

Tropospheric Emissions:
Monitoring of Pollution



TEMPO Level 1 Status

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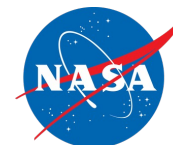
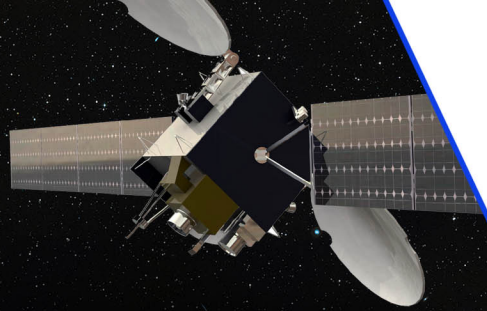
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⁴NOAA/NESDIS ⁵NASA GSFC ⁶BAE ⁷UW–Madison

June 15, 2026

Hourly Measurement of Pollution

60 minutes





Updates in V04 Level 1 Products

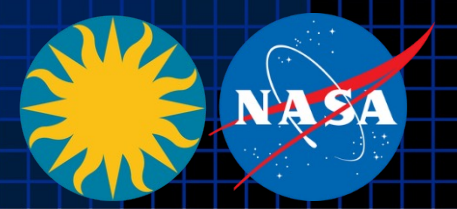


Image processing updates

digital counts

electrons

electrons/s

photons/s/cm²/nm/sr

photons/s/cm²/nm

$$\text{Radiance} = \frac{\{[(L0 / \text{coadd} - \text{offset} - \text{nonlinearity} - \text{crosstalk}) * \text{gain} - \text{smear}] / (\text{integration time}) / \text{prnu} - \text{dark} - (\text{stray light})\} * (\text{calibration coefficient})}{\text{diffuser transmittance}}$$

$$\text{Irradiance} = \frac{\{[(L0 / \text{coadd} - \text{offset} - \text{nonlinearity} - \text{crosstalk}) * \text{gain} - \text{smear}] / (\text{integration time}) / \text{prnu} - \text{dark} - (\text{stray light})\} * (\text{calibration coefficient})}{\text{diffuser transmittance}}$$

* [red box] : Updated parameters & variables

Updates that had the most significant impact on Level 2 retrievals

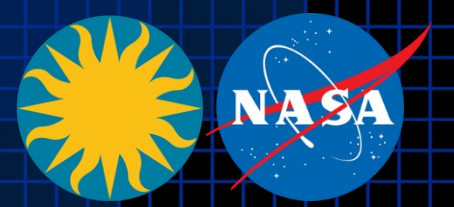
- *Diffuser transmittance*: Improved Sun-normalized radiance → cloud fraction → trace-gas air mass factors
- *Stray light correction*: Improved formaldehyde slant columns in cloudy areas + ozone profile retrieval

Spectral calibration update

- *Slit function parameterization*: Asymmetric super-Gaussian (V03) → Symmetric super-Gaussian (V04)
- ✓ Improved wavelength grid fitting



Toward Version 5



➤ **Planned major updates**

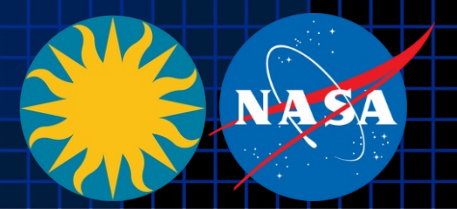
- Instrument degradation correction
- Dynamic bad pixel detection
- Polarization correction

➤ **Planned additional updates**

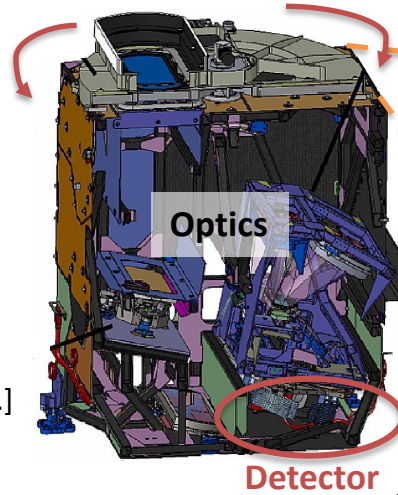
- Etaloning correction update
- Stray light correction update
- Spectral calibration update
- Absolute radiometric calibration update



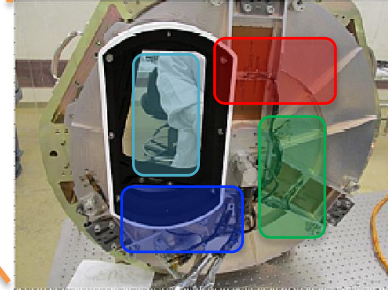
Instrument Degradation



Calibration mechanism assembly



Open (Earth) Closed (Dark)



Reference diffuser (Sun, once per 3 months)

Working diffuser (Sun, once per week)

Diffuser degradation

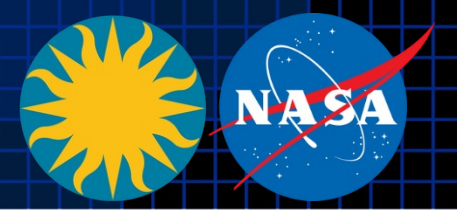
Optics/detector degradation

$$(\text{Solar irradiance}) = (\text{Electric current}) * (\text{Calibration coefficient}) / (\text{Diffuser transmittance})$$

- **V04 implementation:** No degradation correction
- **Planned V05 update:** Calibration coefficient and diffuser transmittance vary with accumulated exposure time.

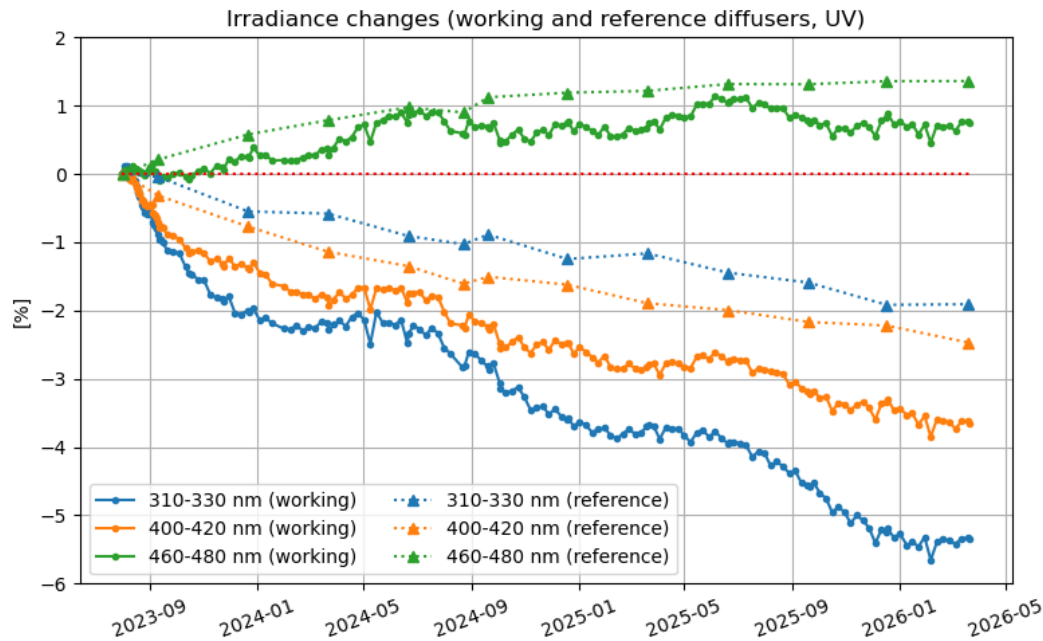


V04 Solar Irradiance Trending

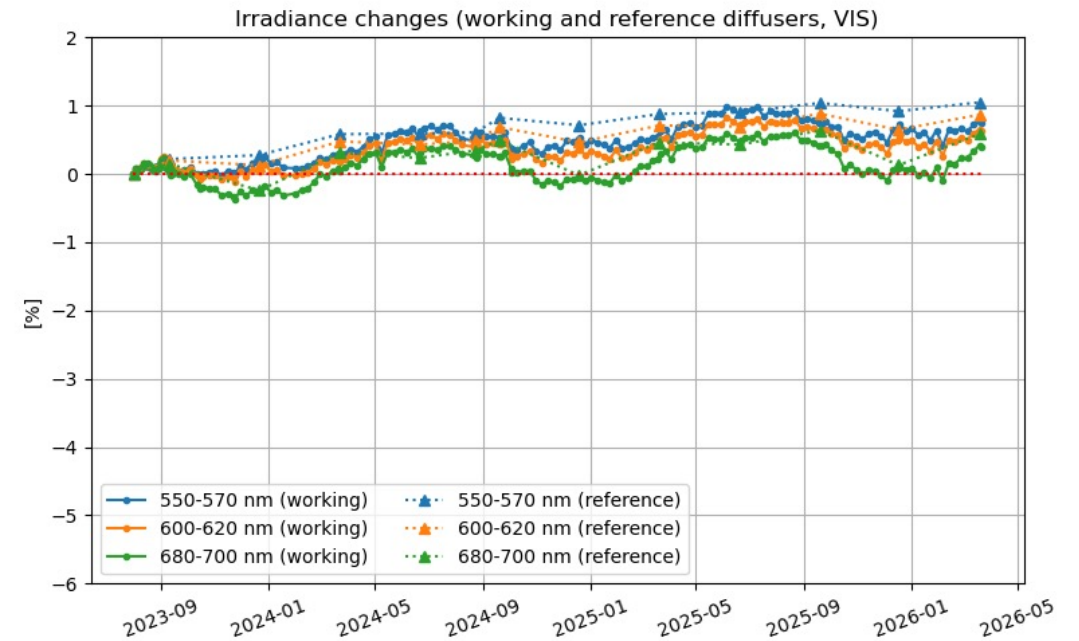


2023/08–2026/03, Earth-Sun-distance-corrected (no degradation correction)

UV (290–490 nm)



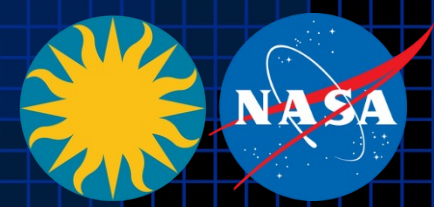
VIS (540–740 nm)



$$\begin{aligned} \text{(V04 TEMPO solar irradiance variation)} &= \text{(Diffuser degradation)} \\ &\text{(after Earth-Sun distance correction)} \\ &+ \text{(Goniometry correction residual)} \rightarrow \text{Seasonal variation} \\ &+ \text{(Optics/detector degradation)} \\ &+ \text{(Solar activity)} \end{aligned}$$

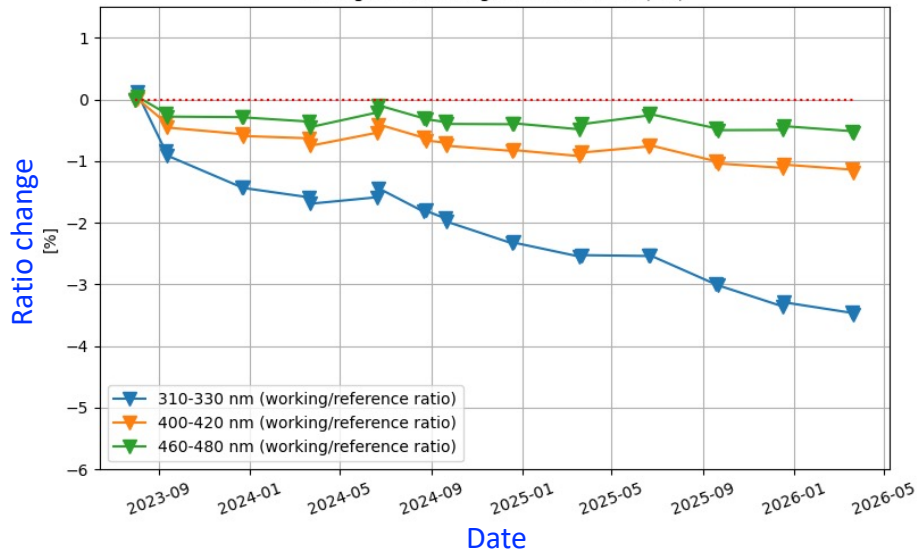


Diffuser Degradation Correction



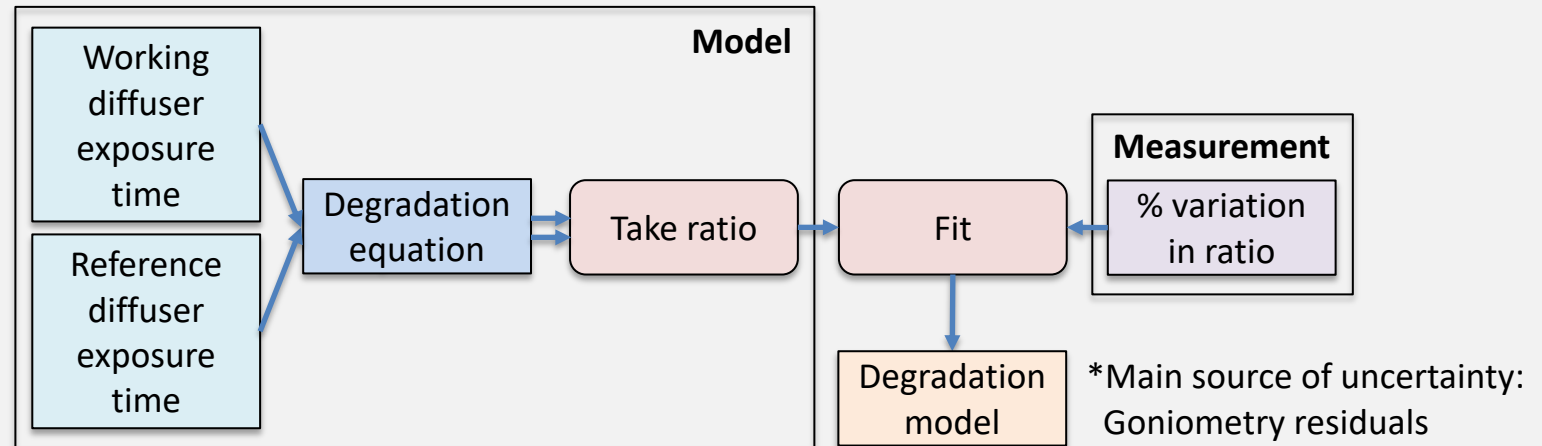
Working-reference irradiance ratio (UV)

Changes in working/reference ratio (UV)



- Theory:**
 (% variation in ratio) is driven by (Diffuser degradation) + (Goniometry correction residual)
~~+ (Optics/detector degradation) + (Solar activity)~~
Nearly cancel out

- Diffuser degradation model:**
 (% degradation of diffuser transmittance) = $f(\text{Accumulated diffuser exposure time})$

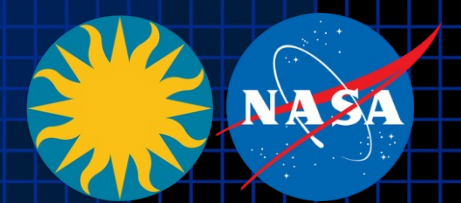


- Goal:** Perform both retrospective and prospective corrections, using the degradation model.

Current progress: (1) An initial version of the diffuser degradation model has been developed (see [Dave Flittner's](#) presentation).
 (2) The impact on total ozone retrieval has been investigated (see [Junsung Park's](#) presentation).

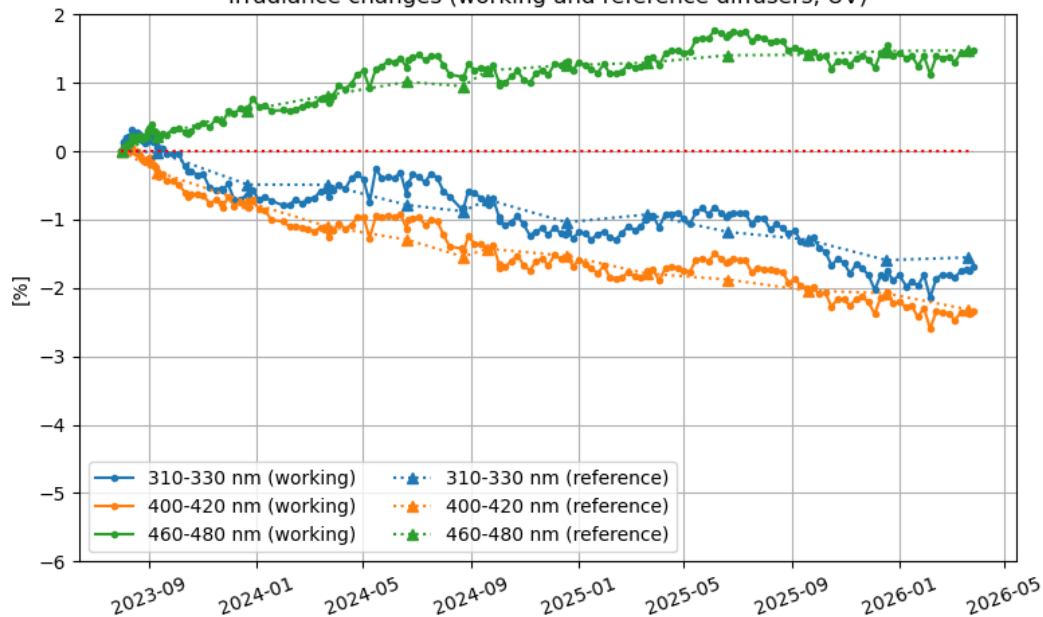


Optics/Detector Degradation Correction



After diffuser degradation correction (UV)

Irradiance changes (working and reference diffusers, UV)



$$\begin{aligned} (\text{Solar irradiance variation}) &= \cancel{(\text{Diffuser degradation})} \\ &+ (\text{Goniometry correction residual}) \rightarrow \text{Seasonal variation} \\ &+ (\text{Optics/detector degradation}) \\ &+ (\text{Solar activity}) \end{aligned}$$

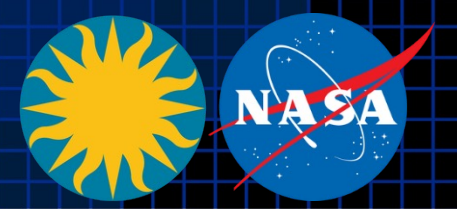
- (Goniometry correction residual) = $f(\text{Day of year})$
- (Optics/detector degradation) = $f(\text{Accumulated optics/detector exposure time})$
 $\sim f(\text{Days since first light})$

Goal: Establish the two functions and perform both retrospective and prospective corrections.

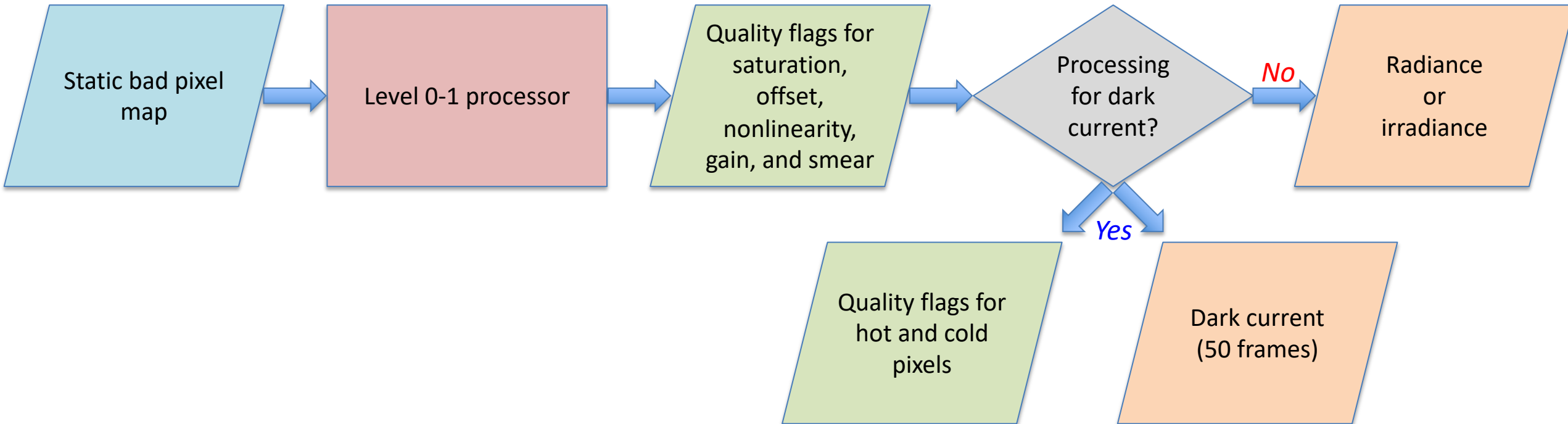
*Note: Strong solar lines should be avoided when deriving the functions.



Dynamic Bad Pixel Detection

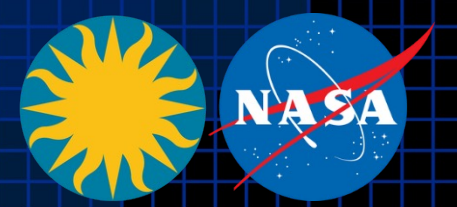


Current approach

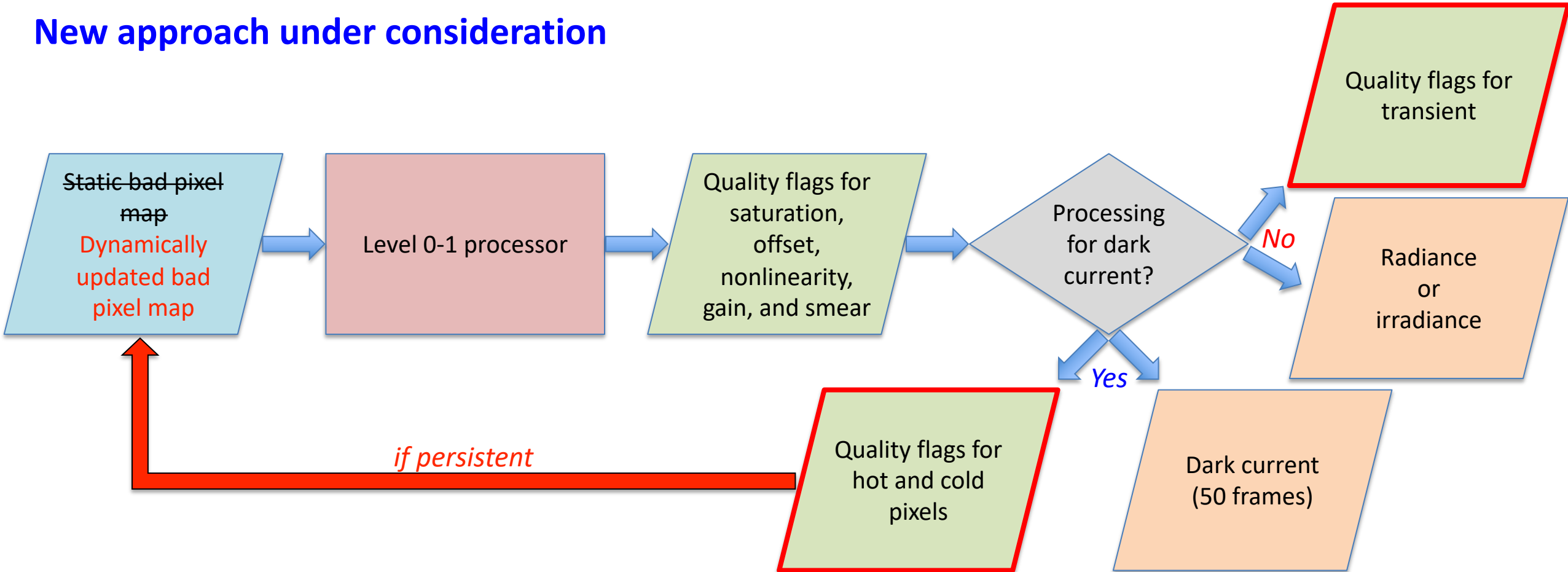




Dynamic Bad Pixel Detection



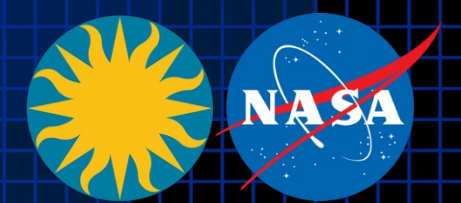
New approach under consideration



Most significant outcome: Level 2 retrievals are further stabilized by using only reliable CCD pixels.

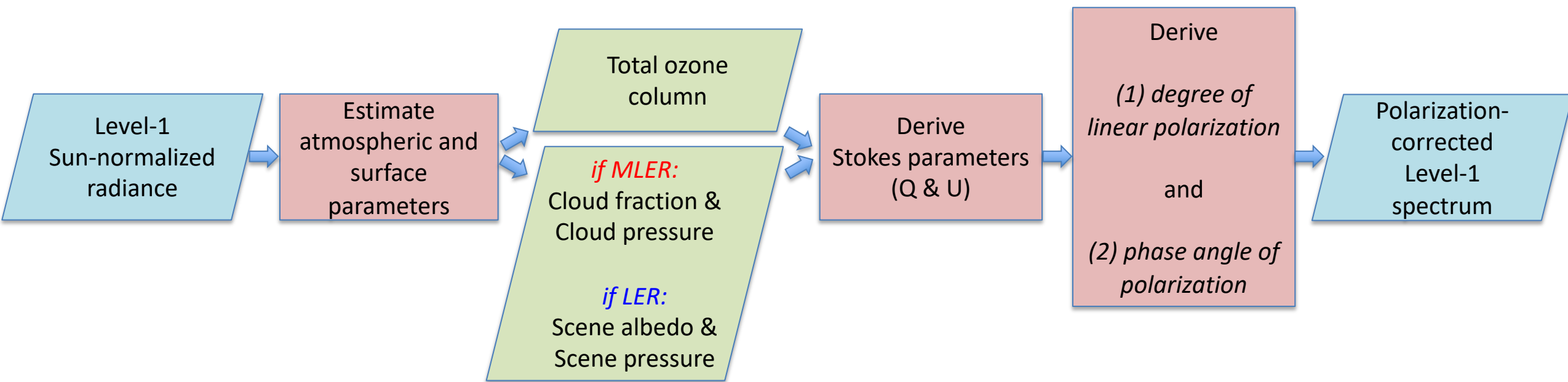


Polarization Correction



Earth radiance

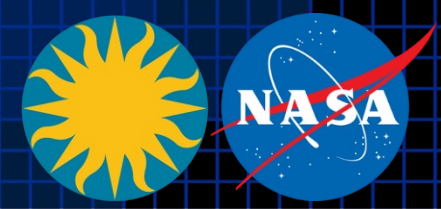
Source of polarization: Earth's atmosphere & surface



Most significant outcome: Fitting residuals in Level 2 retrievals are expected to decrease.

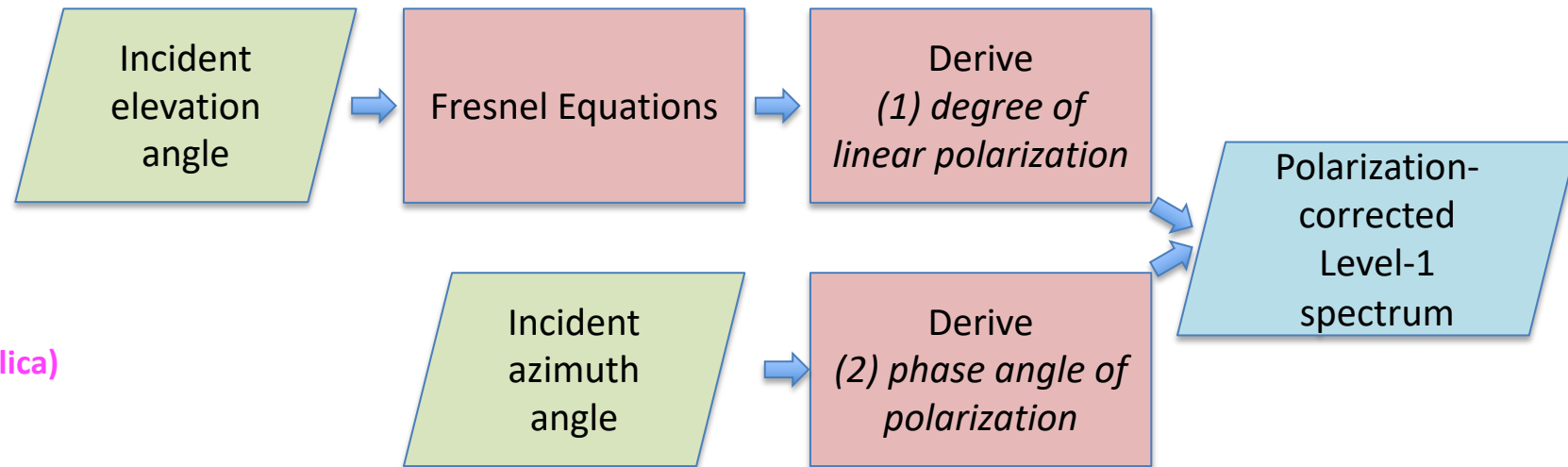
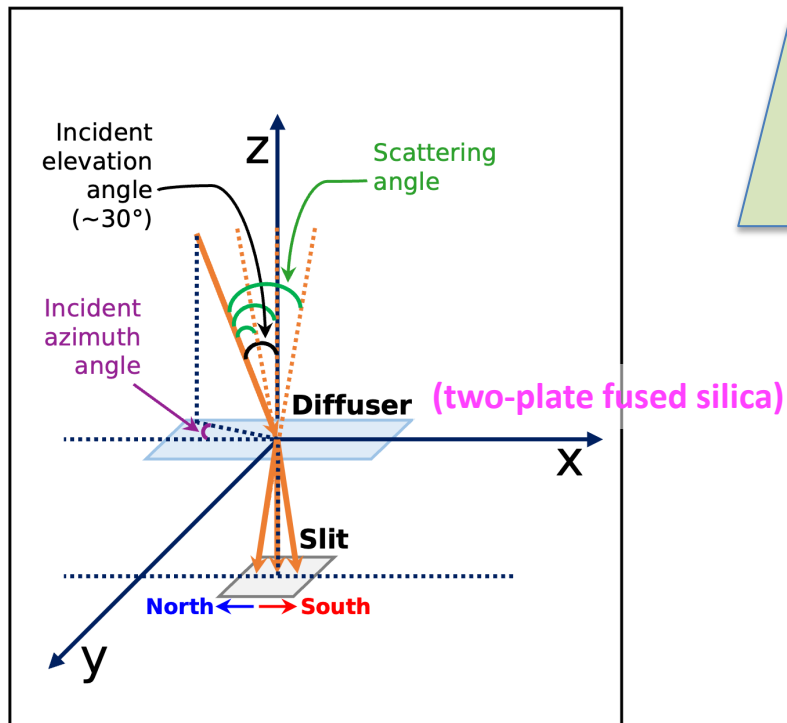


Polarization Correction



Solar irradiance

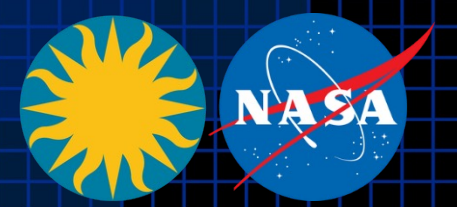
Source of polarization: Solar diffuser



Most significant outcome: Fitting residuals in Level 2 retrievals are expected to decrease.

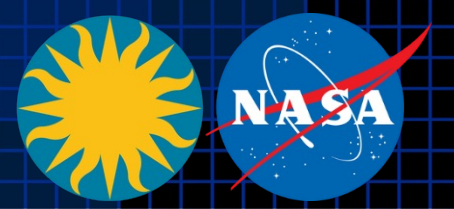


Summary



- In Version 4, we enhanced
 - Absolute radiometric calibration
 - Stray light correction
 - Spectral calibration
 - Diffuser goniometry correction, etalon fringe correction, parity normalization, dark current correction, and smear correction.

- For Version 5, we plan to implement
 - Instrument degradation correction
 - Dynamic bad pixel detection
 - Polarization correction
 - Updated etaloning correction, stray light correction, spectral calibration, and absolute radiometric calibration



Thank you for your attention!

