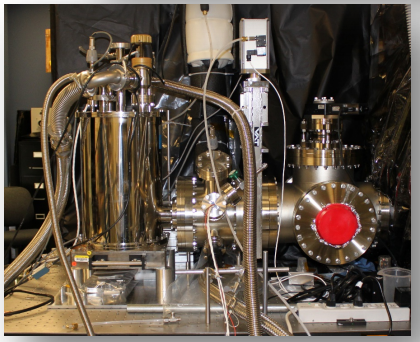
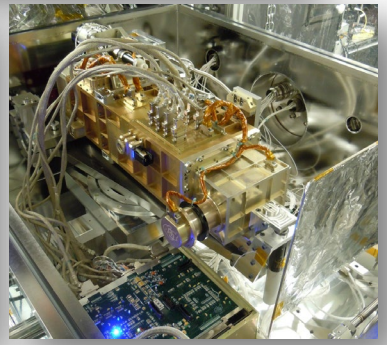
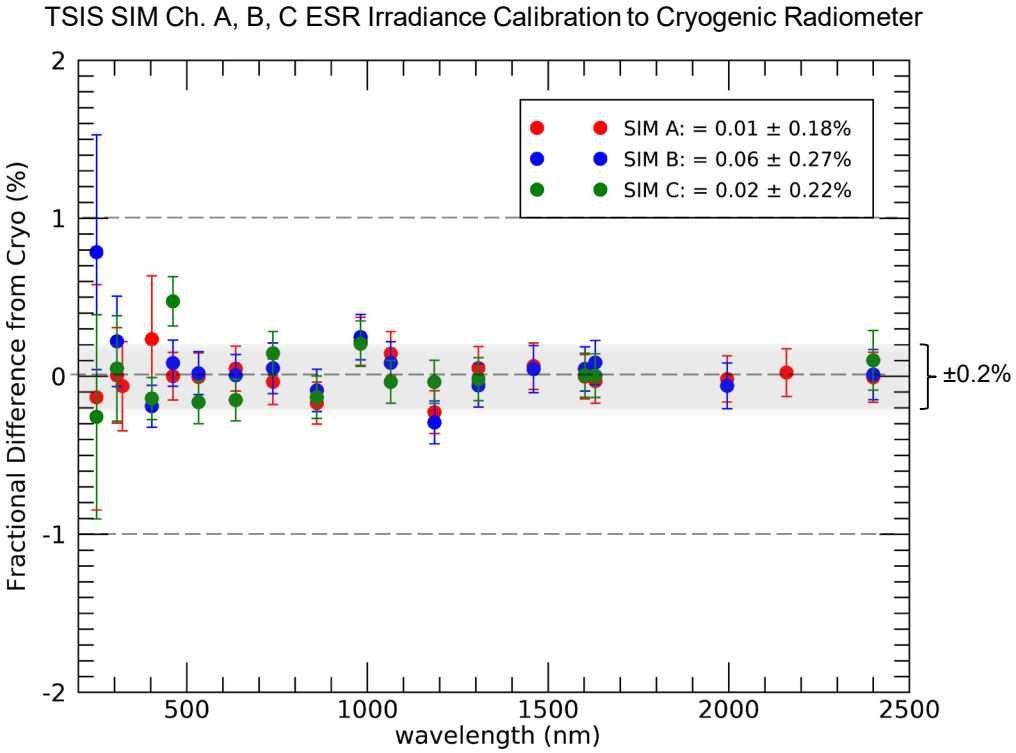
TSIS SIM absolute accuracy

Final full ESR spectrum calibration of irradiance tied to NIST-traceable cryogenic radiometer



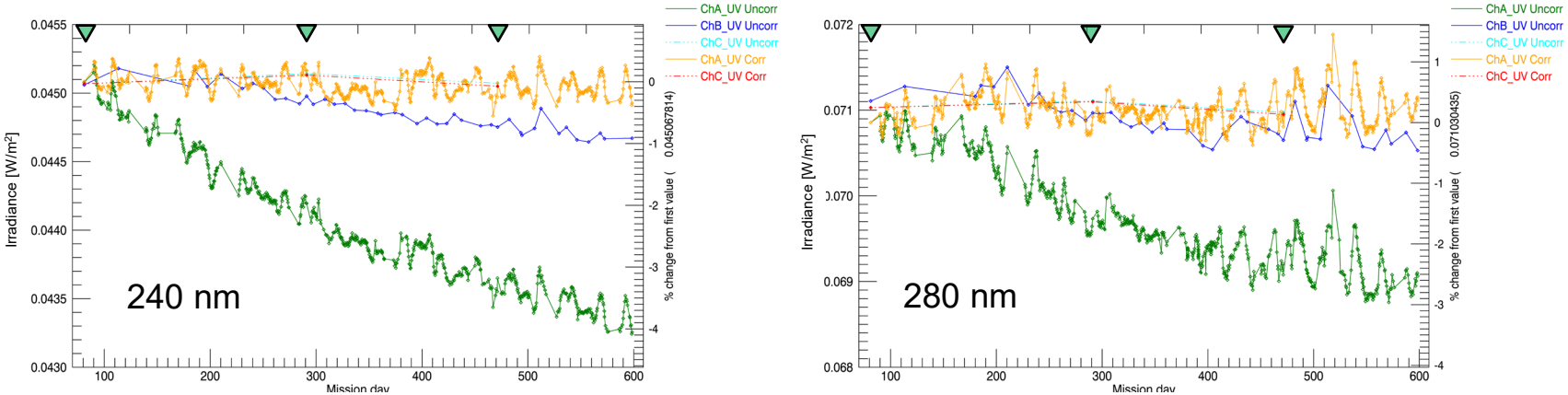


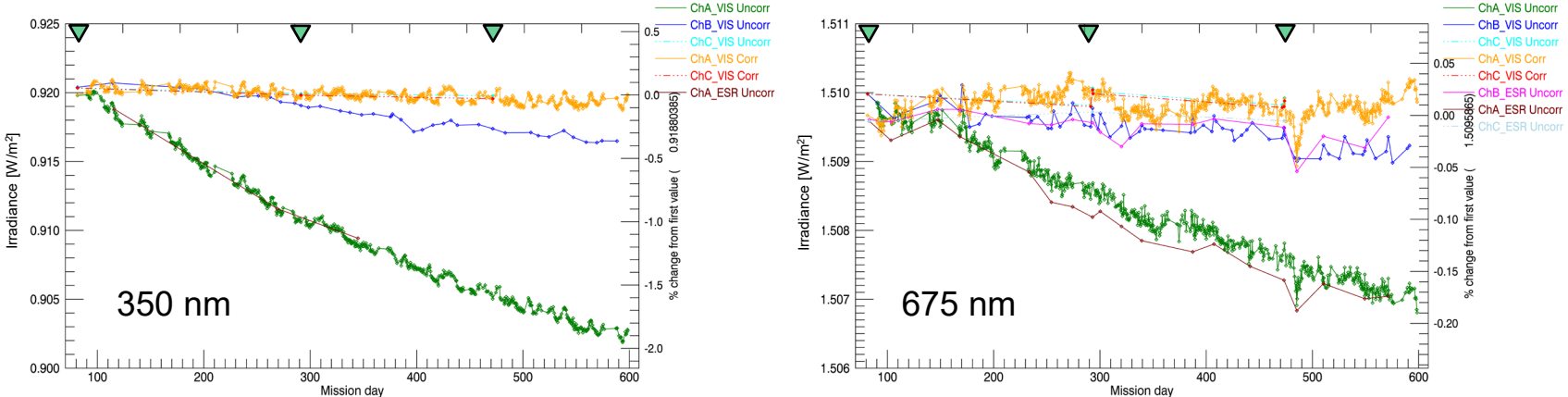




Spectral Stability Corrections

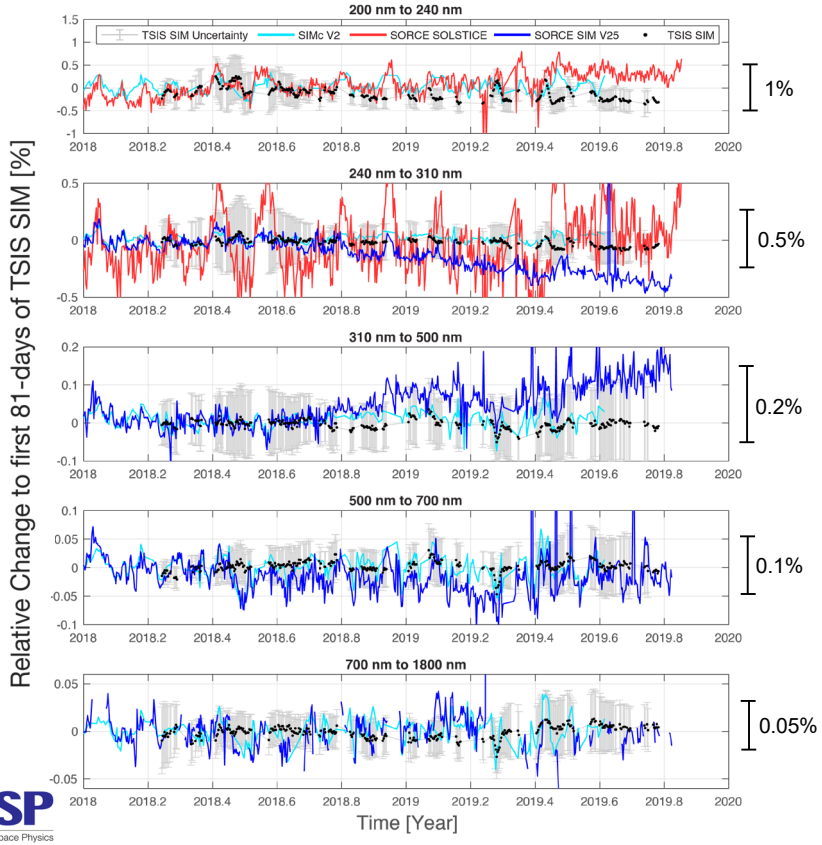
▼ SIM Ch. C scan



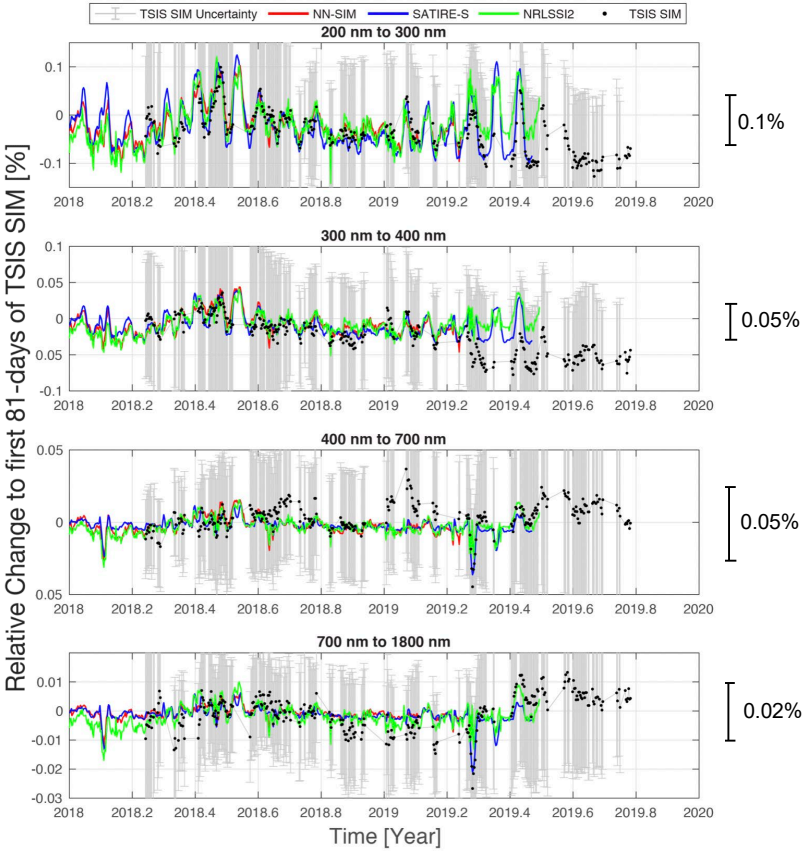


TSIS SIM Overlap Comparison

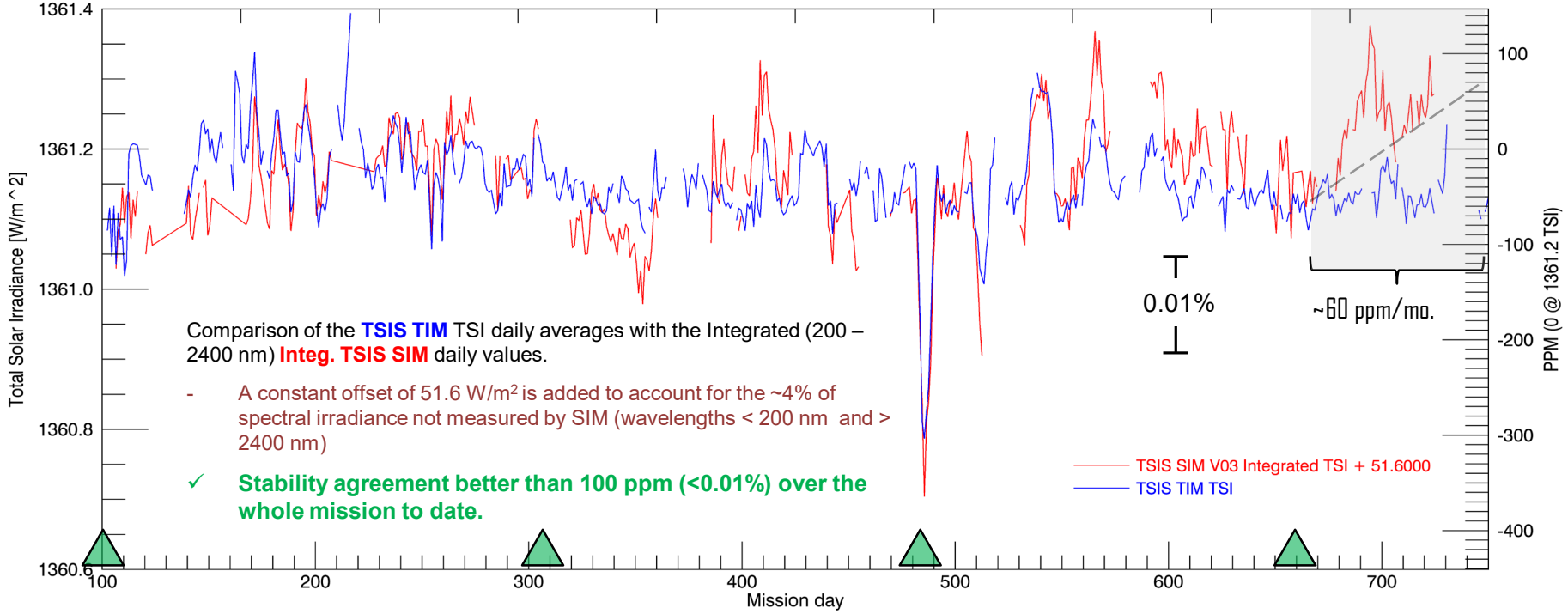
TSIS-1 SIM vs. SORCE



TSIS-1 SIM vs. Models



TSIS TSI to Integrated SSI



Comparison of the **TSIS TIM** TSI daily averages with the Integrated (200 – 2400 nm) **Integ. TSIS SIM** daily values.

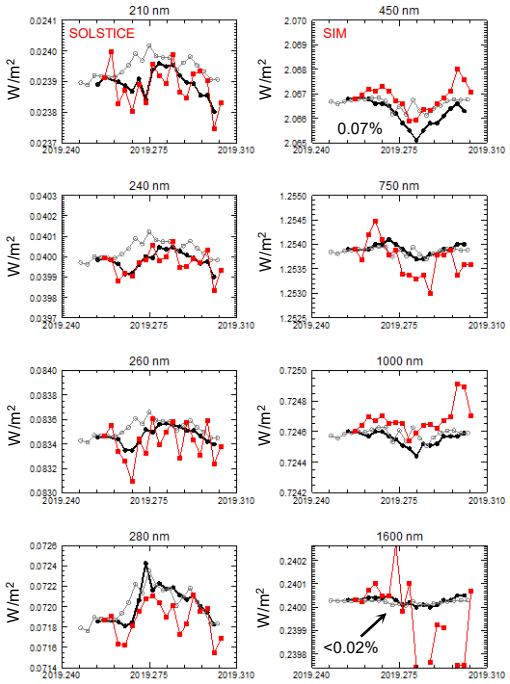
- A constant offset of 51.6 W/m^2 is added to account for the ~4% of spectral irradiance not measured by SIM (wavelengths < 200 nm and > 2400 nm)

✓ **Stability agreement better than 100 ppm (<0.01%) over the whole mission to date.**

▲ = full SIM A, B, & C calibration

Weak sunspot contrast comparison

April 1-21, 2019 sunspot passage

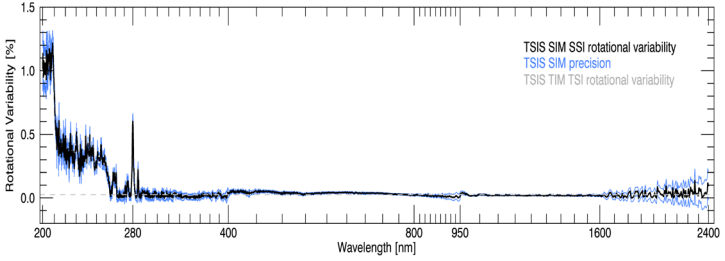


TSIS SIM
NRLSSI2 Model
SORCE

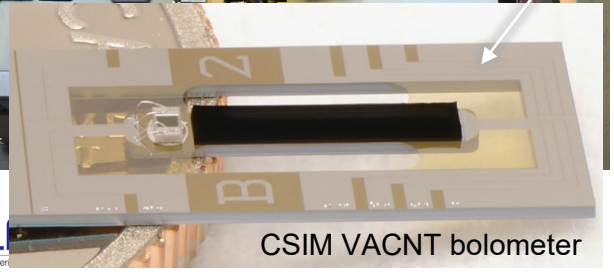
April 1-21 sunspot passage resulted in 0.03% decrease in TSI.

Future model improvements can be obtained by the superior TSIS SIM precision over previous SSI measurements

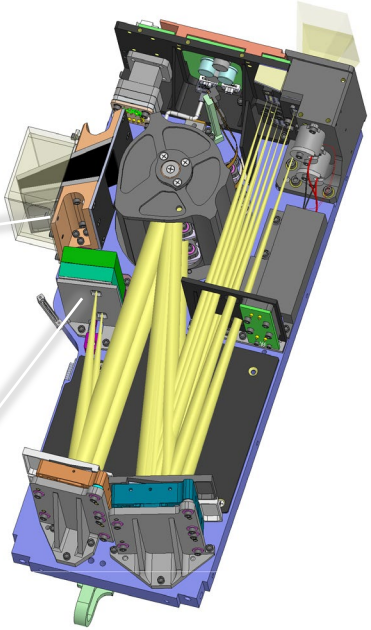
TSIS SIM irradiance variability April 12th - 20th



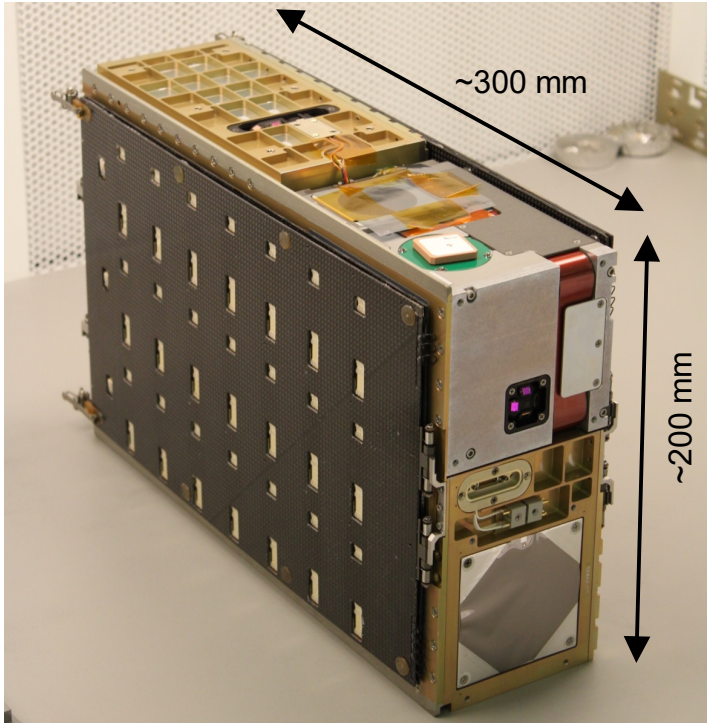
CSIM 6U CubeSat Implementation



CSIM VACNT bolometer

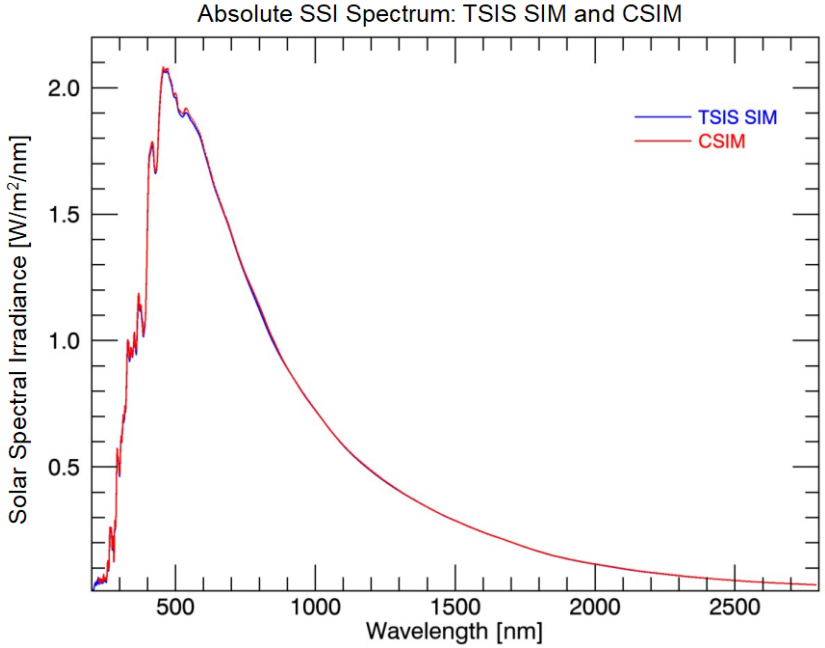


Two Channel prism spectrometer
(200 – 2800 nm)
Absolute ESR and fast Photodiode detectors



TSIS – CSIM Solar Spectrum

Solar Spectral Irradiance (SSI) measurements by TSIS-1 SIM and CSIM during solar minimum period will result in a newly established SSI reference spectrum for Earth Science applications



TSIS-1 SIM
$$$

CSIM 6U
CubeSat
$

Obtained **first ever** on-orbit full SSI absolute validation. Both TSIS-1 SIM and CSIM have calibration tied to NIST-Standards

Found excellent absolute SSI agreement between the CSIM spectrum compared to the TSIS-1 SIM spectrum.

Absolute Mean differences:
300 – 2400 nm: 0.44 ± 0.70 %

SSI Weighted offsets:
300 – 2400 nm: 0.56 ± 0.49 %

Abs. Diff < 1%

Graeme Stephens, *et al.*, **"The Emerging Technological Revolution in Earth Observations"**, *BAMS*, (2019) 10.1175/D-19-0146.1

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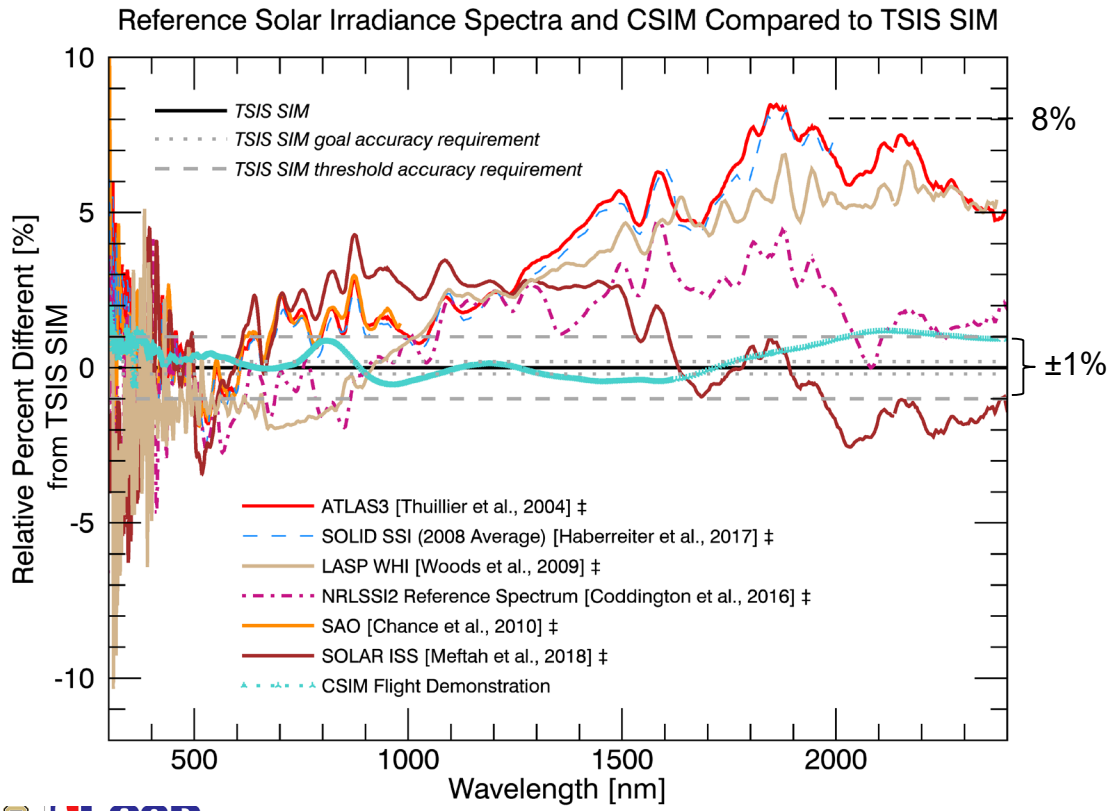
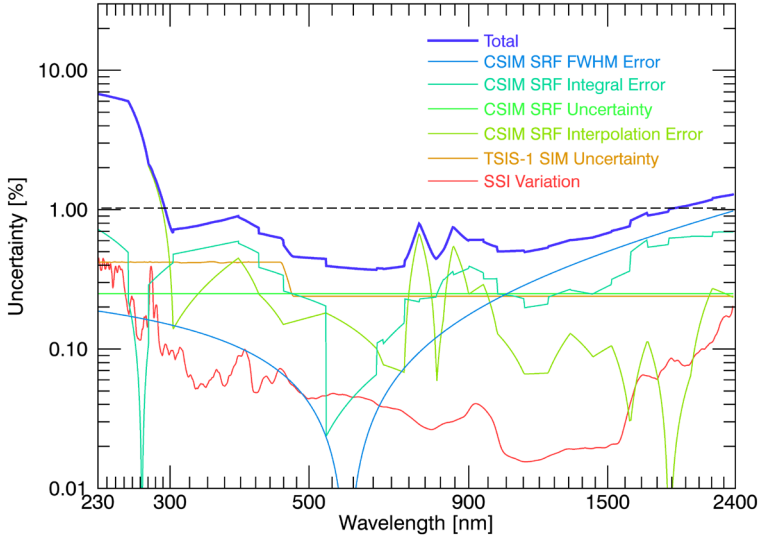
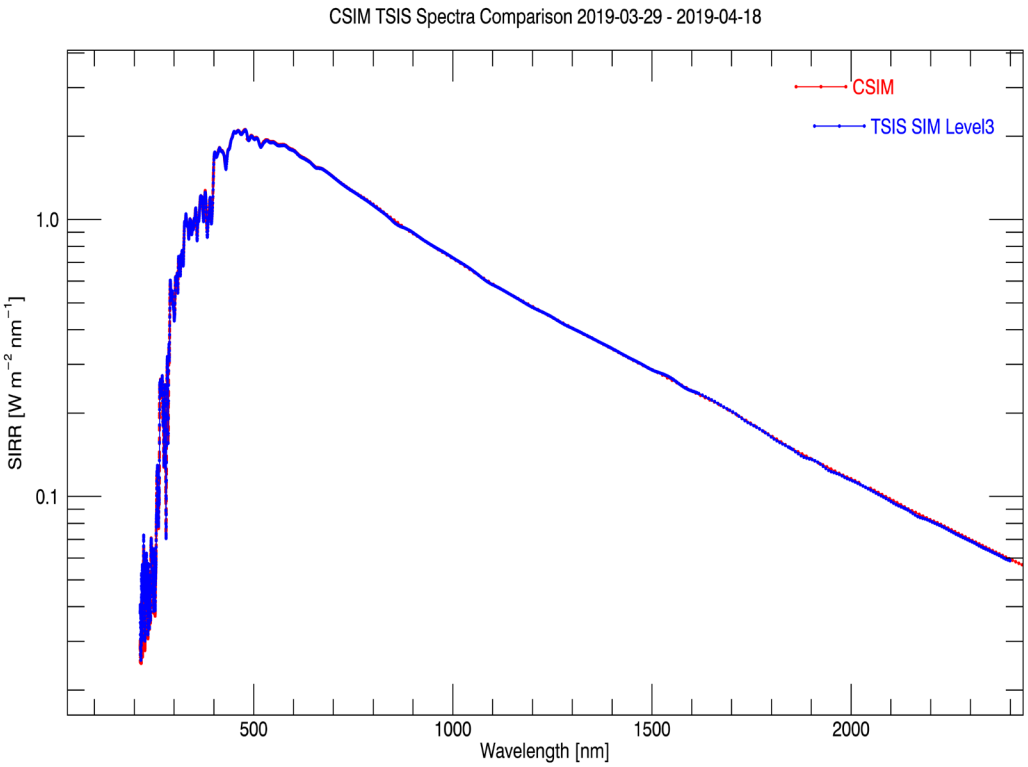
Solar Reference Spectrum



CSIM ESR Channel total uncertainty tied to cryogenic radiometer in SRF



CSIM –TSIS Overlap



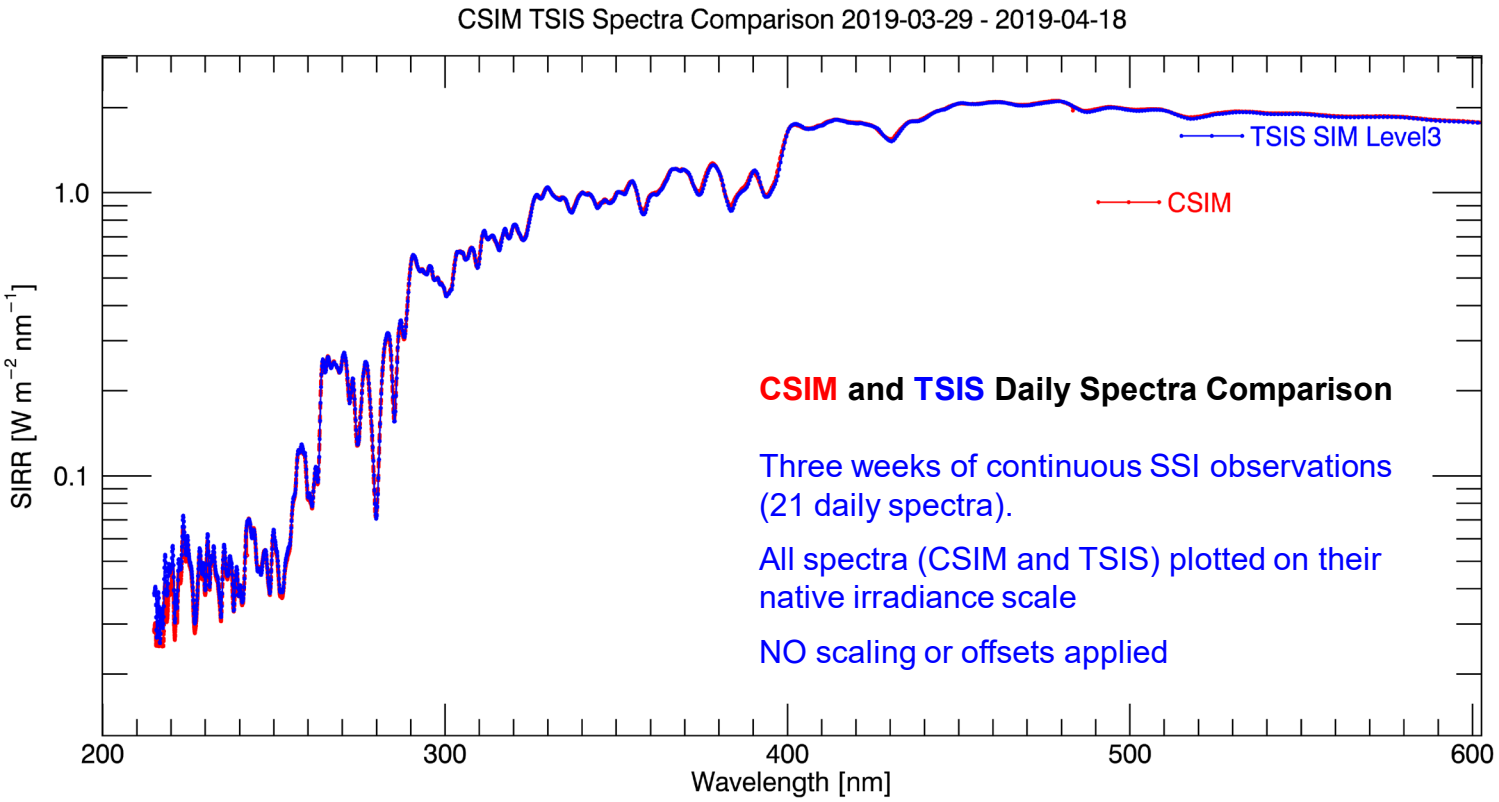
CSIM and TSIS Daily Spectra Comparison

Three weeks of continuous SSI observations (21 daily spectra).

All spectra (CSIM and TSIS) plotted on their native irradiance scale

NO scaling or offsets applied

CSIM –TSIS Overlap



CSIM and TSIS Daily Spectra Comparison

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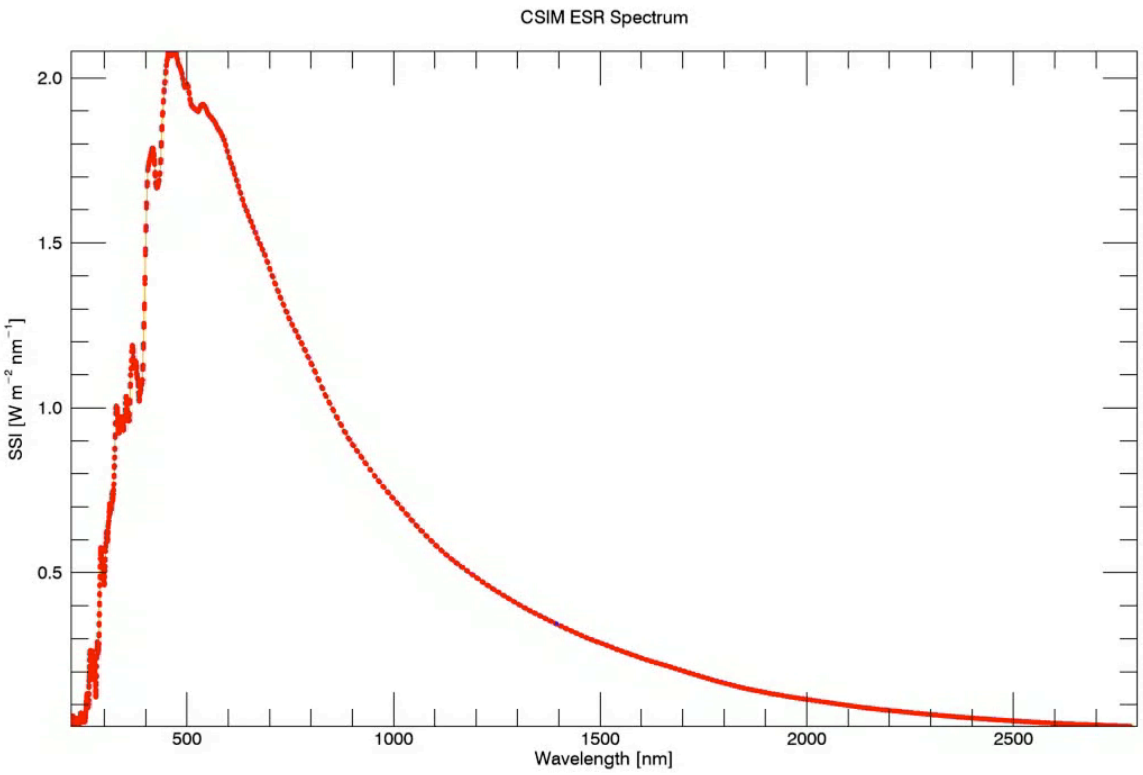
NO scaling or offsets applied

CSIM ESR Absolute SSI Repeatability



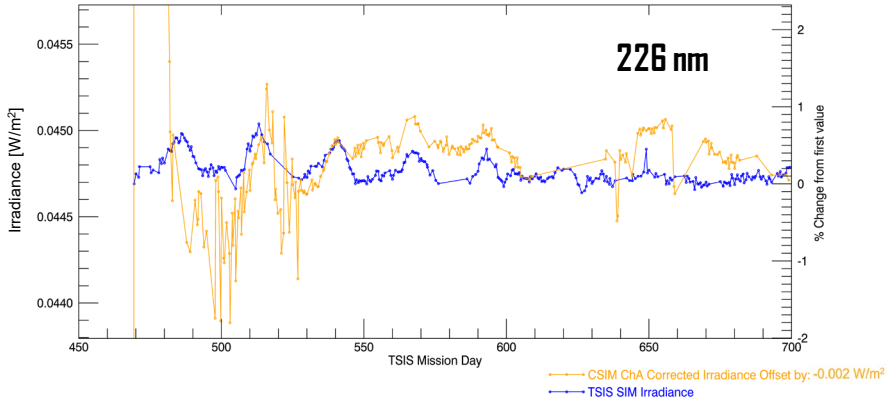
CSIM ESR Absolute SSI

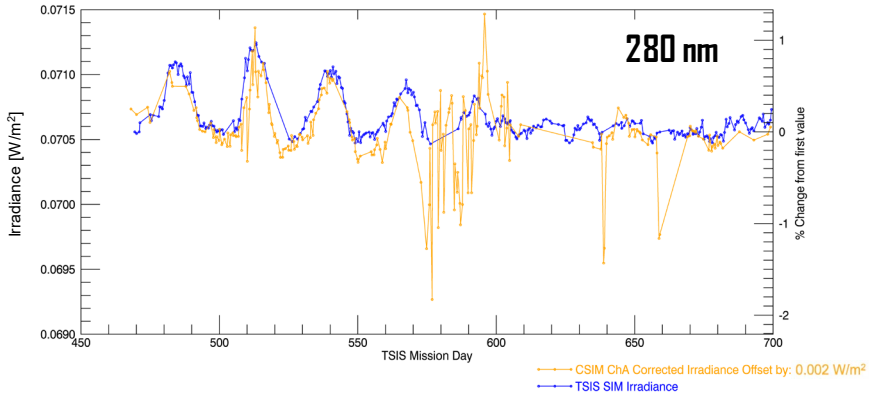
Every 2 weeks we obtain a full CSIM ESR spectrum

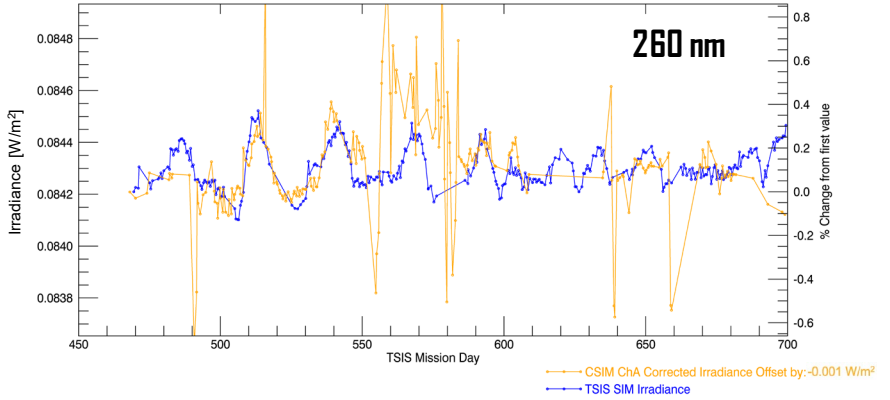
- Ch. A & B deg. corrections
- Photodiode A/W calibration

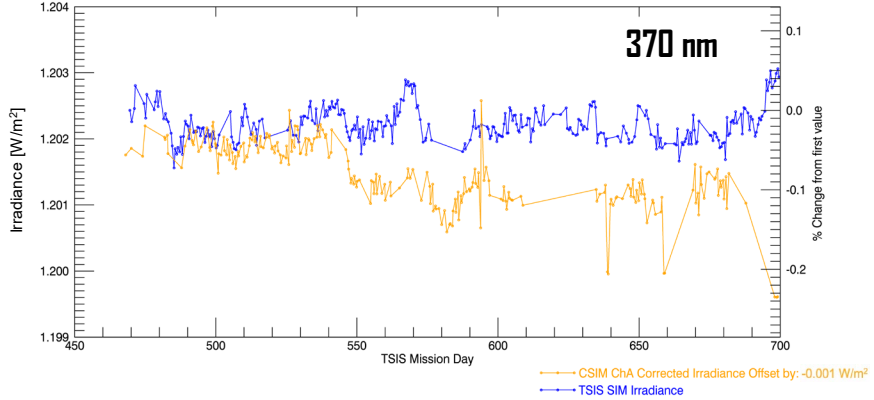
Still refining S/C pointing corrections and prism temperature (index of refraction) corrections.

CSIM Spectral Time Series (UV)

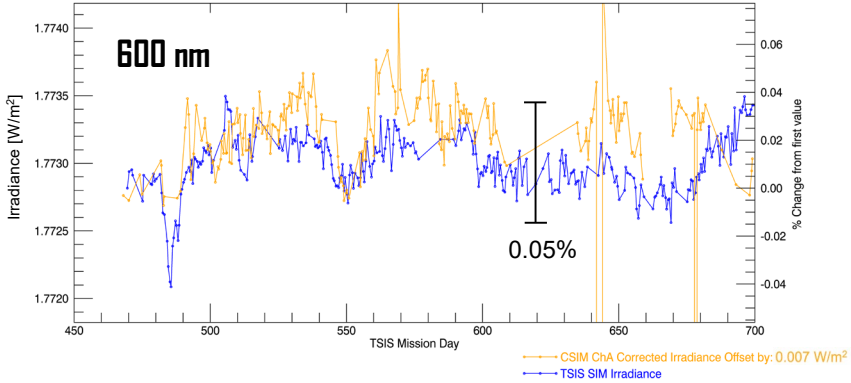


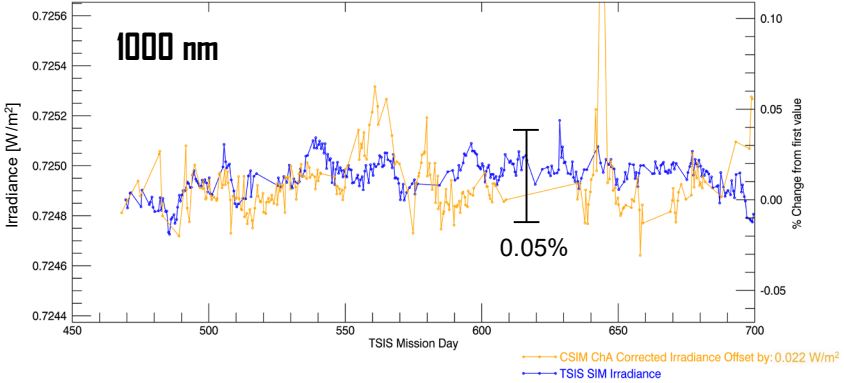


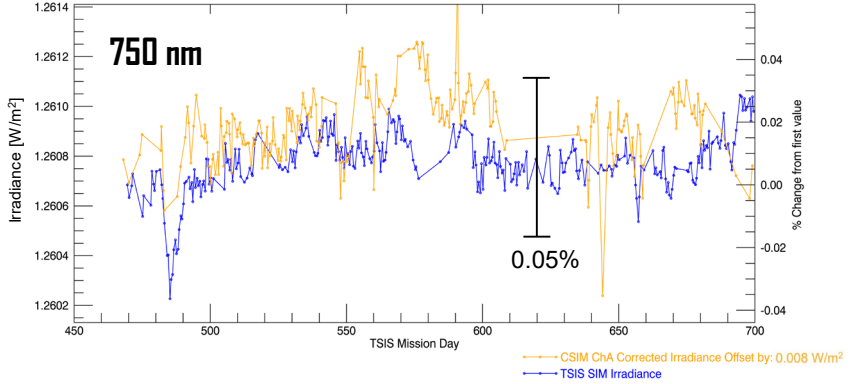


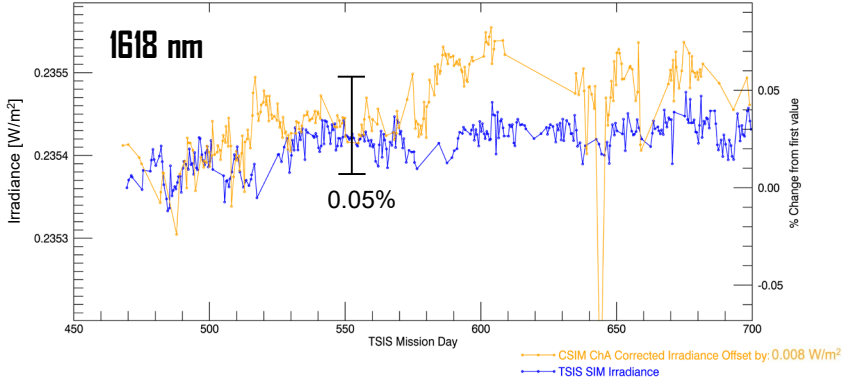


CSIM Spectral Time Series (Vis-IR)

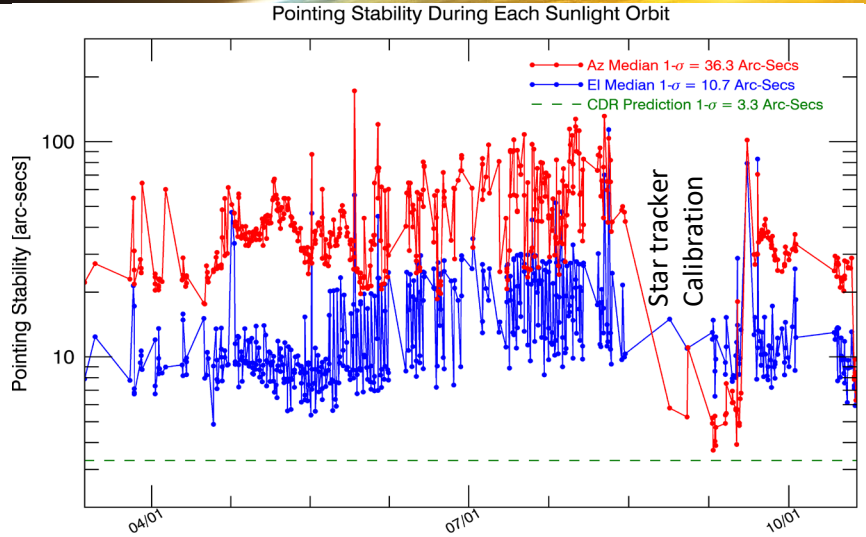


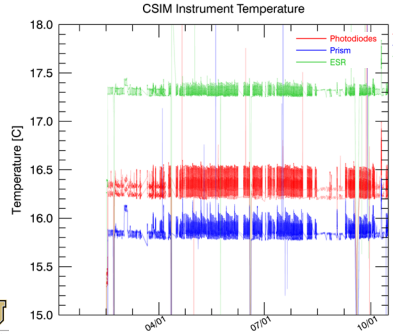


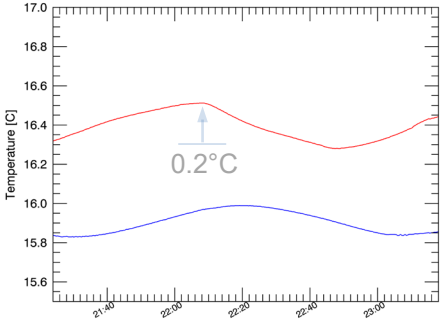




CSIM Pointing & Temperature stability







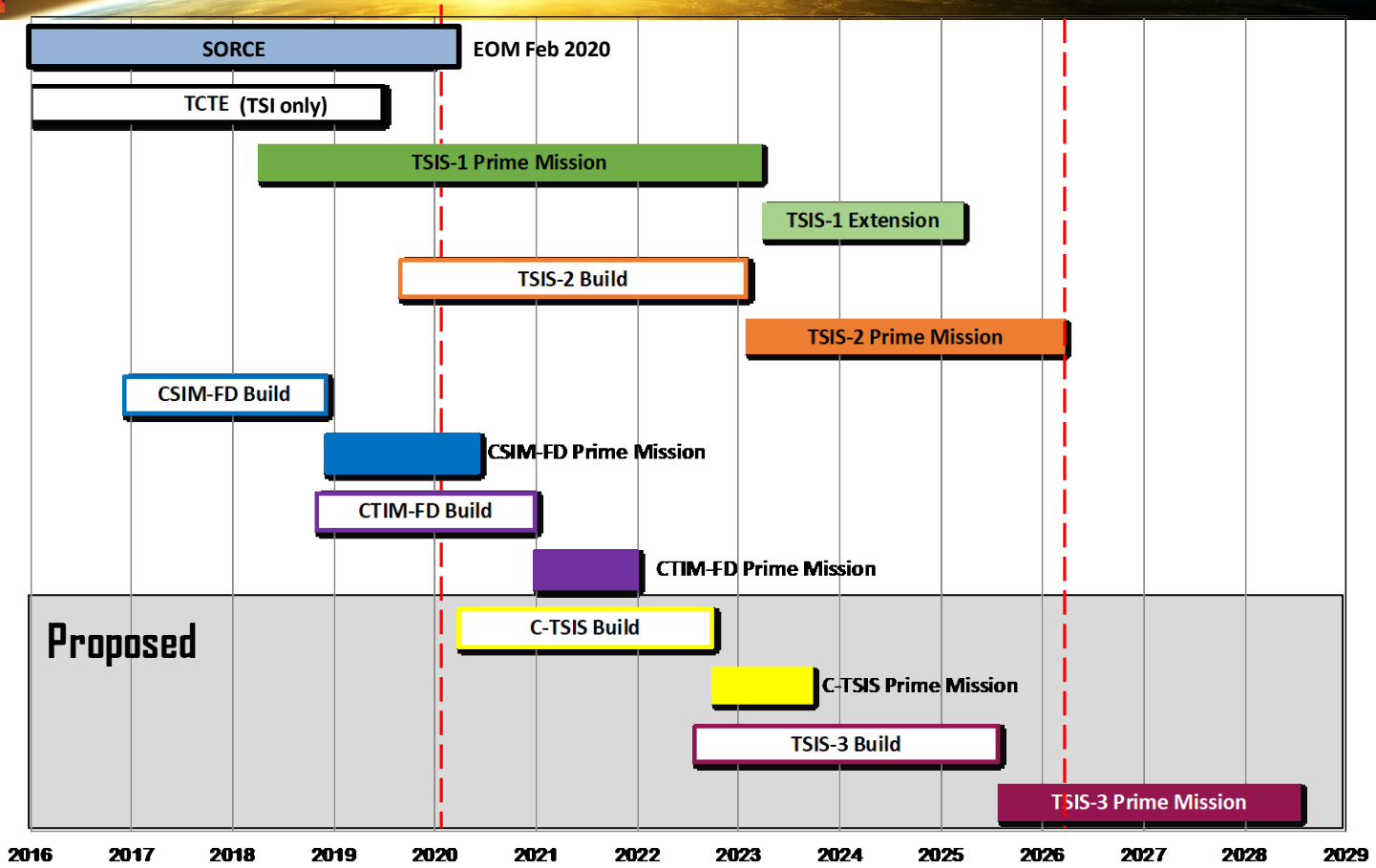
CSIM pointing offsets are larger than expected

- The BCT pointing stability is poor, less stability in the azimuth direction (dispersion direction, most unfavorable)
  - In early September, we completed a BCT star tracker calibration scan to reset the FSS to star tracker pointing. This initially cured the offset in Azimuth, but then drifted back
  - Continue to monitor the trends over the next several months to verify the stability.
  - Noise in pointing stability data appears to have noise ”spikes” common to the diode data.

CSIM temperature stability excellent

- Orbit to orbit stability ~0.2°C
- Mission stability shows no trends

Future of Solar Irradiance Continuity?



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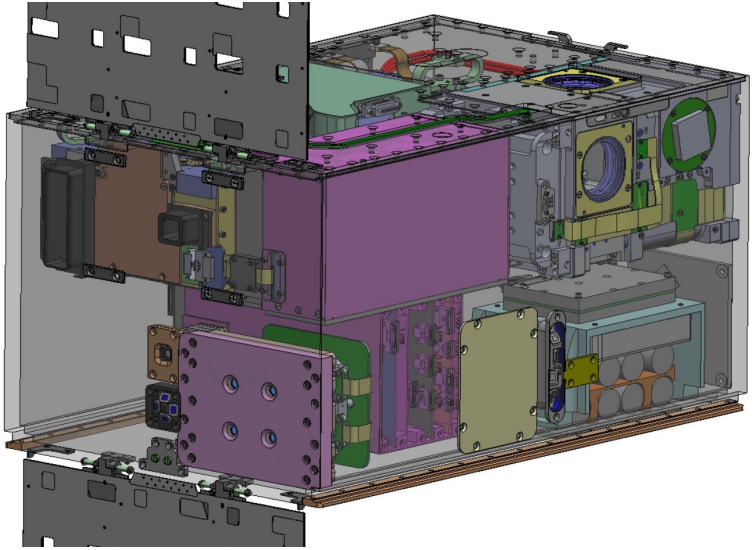
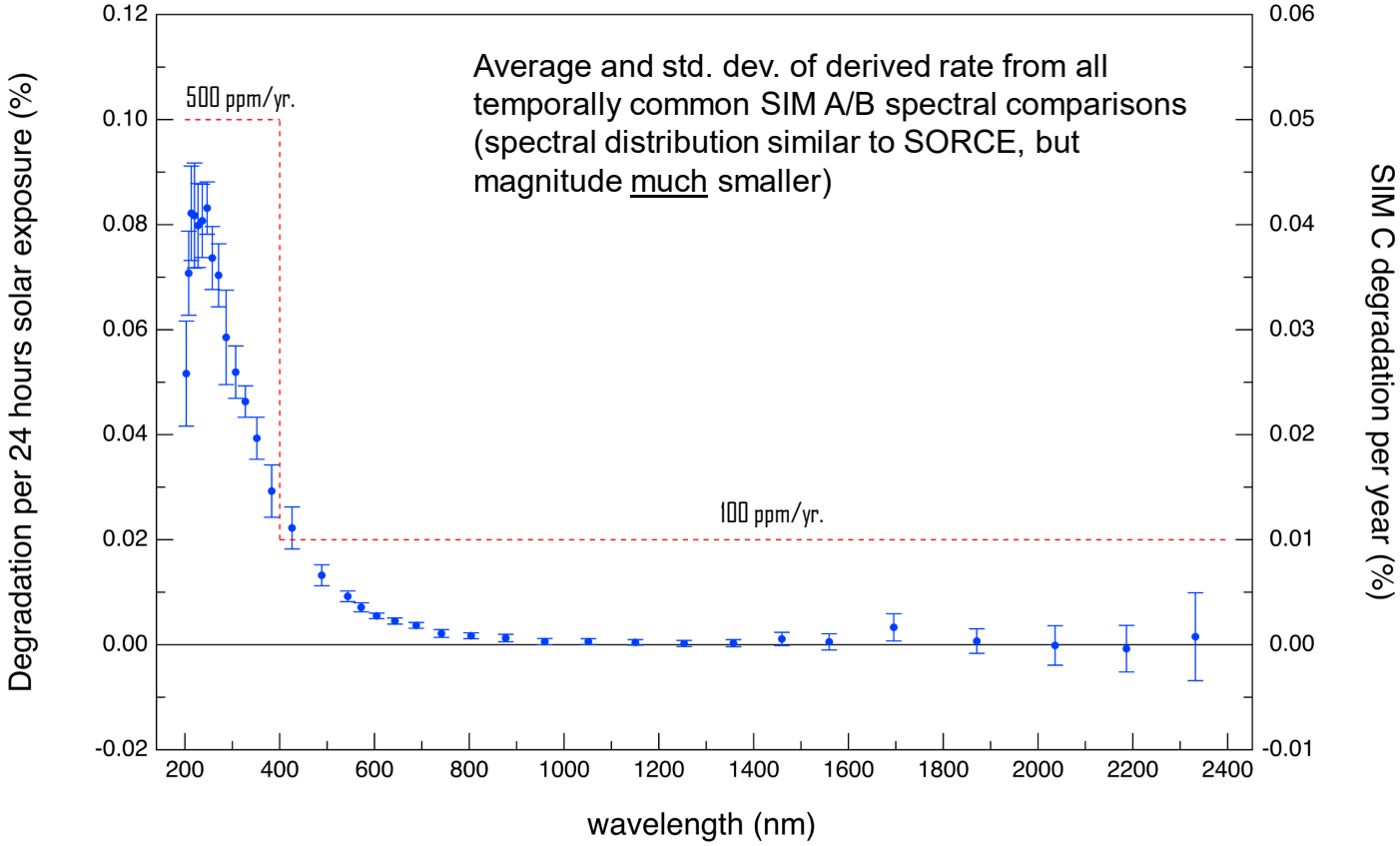
C-TSIS Mission Demonstration

- Demonstration that CSIM and CTIM can fully meet TSIS requirements in accuracy, stability, and reporting
  - Provide a 6 month overlap with TSIS-2
- Upgrade CSIM to a 3 channel instrument
- CTIM 1 Detector head (4 channels)
- Extend LASP 6U CubeSat design to 12U
- Improve parts reliability (Screening, Rad. Testing)
- Selectively move from CubeSat-class project engineering and production processes towards Class-D like project requirements (EEE parts, QA, SE, CM)
- Demonstrate regular and reliable mission operations, data capture, processing through improving automation and efficiencies from CSIM and CTIM lessons learned



BACK UP SLIDES

Spectral Degradation Rates