CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

TEMPO L1B Status Update

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May 7, 2024

TEMPO Level 1 Data Products

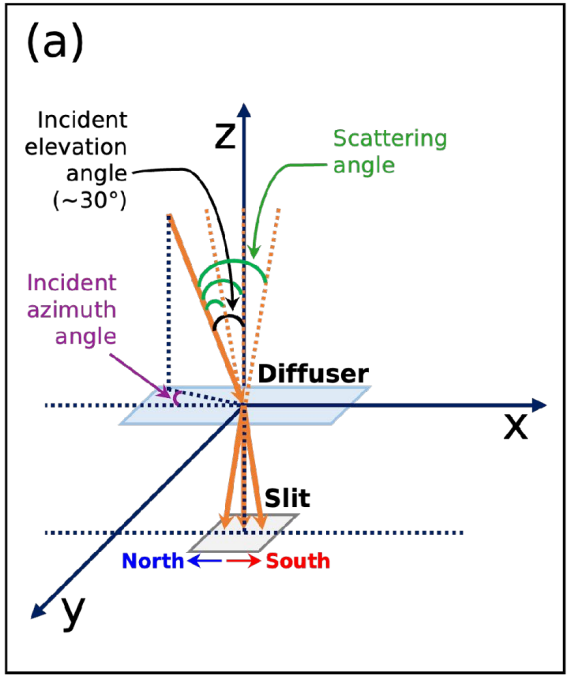
Product	Level	Description	Nominal sampling frequency
DRK	1a	Dark exposure	Variable (typically sampled before the beginning of the other types of exposure)
RAD	1b	Geolocated Earth radiances	Once per hour or more frequent (during daylight hours)
RADT	1b	Geolocated Earth radiances (twilight)	Variable
IRR	1b	Solar irradiance (working diffuser)	Once per week
IRRR	1b	Solar irradiance (reference diffuser)	Once per 3 months

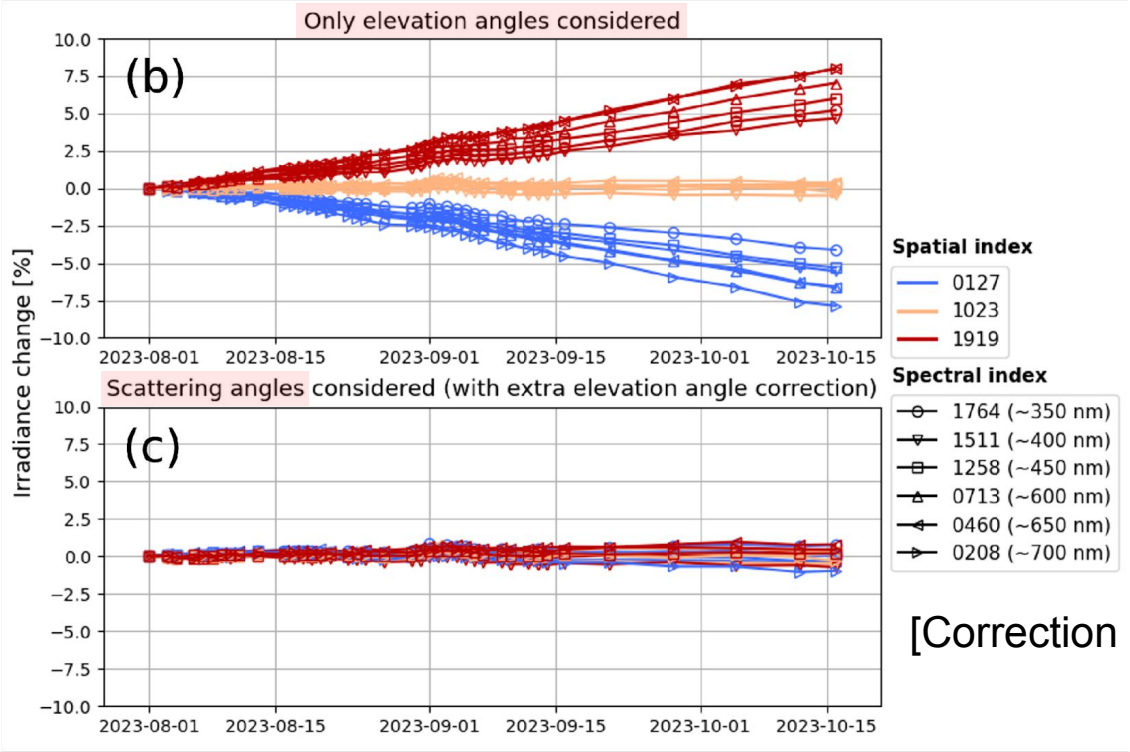
TEMPO Level 1 Data Products

	Version 2	Version 3
Release date	February 26, 2024	(Tentative) May 20, 2024
Collection (Validation level)	Beta	
User Guide	Available online at the NASA Earthdata website 	
ATBD	Available upon request (Version 1.0)	

Key features in Version 2 (February release)

- Row-by-row electronic offset correction implemented
- Smear correction using photoactive pixels
- Dynamic updates of radiance wavelength grids (copying them from the latest solar data)
- Diffuser BTDF (goniometry) correction (accounting for scattering-angle dependence)





[Correction method development: David Flittner]

Major updates in Version 3

- Earthshine radiance (RAD) and Solar irradiance (IRR) products
  - Dark current correction improved
  - (Spectral) stray light correction turned on
  - Radiance wavelength calibration turned on
- Twilight radiance product (RADT)
  - Newly added

Update – Dark current correction

The CCDs can't measure (ir)radiance and dark current simultaneously in the image regions. Estimation required

Arrhenius equation

$$\ln(D) = \ln(a_0) + a_1 \cdot \frac{1}{T}$$

Dark current

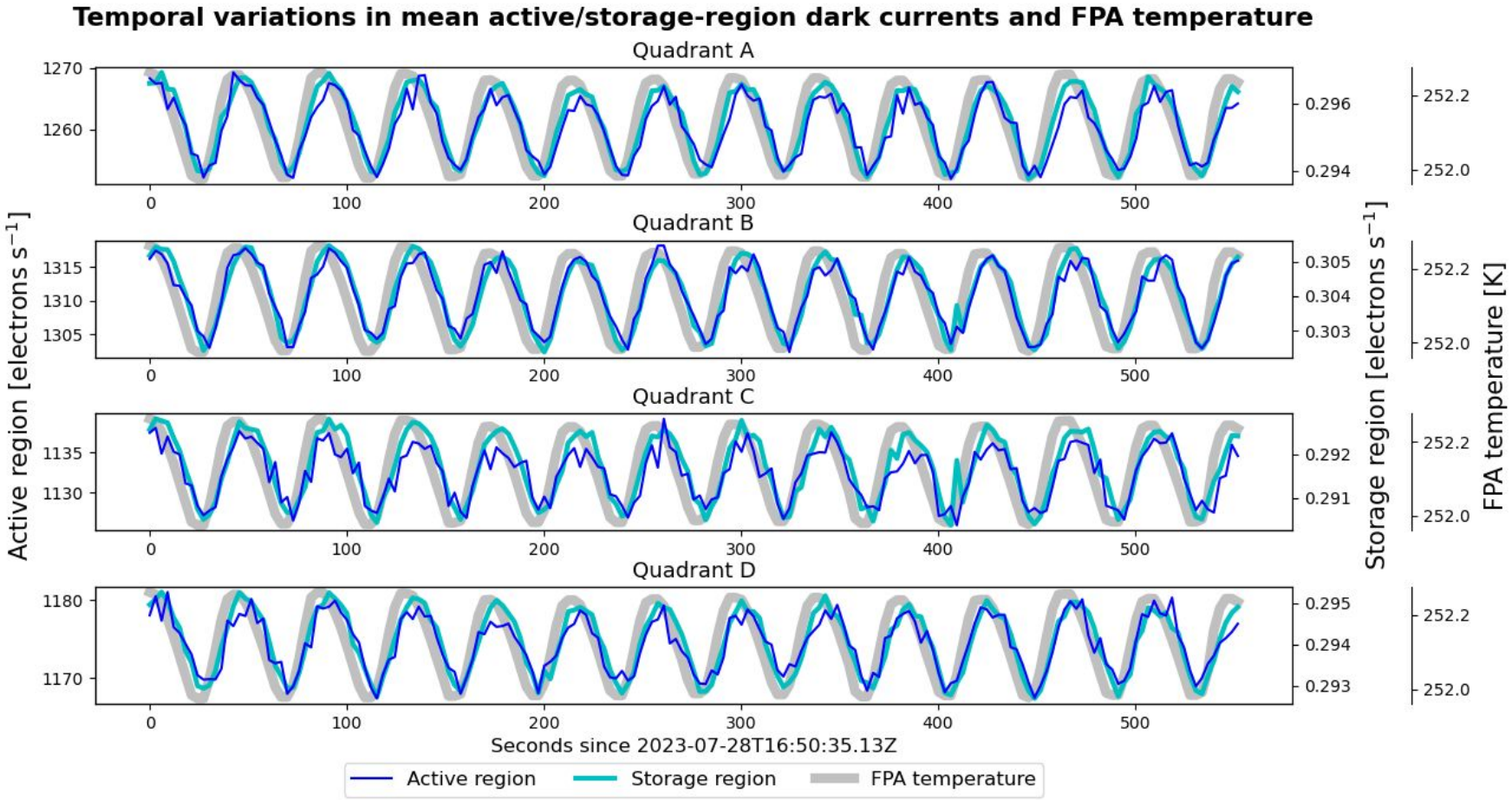
Coefficients

FPA temperature

Estimation

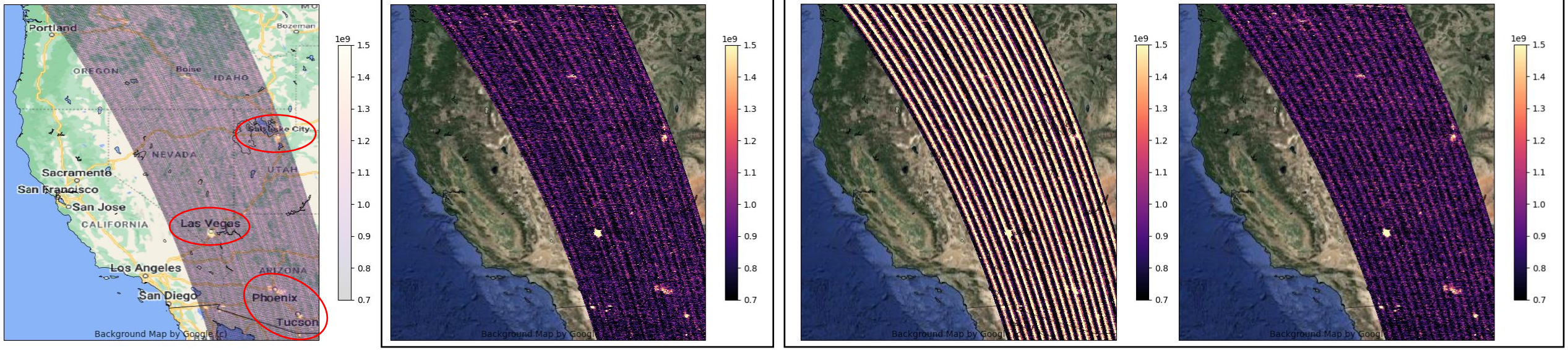
$$D_2 = D_1 \cdot \exp\left[a_1 \cdot \left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$$

Updated in Version 3
(pre-launch derived in-flight derived)



Update – Dark current correction

Verification – Twilight measurement (03/17/2024, 11:11:00 UTC; 6-s exposure)



Dark current correction method	Storage region	Arrhenius (FPA temperature)
Pros	Accurate for small signals	Stable temperature measurement
Cons	Measurement uncertainty / Contamination for large signals	Errors in derived coefficients
Application	RADT (twilight)	RAD, IRR

Update – Stray light correction

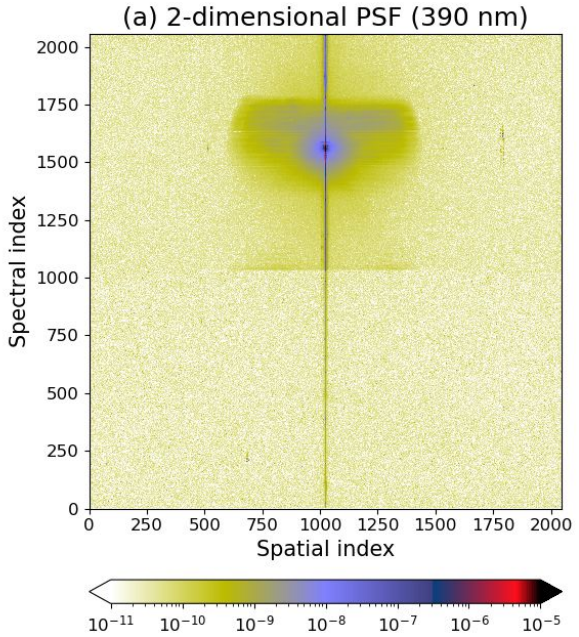
1-dimensional point spread function (PSF)

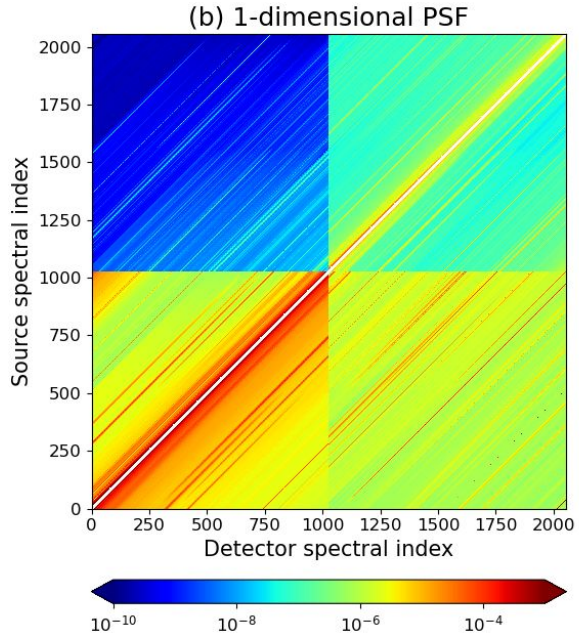
$$\boldsymbol{R}_{\mathrm{meas}} = [\boldsymbol{I} + \boldsymbol{D}] \cdot \boldsymbol{R}^{\mathrm{ib}}_{\mathrm{meas}} \quad \rightarrow \quad \boldsymbol{R}^{\mathrm{ib}}_{\mathrm{meas}} = [\boldsymbol{I} + \boldsymbol{D}]^{-1} \cdot \boldsymbol{R}_{\mathrm{meas}}$$ (Zong et al., 2007)

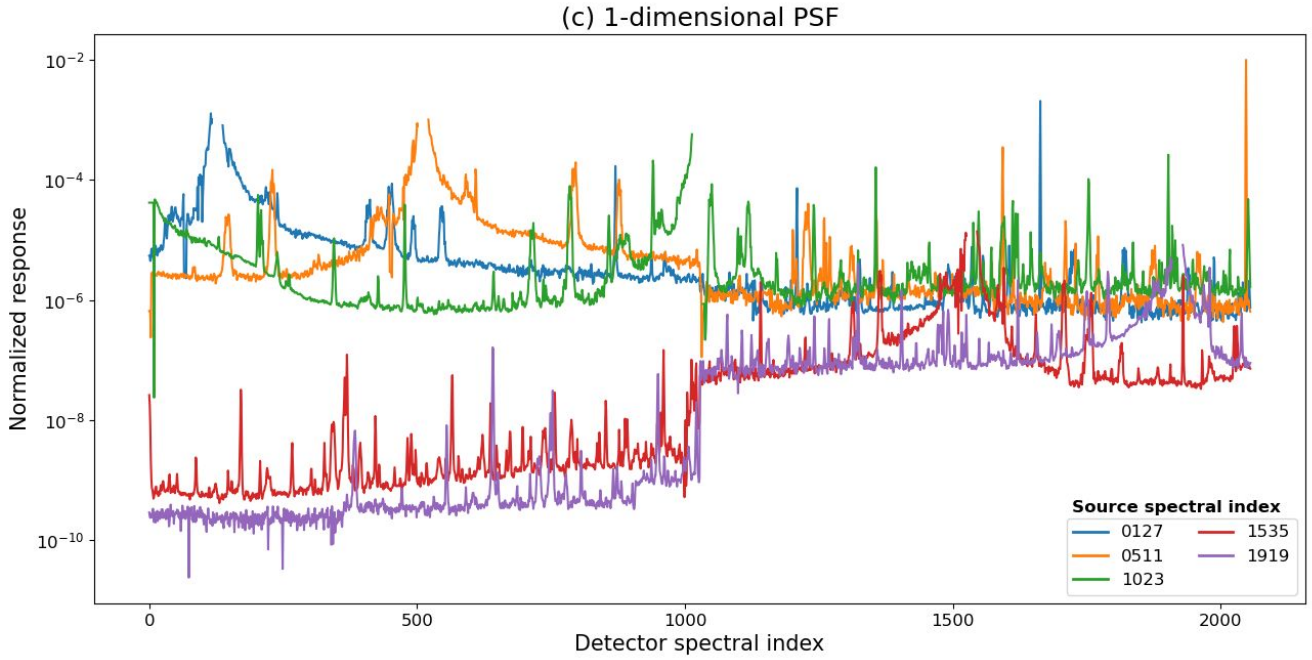
Measured signals

Identity

In-band signals (without stray light)





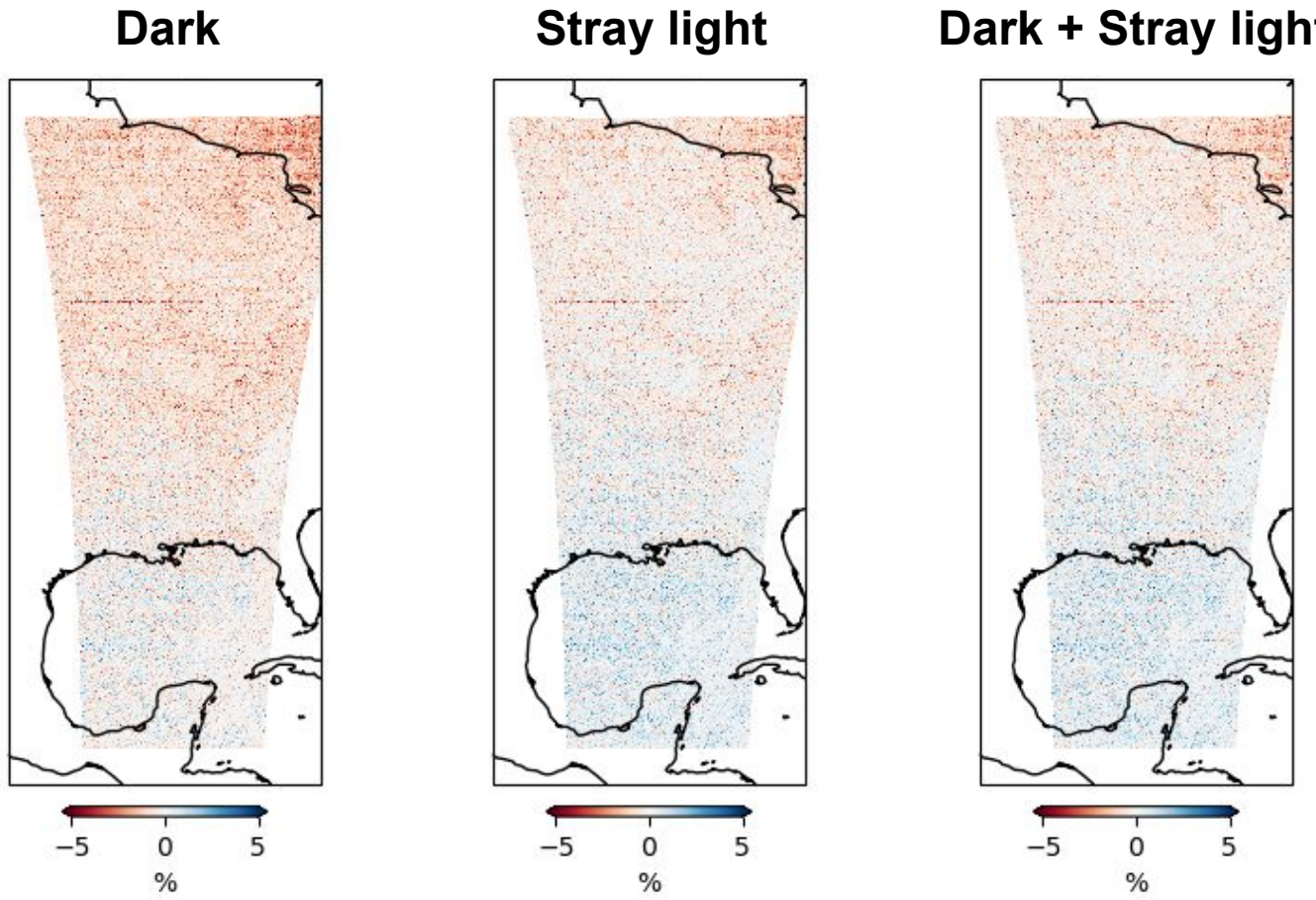


[PSF data processing: David Flittner]

Impact of Level 1 updates on Level 2 retrieval

Changes in NO_2 fitting uncertainties – 03/28/2024 12:50:15 UTC

Red: Uncertainty decreased
Blue: Uncertainty increased

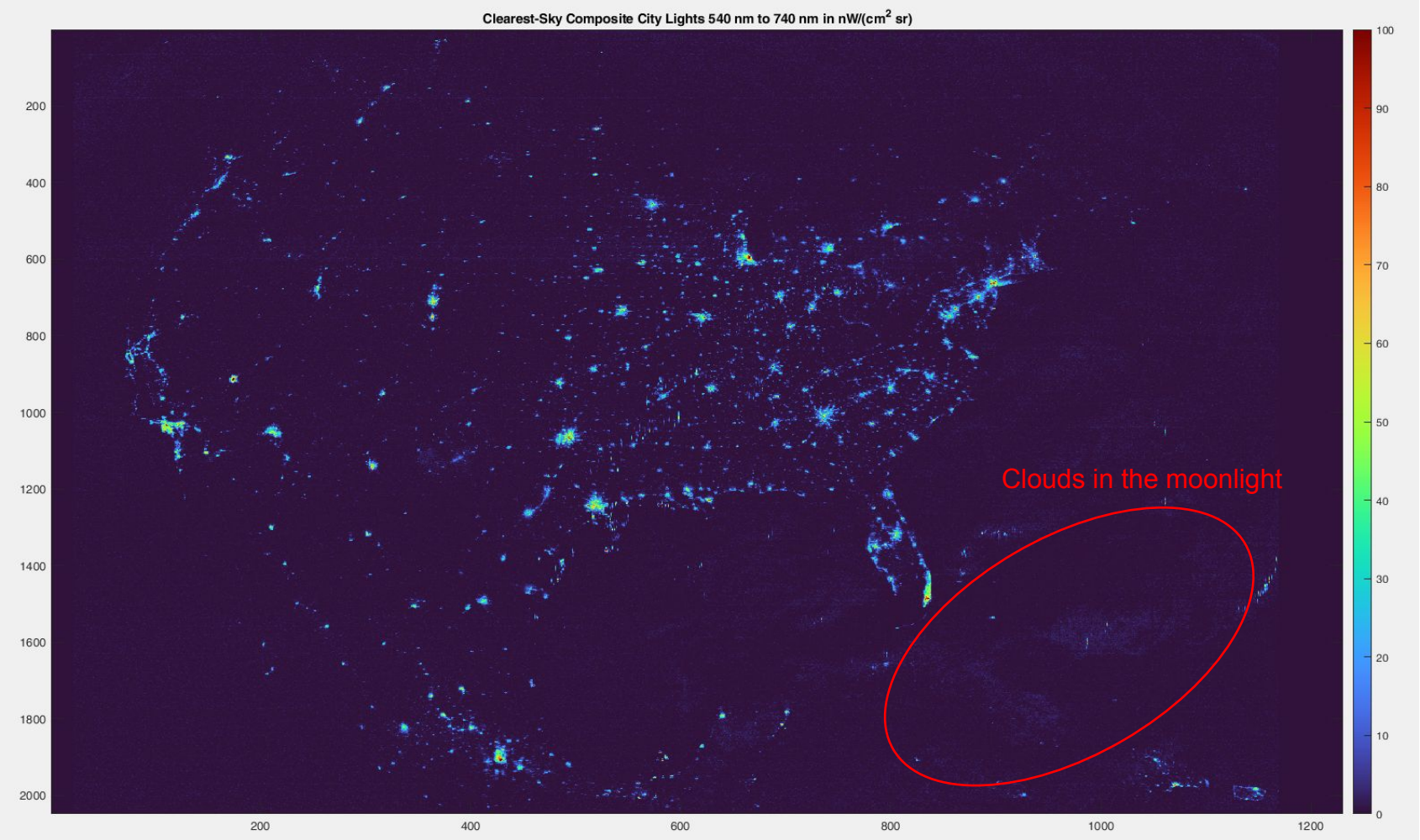


[Credit: Caroline Nowlan]

Uncertainties decreased in general, especially for low signals (high solar zenith angles).

City lights (Post-processed RADT)

6-s exposure composite (March 2024)

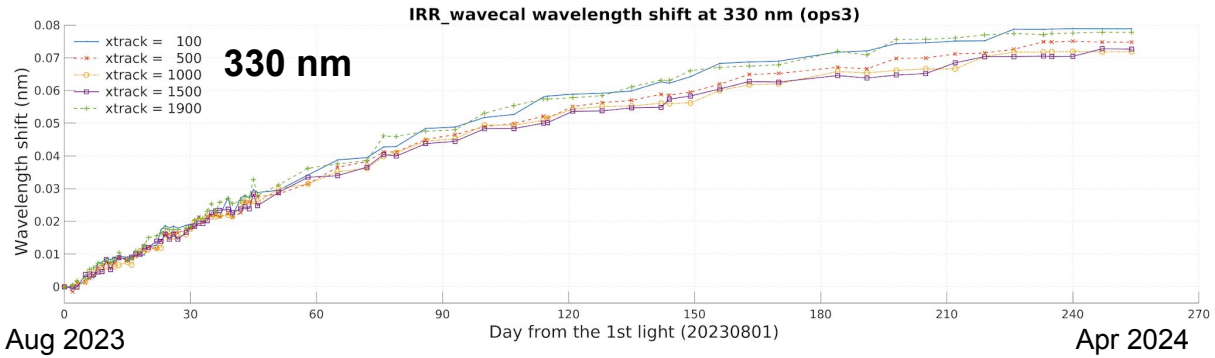


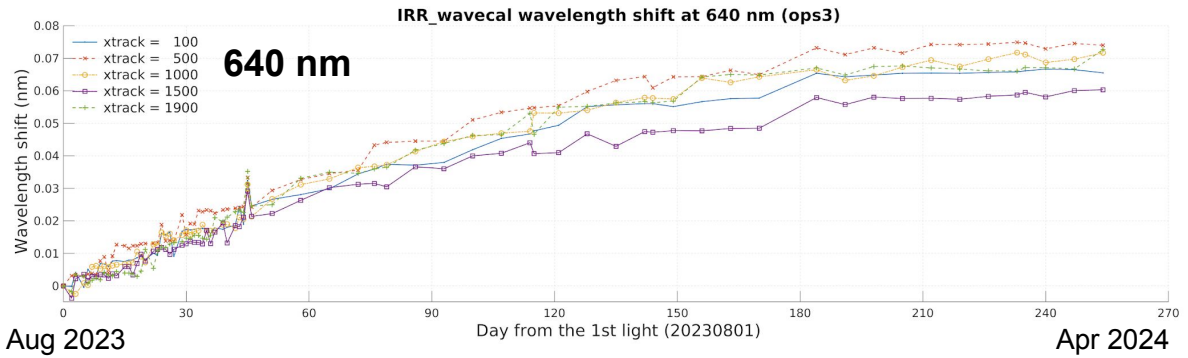
[Credit: James Carr]

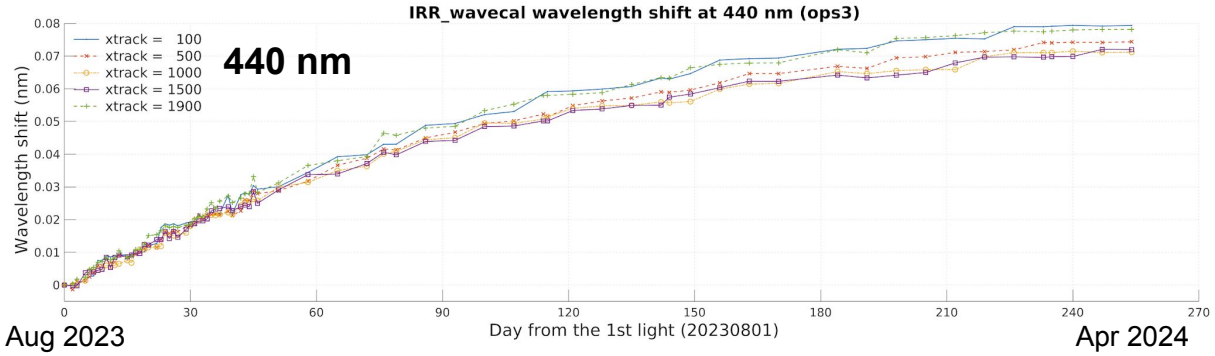
Radiance derivation □ Post-processing (de-speckling, de-streaking, etc.) □ Composite

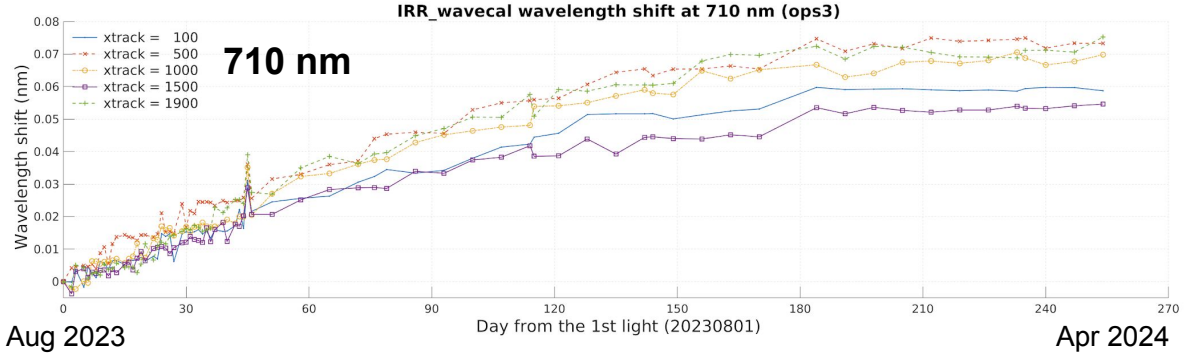
Trending

Wavelength shift – Solar irradiance









[Credit: Weizhen Hou]

Wavelength shifts have increased across all CCD pixels, but the rate of change is decreasing.

Trending

Slit function (super-Gaussian) – Solar irradiance

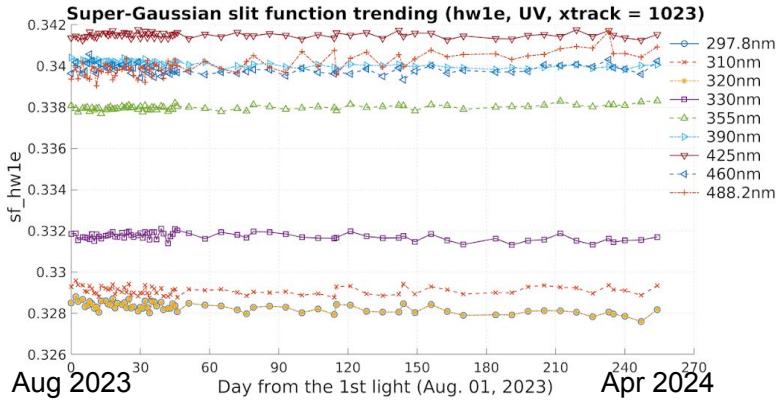
Width parameter

(half-width at 1/eth maximum)

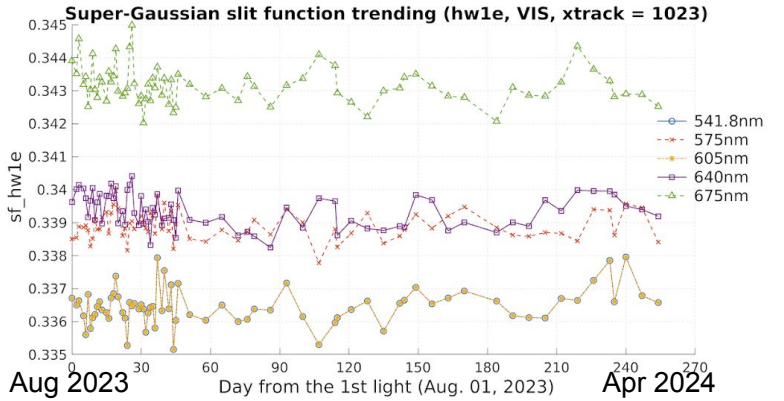
Shape parameter

(the larger the value, the flatter the top)

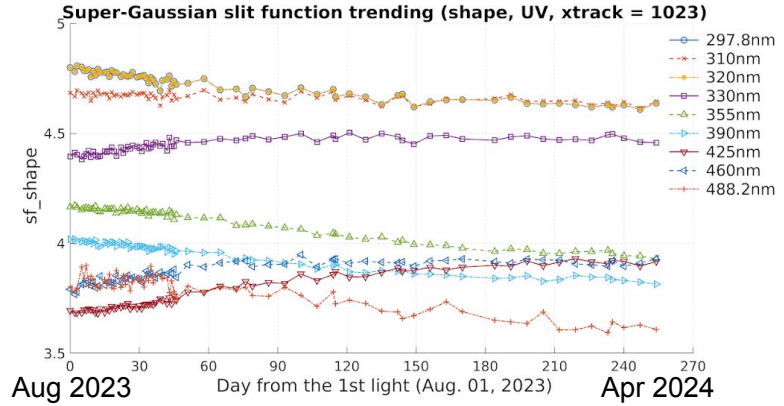
UV



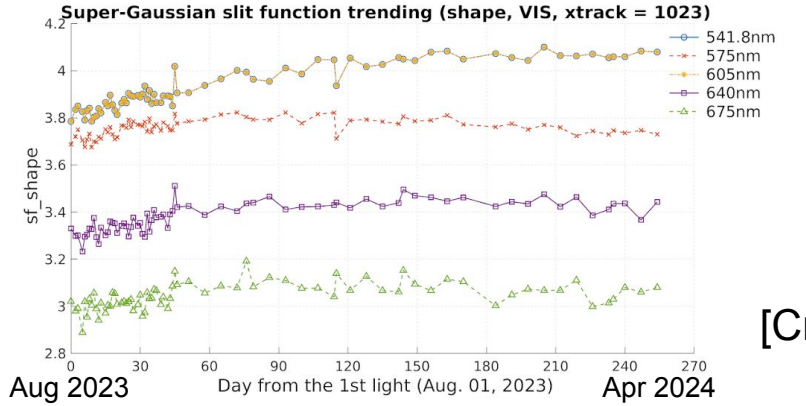
VIS



UV



VIS



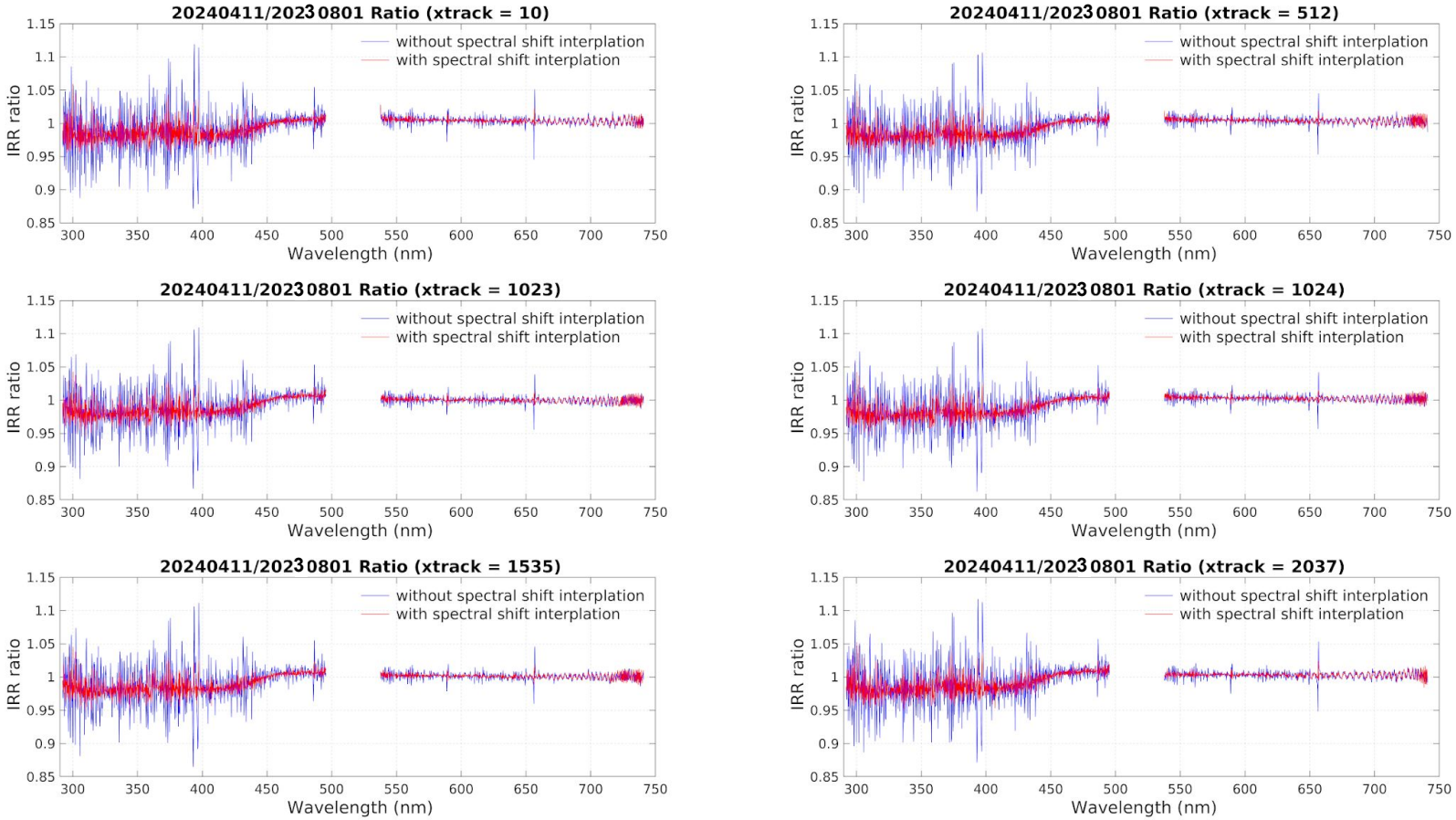
[Credit: Weizhen Hou]

Stable throughout the ~8-month period

Trending

Degradation in solar irradiance

Solar irradiance ratio: April 11, 2024 / August 1, 2023 (~8-month gap)



[Credit: Weizhen Hou]

Changes observed typically within 4% for UV and 2% for VIS (after accounting for the change in Sun-Earth distance)

Summary

- Version 3 Level 1 products will be released soon.
- The twilight radiance product (RADT) has been added.
- The qualities of radiance and irradiance have been improved due to stray light correction and updates to dark current correction.
- Radiance wavelength calibration has been enabled.
- Trending will be performed on a routine basis to monitor and understand the instrumental performance.