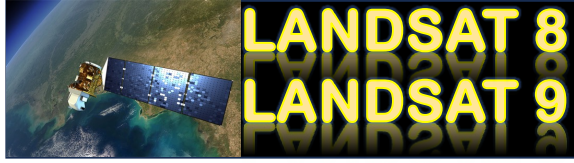
On-orbit temporal trending of the OLI radiance scale cross-cal for the Landsat mini-constellation using solar diffuser panels

Raviv Levy (SSAI), Kurtis Thome (NASA-GSFC)

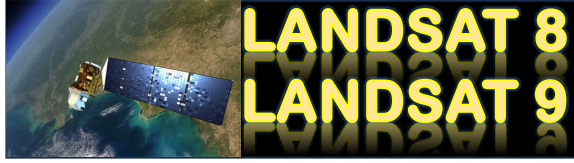


Landsat 8/9 OLI overview

- Pushbroom configuration imaging spectrometer systems
  - 8 spectral bands + panchromatic band
  - 6916 detectors in each band (13832 detectors for panchromatic)
- On-board calibration system
  - Shutter
  - Lamps
  - 2 x Space grade Spectralon™ NIST traceable reflective diffuser panels

OLI Spectral bands

Band #	Name	CW [μm]
1	CA (Costal Aerosol)	0.443
2	Blue	0.482
3	Green	0.562
4	Red	0.655
5	NIR (Near IR)	0.865
6	SWIR1	1.610
7	SWIR2	2.200
8	Pan (Panchromatic)	0.590
9	Cirrus	1.375

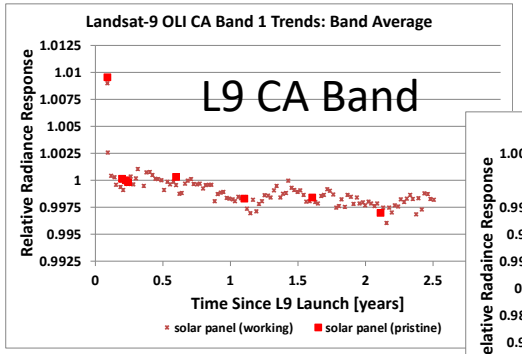


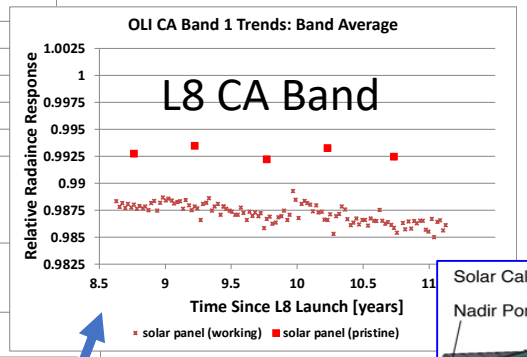
The OLI solar calibration assembly

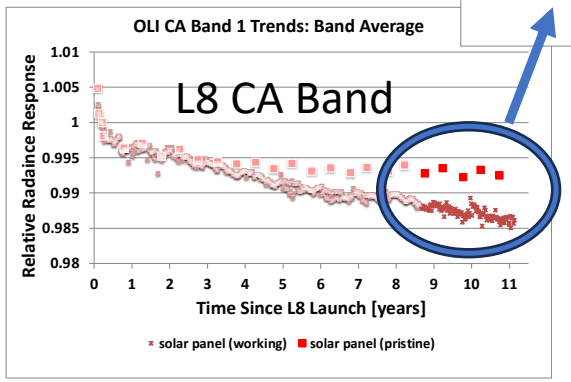
3 style of Solar Diffuser collects

Routine – 2 seconds. ; **ITS -** Sequence of variable 20 integration time (only for working) ;

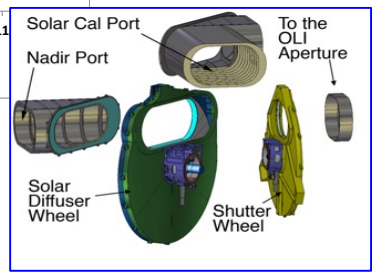
Extended – 60 seconds (only for working)





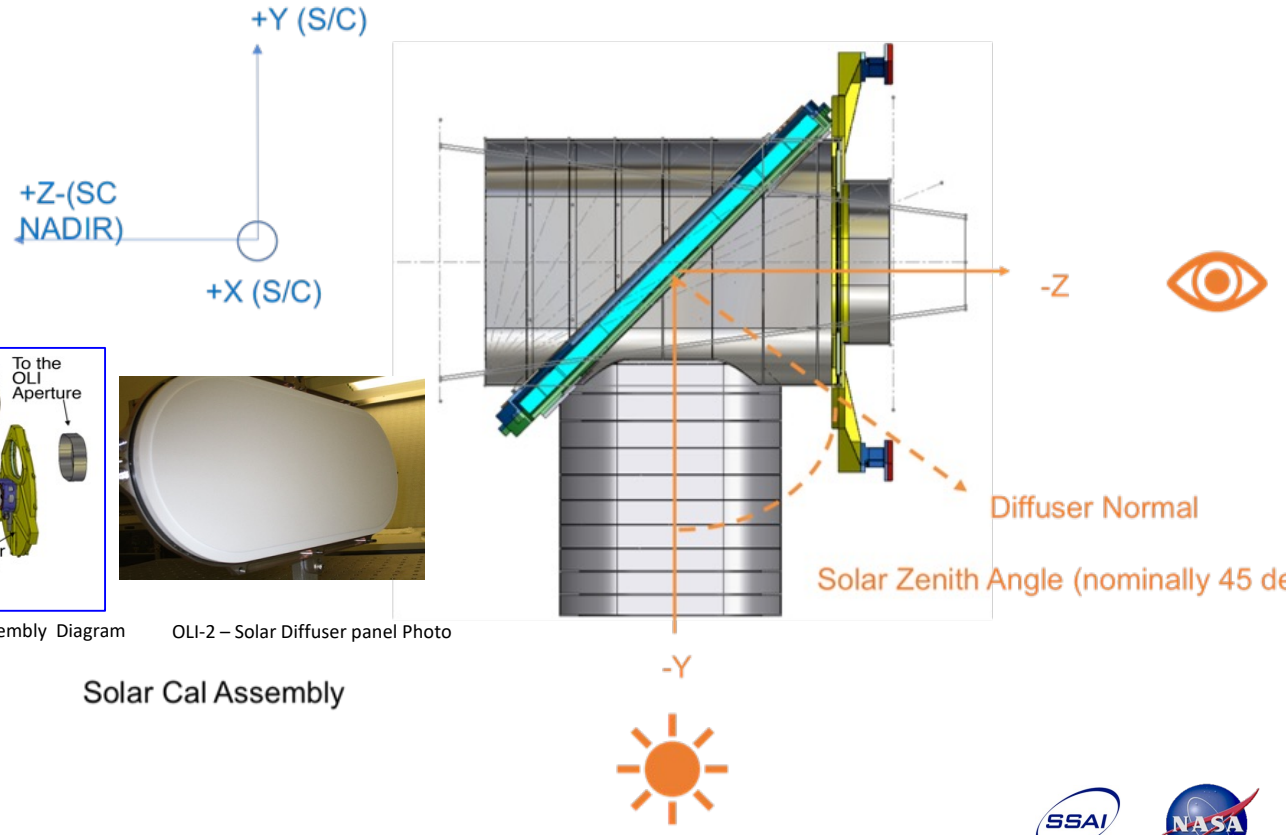


Normalized solar Diffuser response trends

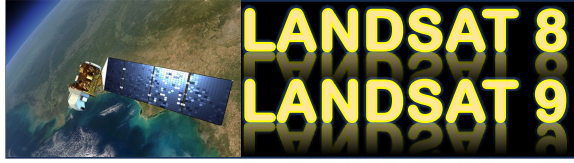


OLII-1 & OLI-2 – Calibration assembly Diagram

OLI-2 – Solar Diffuser panel Photo



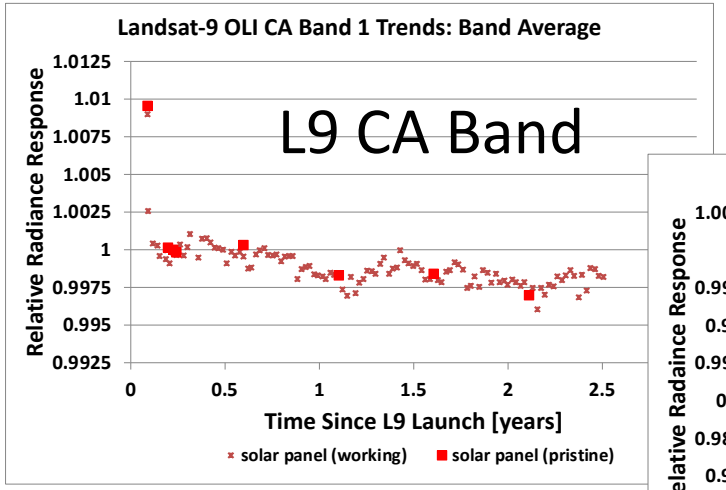
Solar Cal Assembly

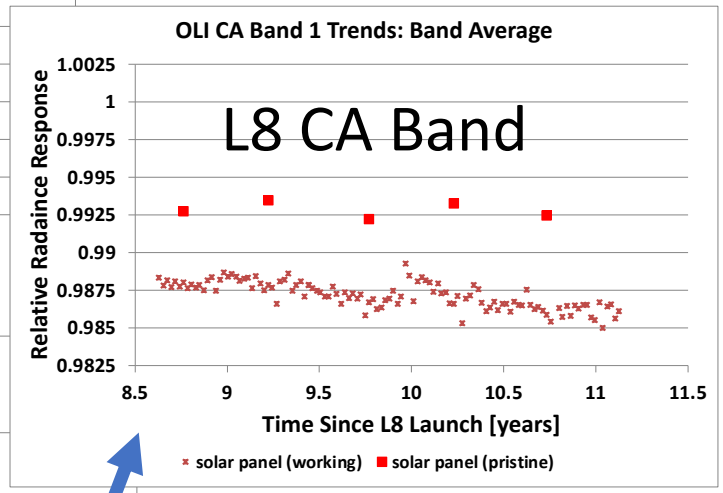


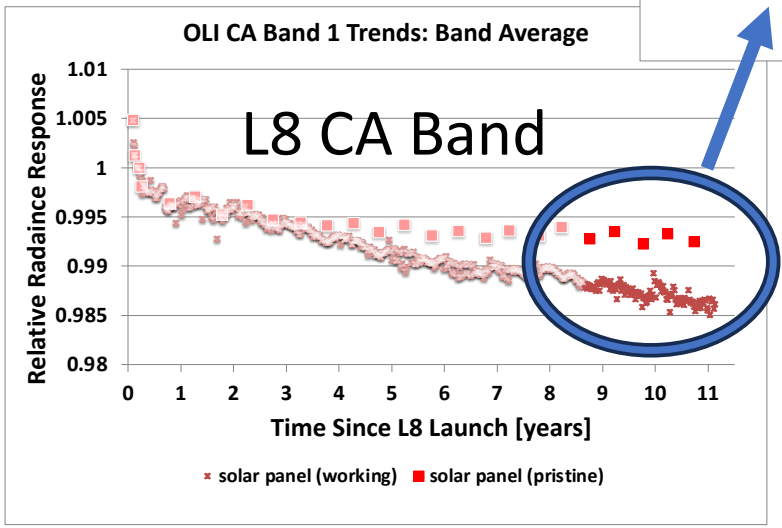
Overview and motivation

- Initial harmonization between Landsat 8 and Landsat 9 OLI.
- L8 to L9 Solar Diffuser Radiance Ratios.

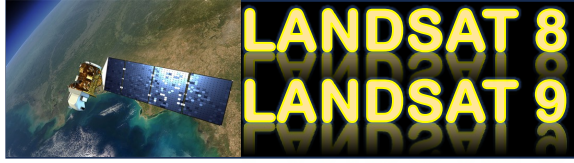
Normalized Solar Diffuser response trends







Plots highlighting timeframe differences between L9 and L8.

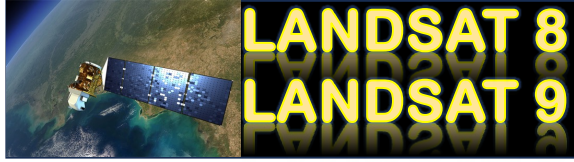


The L8/L9 X-cal

- Initial cross-cal : limited to 2 periods early in the mission operation
  - The 5-days underfly[1] (before L9 reach the WRS2 tracking orbit)
  - Earth scene based EPICs analysis[2,3] early in 2022 (while at WRS2 orbit)
- Tracked via vicarious with uncertainties at levels of <2.5% (1-sigma)

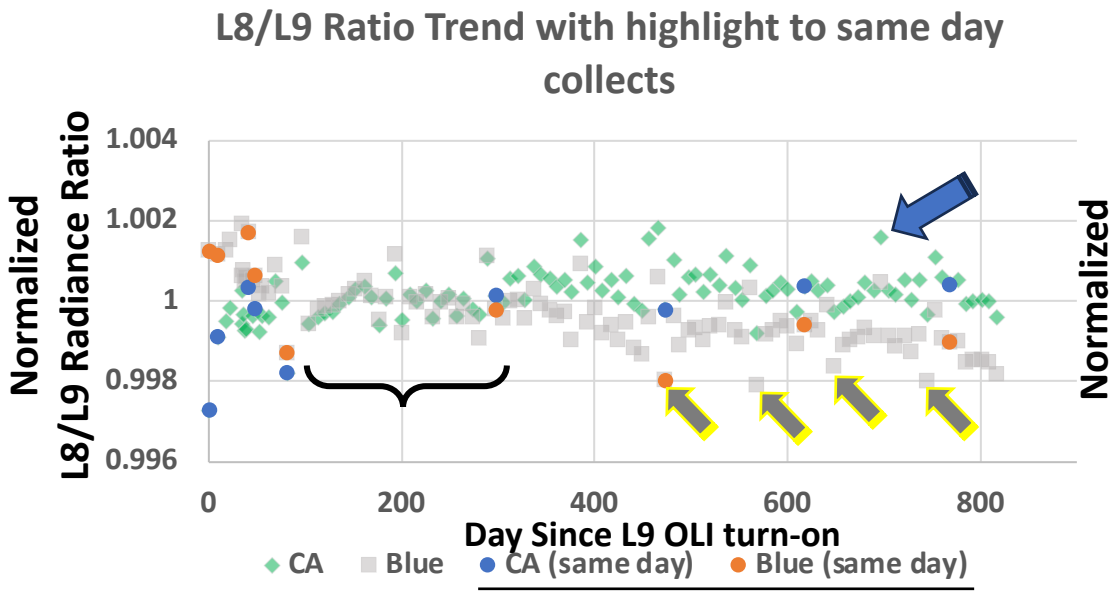
At same time period - weekly collects of Solar cal data , and newly added same day simultaneous diffusers collects.

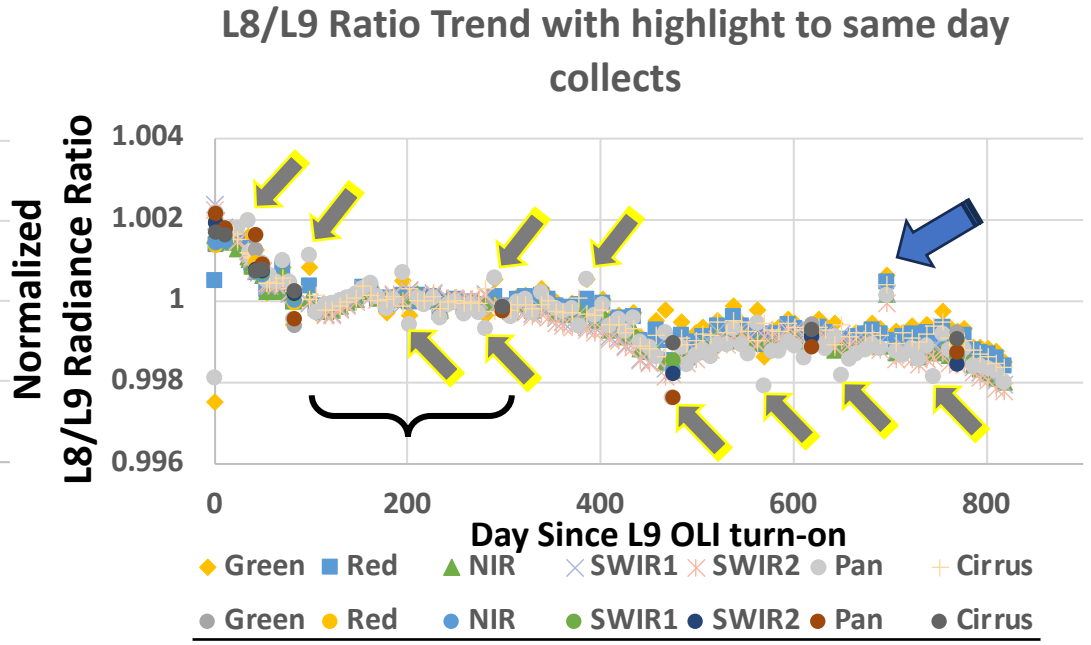
1: https://doi.org/10.3390/rs15071788
2: https://doi.org/10.3390/rs15092330
3: https://doi.org/10.3390/rs14246216



Continuum of relative radiometric scales comparisons

Checking sensitivity of Spacecraft events and Collect type variations





Plots illustrate that for nearly 2.25yrs of on-orbit operation the Landsat mini constellation has locked its relative calibration to within

+/- 0.3%

: point to Jump in trend (9/27/23) -> due to impact of DMU#022 (impacts all bands)

: Points to ratio that **mix ITS Solar data** from either L9 and L8 **with Routine collects (impacts all bands)**

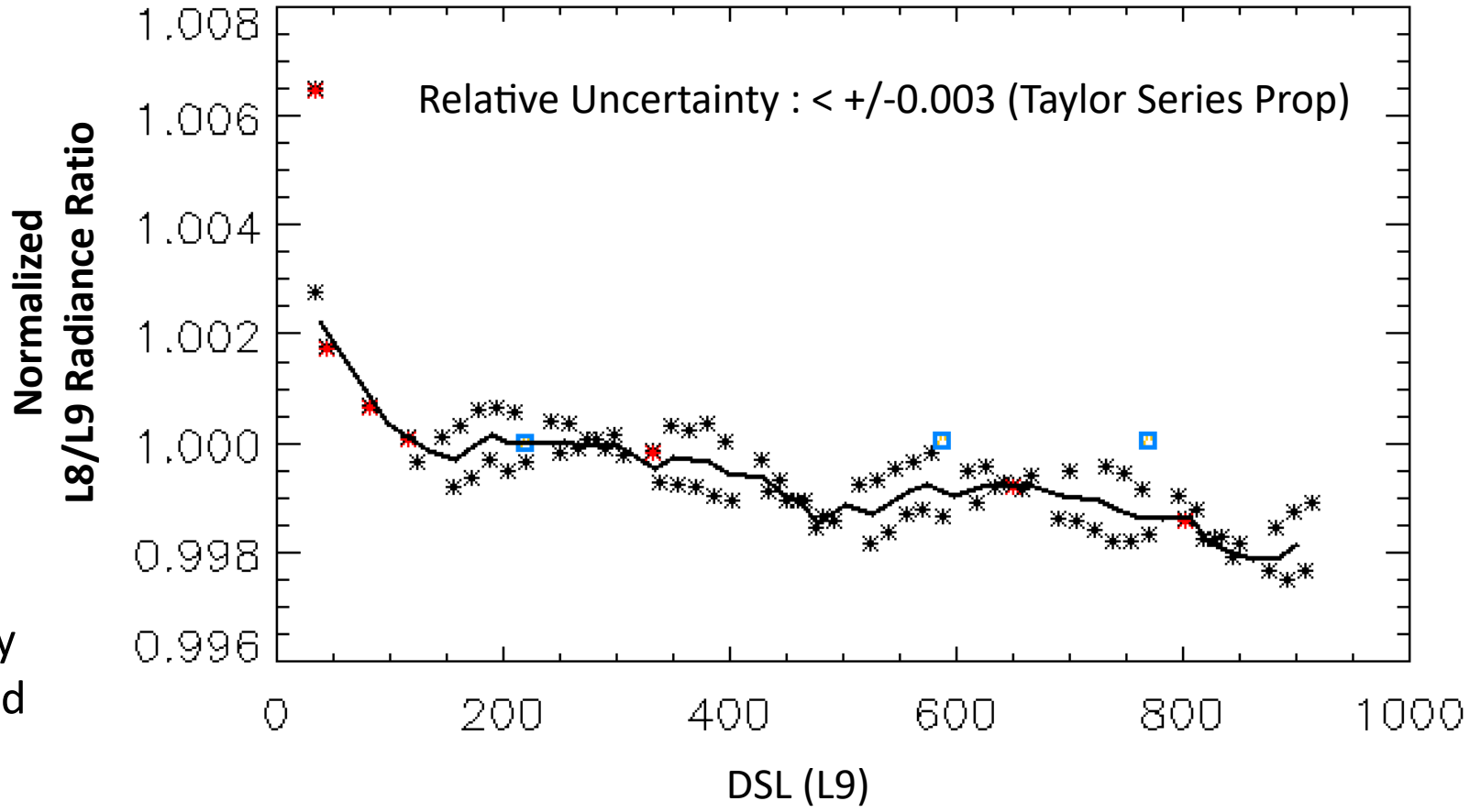
Plots include 9 same-day collects (non-shaded circles underlined in plot legend)

Reference L1R based

Cleaned up trends only nominal collects for working and pristine diffusers

Band Avg SWIR 1 relative radiometric scales comparisons

Official L1R based



Working SD

* same day

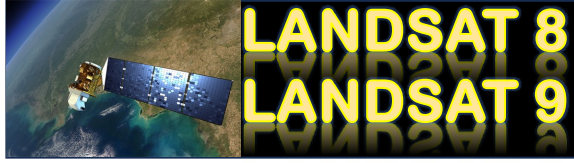
* +/- 1 day

— Avg of +/- 1day

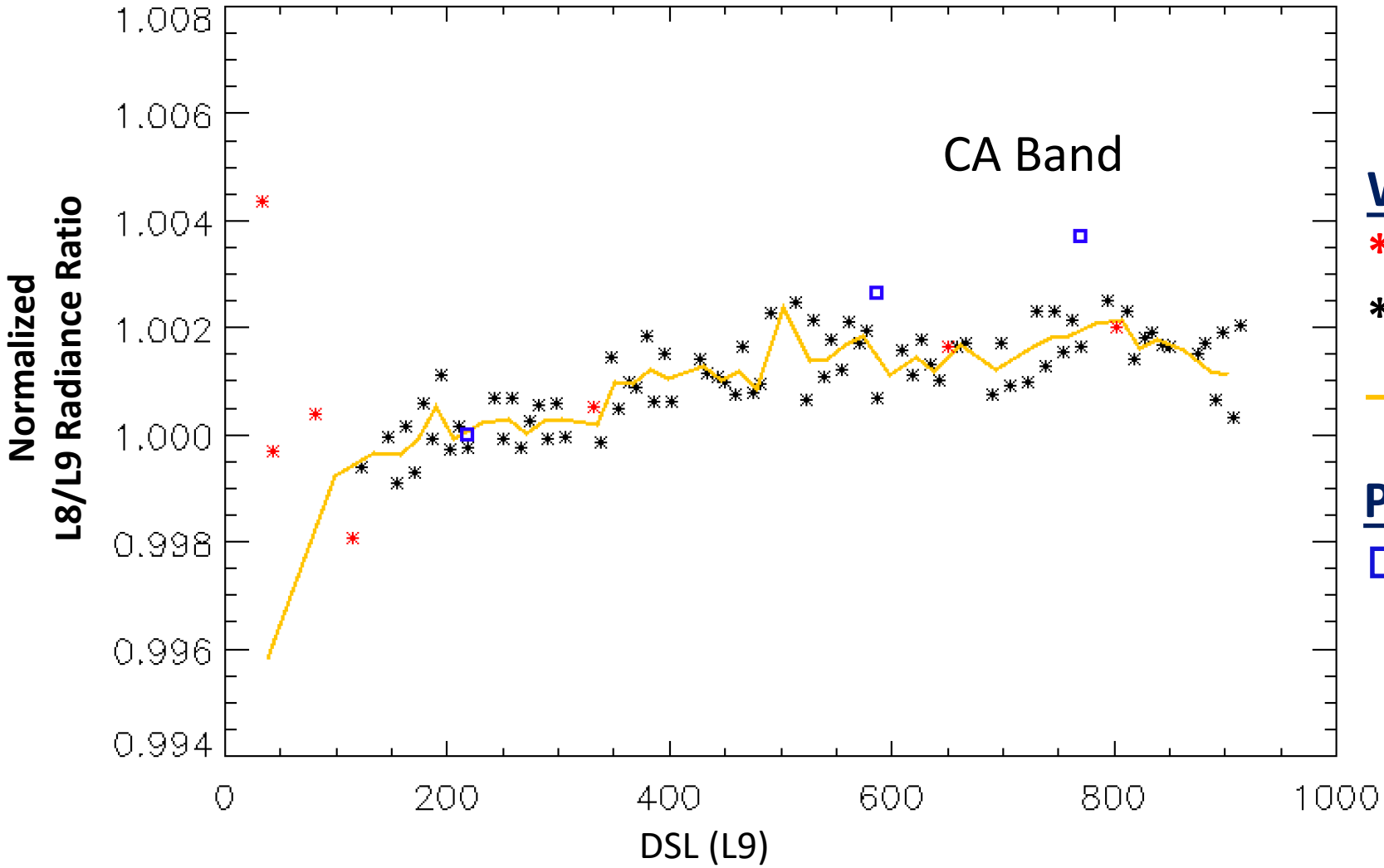
Pristine SD

□ +/- 1 day

Omitted same day collects that mixed non-routine solar collects.



Clear set of Plots bands 1 though 2



Working SD

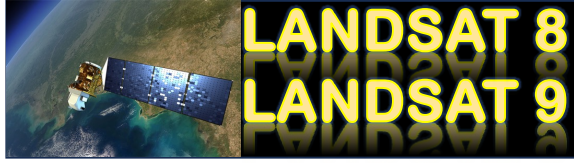
* same day

* +/- 1 day

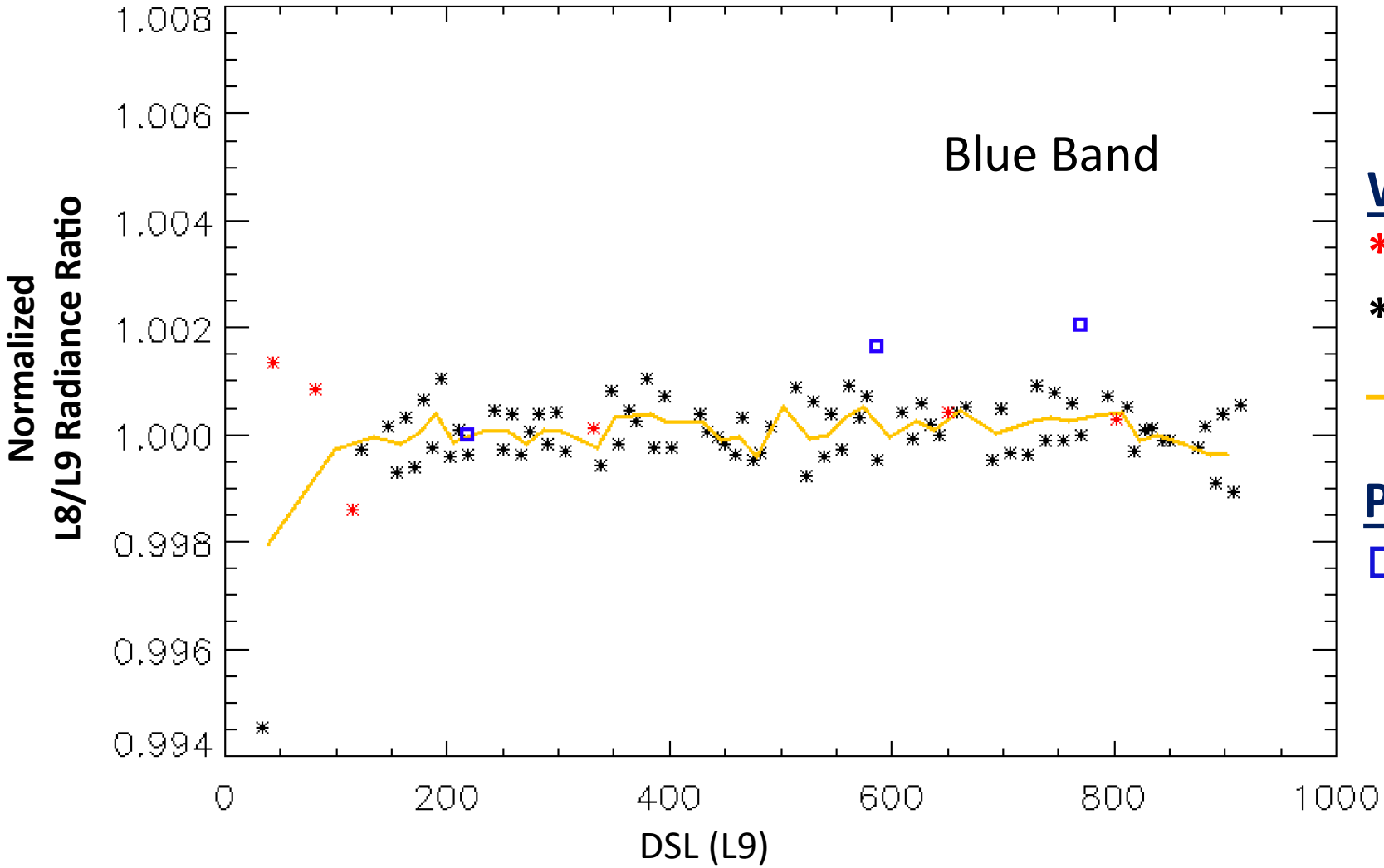
— Avg of +/- 1day

Pristine SD

□ +/- 1 day



Clear set of Plots bands 1 though 2



Working SD

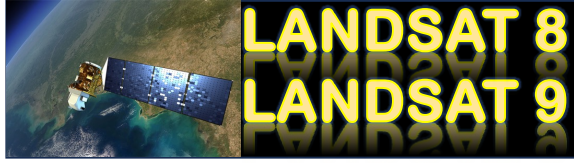
* same day

* +/- 1 day

— Avg of +/- 1day

Pristine SD

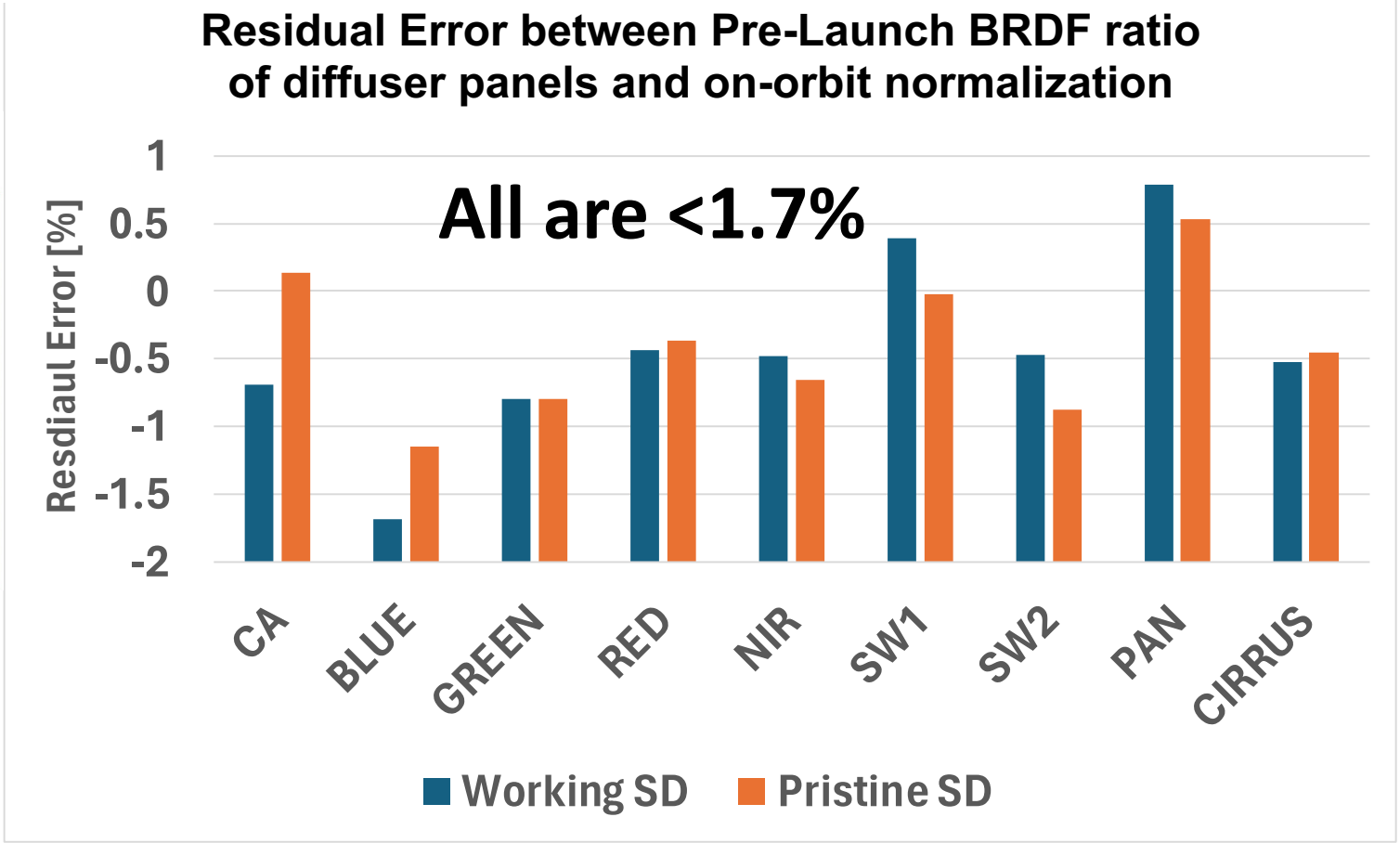
□ +/- 1 day



SD Radiance product ratio validation vs expected pre-launch diffuser RF ratio

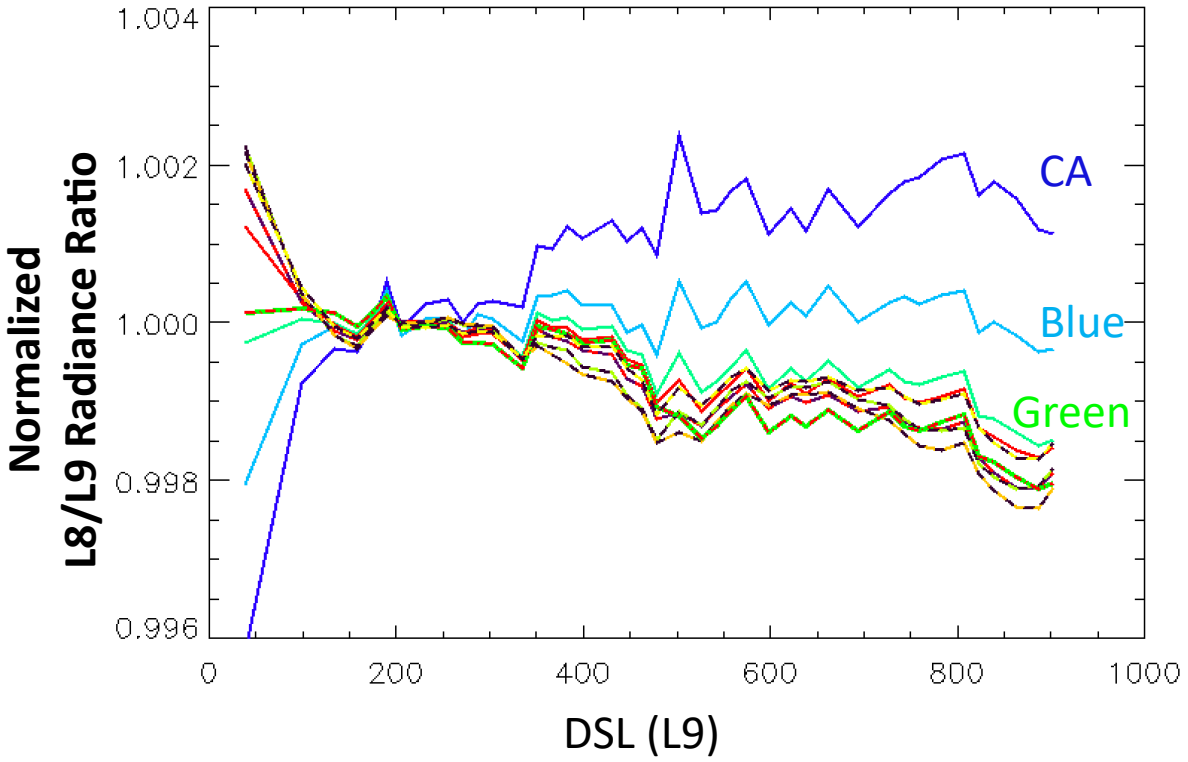
Checking how big is the error in applying normalization

Special Band	Pre-Launch Working DS ratio L8/L9	Pre-Launch Pristine DS ratio L8/L9	Working SD Mean ratio of DSL 100-300	Pristine SD ratio early in the mission	Working SD residual error [%]	Pristine SD residual error [%]
CA	1.0025962	0.9943808	0.99564481	0.99580479	-0.69	0.14
BLUE	1.0088266	1.0005224	0.99176234	0.98897	-1.69	-1.15
GREEN	1.0023358	0.9962028	0.994272	0.988277	-0.80	-0.80
RED	0.9996778	0.9916682	0.995319	0.987999	-0.44	-0.37
NIR	0.9978643	0.9917259	0.993104	0.98514	-0.48	-0.66
SW1	0.9896674	0.9866557	0.993559	0.986494	0.39	-0.02
SW2	0.9954068	0.9899383	0.990745	0.981257	-0.47	-0.88
PAN	1.0038399	1	1.01175	1.00532	0.79	0.53
CIRRUS	0.9950487	0.9868473	0.989839	0.982432	-0.52	-0.45

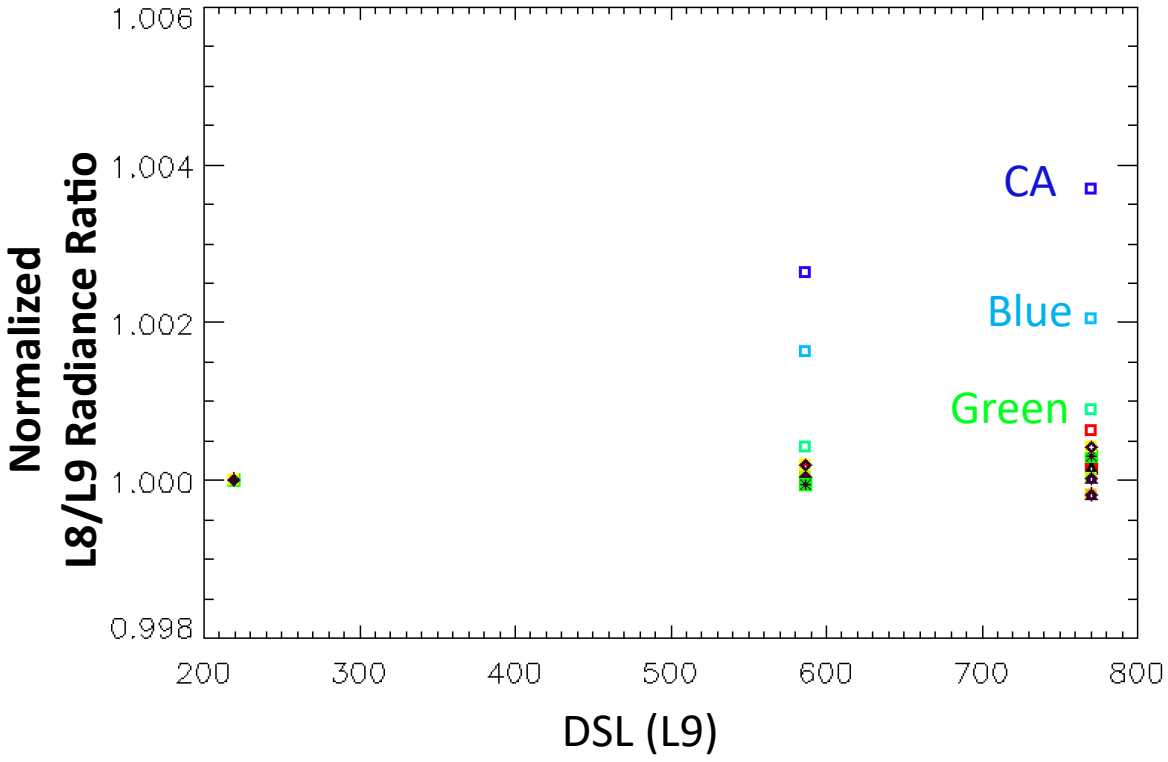


All bands average trend plots and same date points for Working and Pristine Diffusers

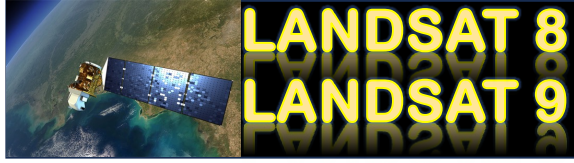
Working Diffuser



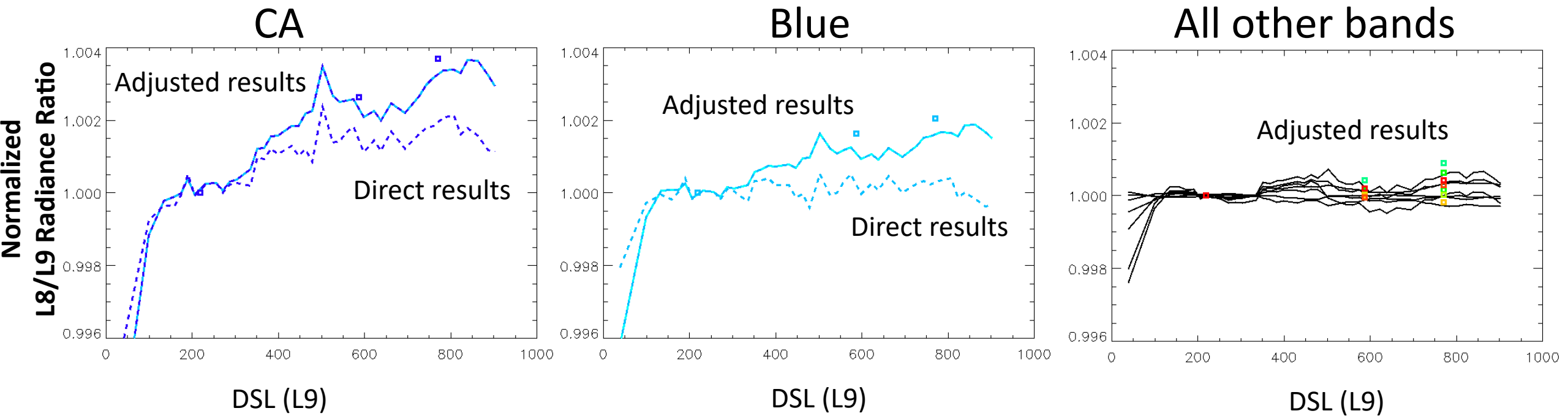
Pristine Diffuser



Up trend in CA and Blue hints on possible L9 change in OLI throughput response.
Correction estimates to L9 based on Pristine Diffuser trends are ~0.4% in CA and ~0.2% in Blue

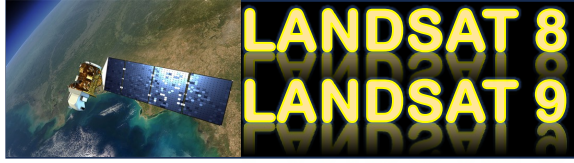


Adjusting to make Working diffuser match Pristine trend by adjusting for avg trend of all 3 SWIR bands



This show that L9 need a linear correction of:

~0.4% in CA and ~0.2% in Blue starting from DSL 770 (early 2Q 2024)

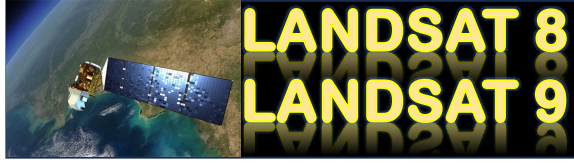


What the results show

- Demonstrating a novel method to track at a level below **0.5%** the relative variation in the cross-calibration of a constellation through the mission lifetime.
- Same day response trend can be emulated by averaging of +/- 1 day collect-pairs.
- OLI CA and Blue bands Pristine Diffuser response hint on a pending calibration update for L9 while the working diffusers ratio seem to mask part of the impact due to aging effects in both OLI system diffusers.
- For OLI spectral bands 3-9 the working diffuser is showing a response change at a rate of <-0.3% in 2.5yrs. (while the Pristine response ratio is nearly flat)
- Residual annual orbit geometry cycles error overlaid in trend is <0.1% p-2-p
- SC and special collect operations impact trend results
  - Non-linearity SD Cal <+/-0.05%
  - DMU <+/- 0.15%

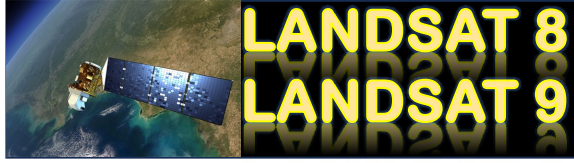
(root cause – likely related to residual temperature impact on any of the following:

Electronics, Optics and diffuser panel)

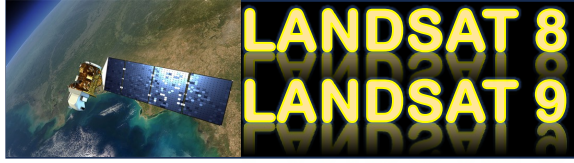


Summary and future solar diffusers cross cal checks

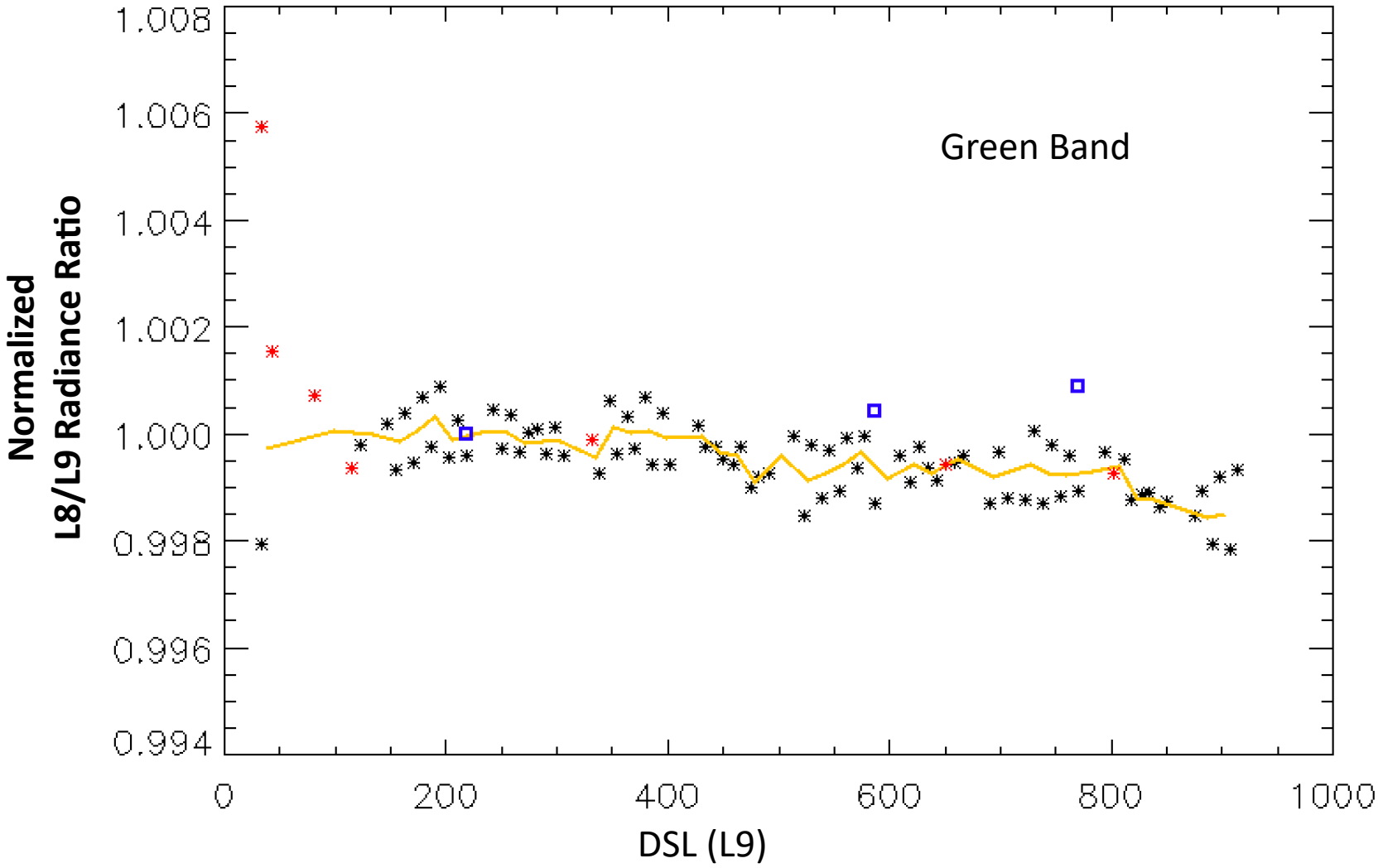
- For Landsat 9 the new OLI reached steady state solar response as early as 30days once SC commenced routine operational state and calibration sequences.
- Based on Pristine diffuser trends in half of L9 mission life we can maintain **< +/-0.1%** cross-cal consistency. It requires calibration updates to both L8 and L9 OLI short spectral bands.
- This method can be applied to larger constellations of sensors that use of solar diffusers. Leading to a single calibration scale per constellation that can be determined early in the mission and tracked overtime.
- This approach has the potential to replace the earth based underfly cross-calibrations.
- Future plan is to demonstrate similar cross-cal analysis on other mini constellations. (MODIS, AUQA, VIIRS , …. other are welcome).
- Knowing the diffuser panel degradation is important for this approach of cross-cal trending.
- With space grade Spectralon at exposure and use plan similar to L8 or L9 working SD we should expect the short wavelength bands to have a panel reflectance change rate of about ~0.2% per year.



Extra SLIDES



Clear set of Plots bands 3 though 9



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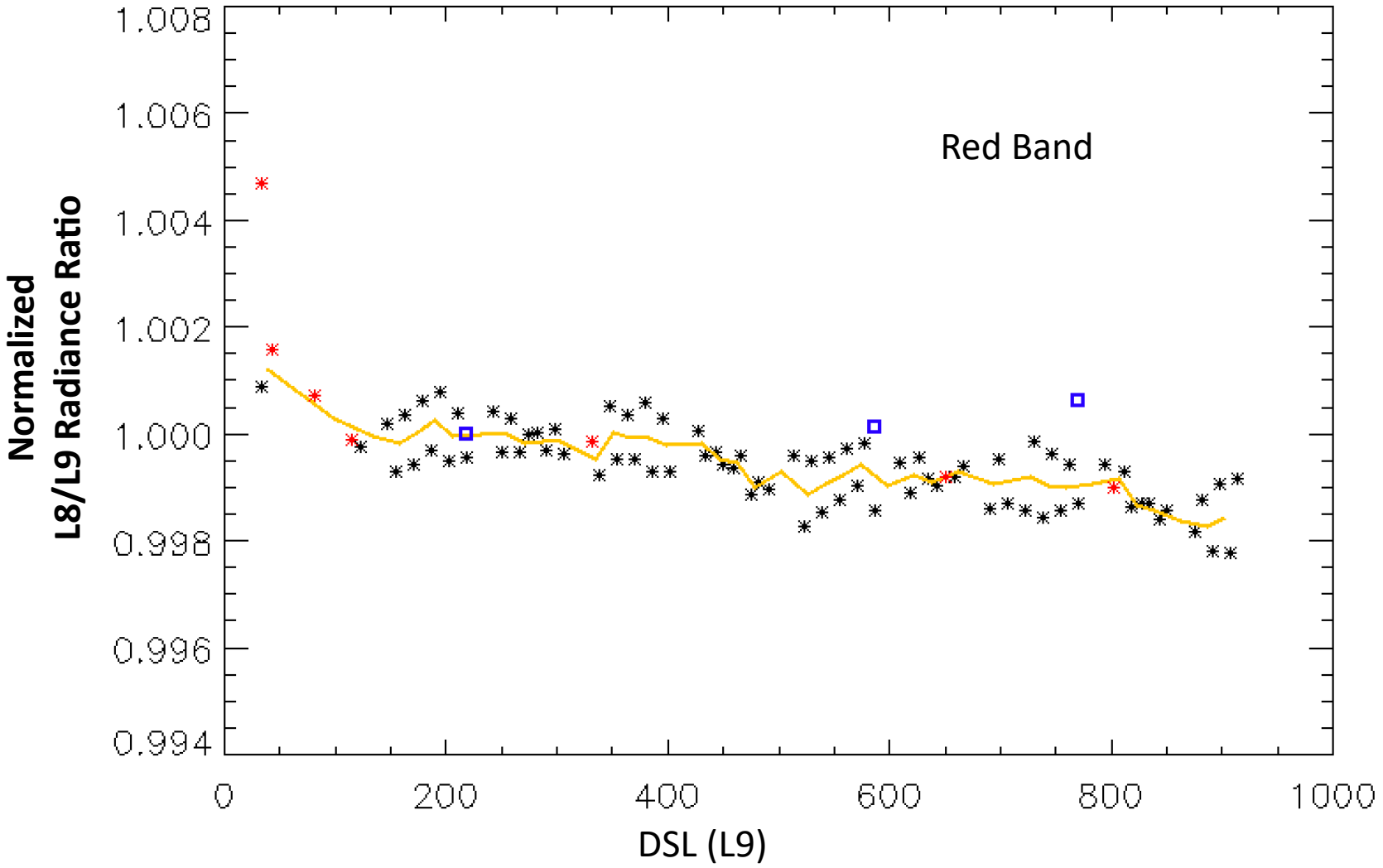

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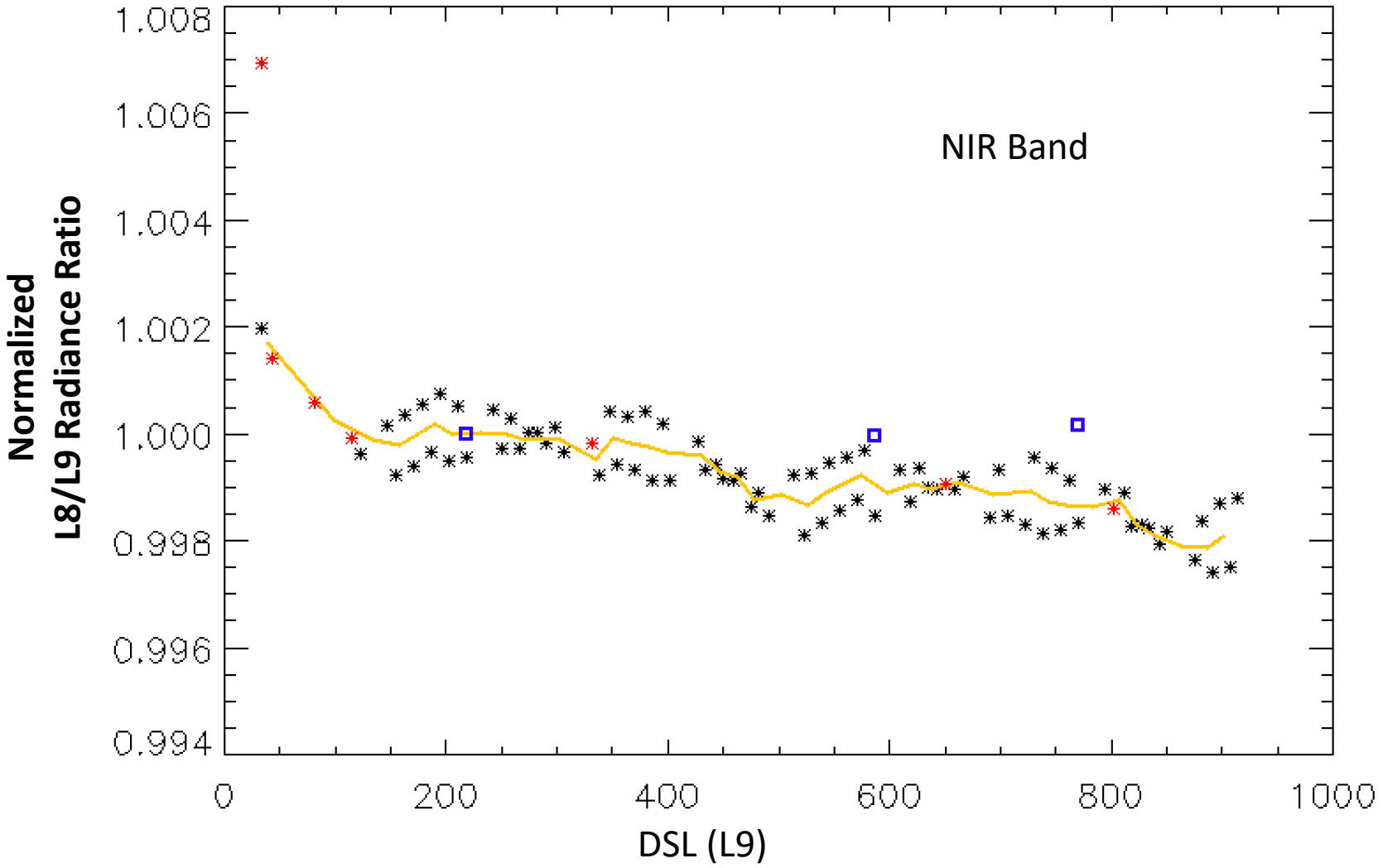

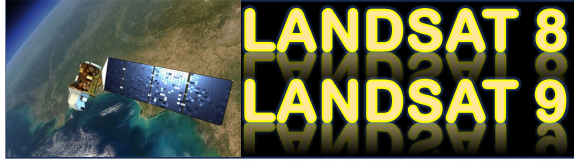

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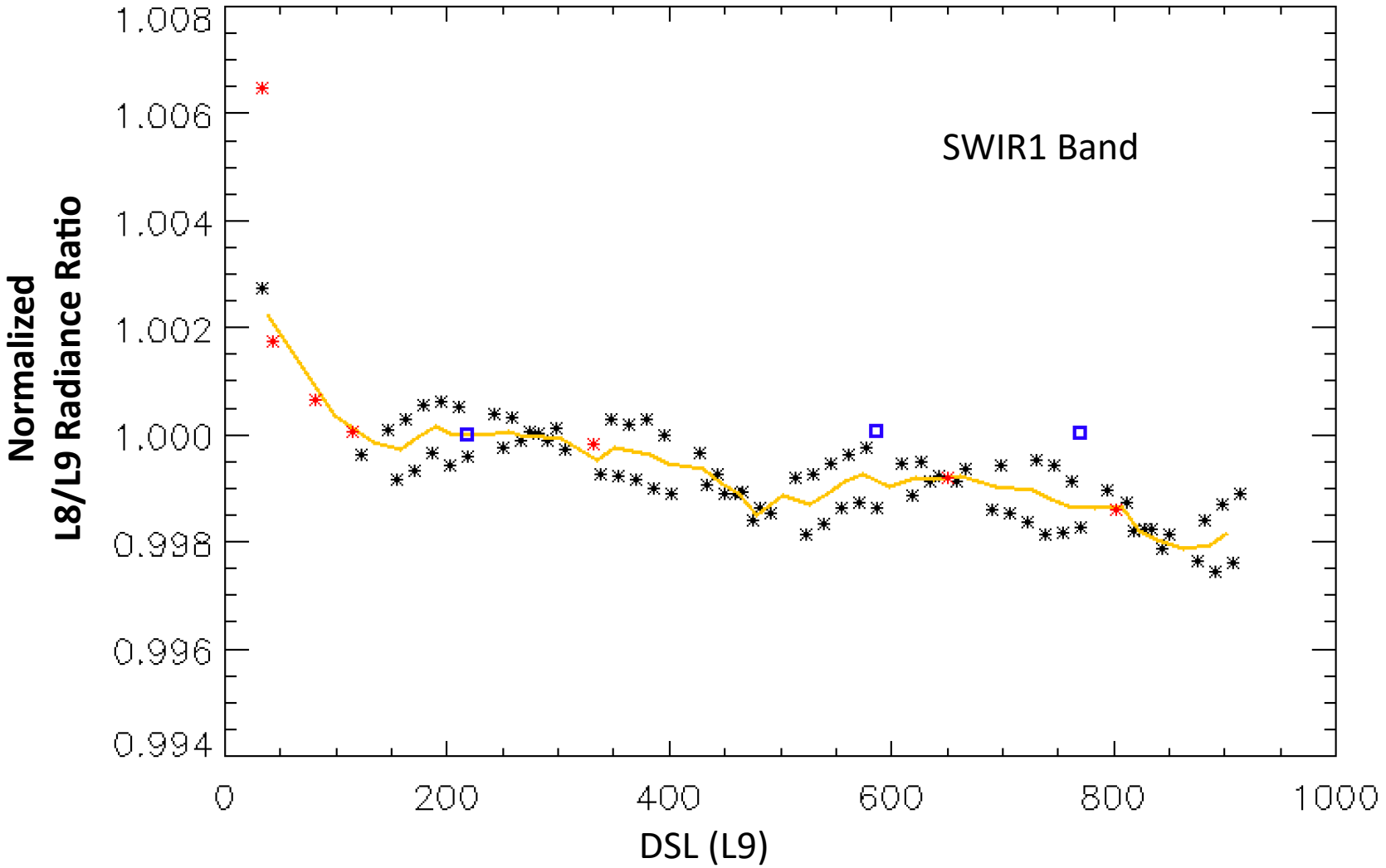

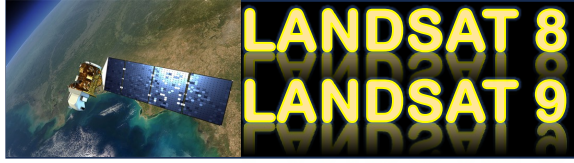

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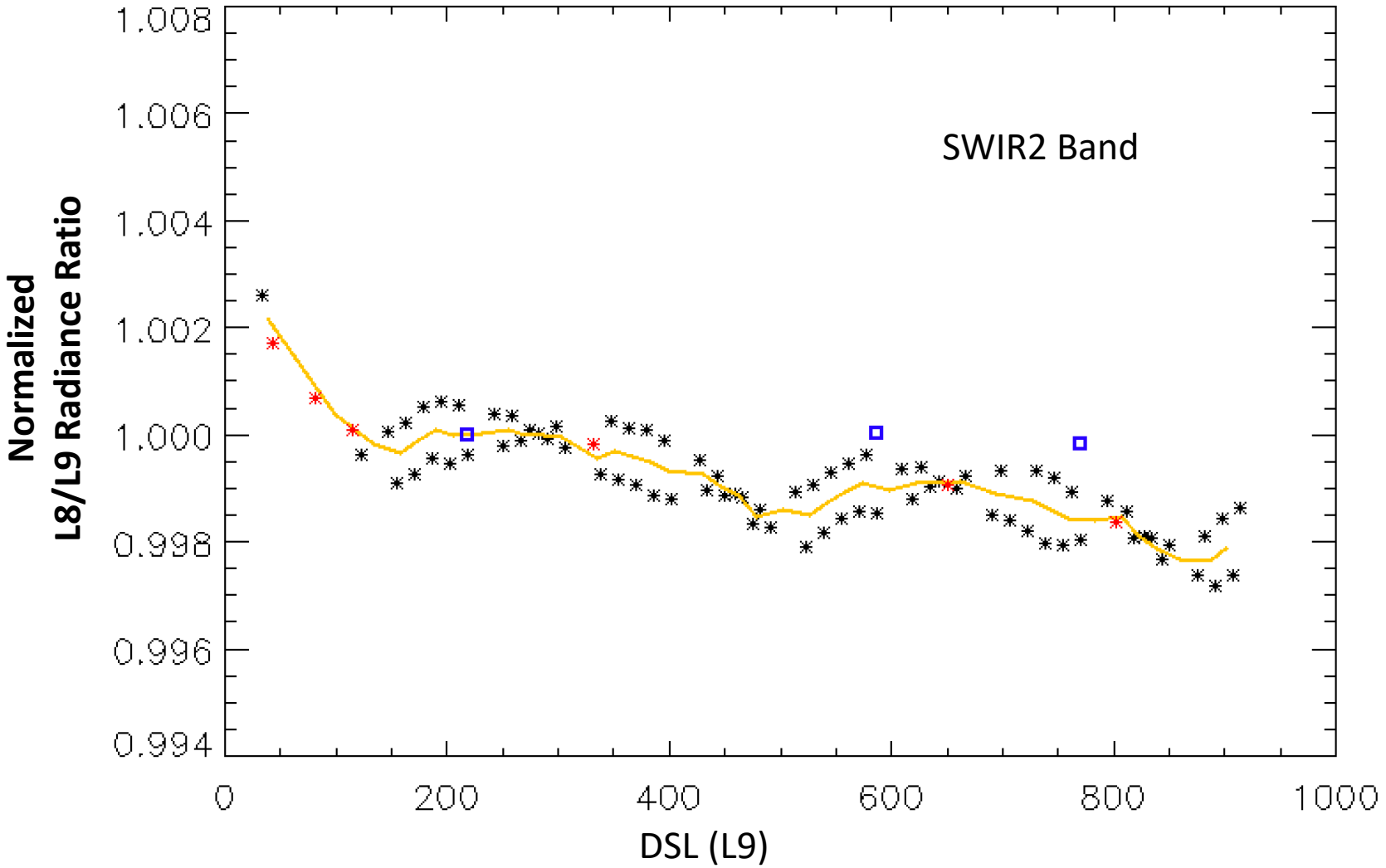

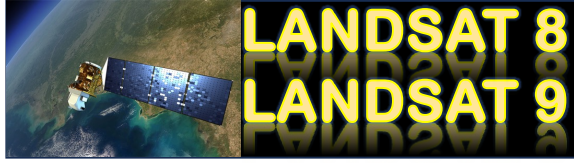

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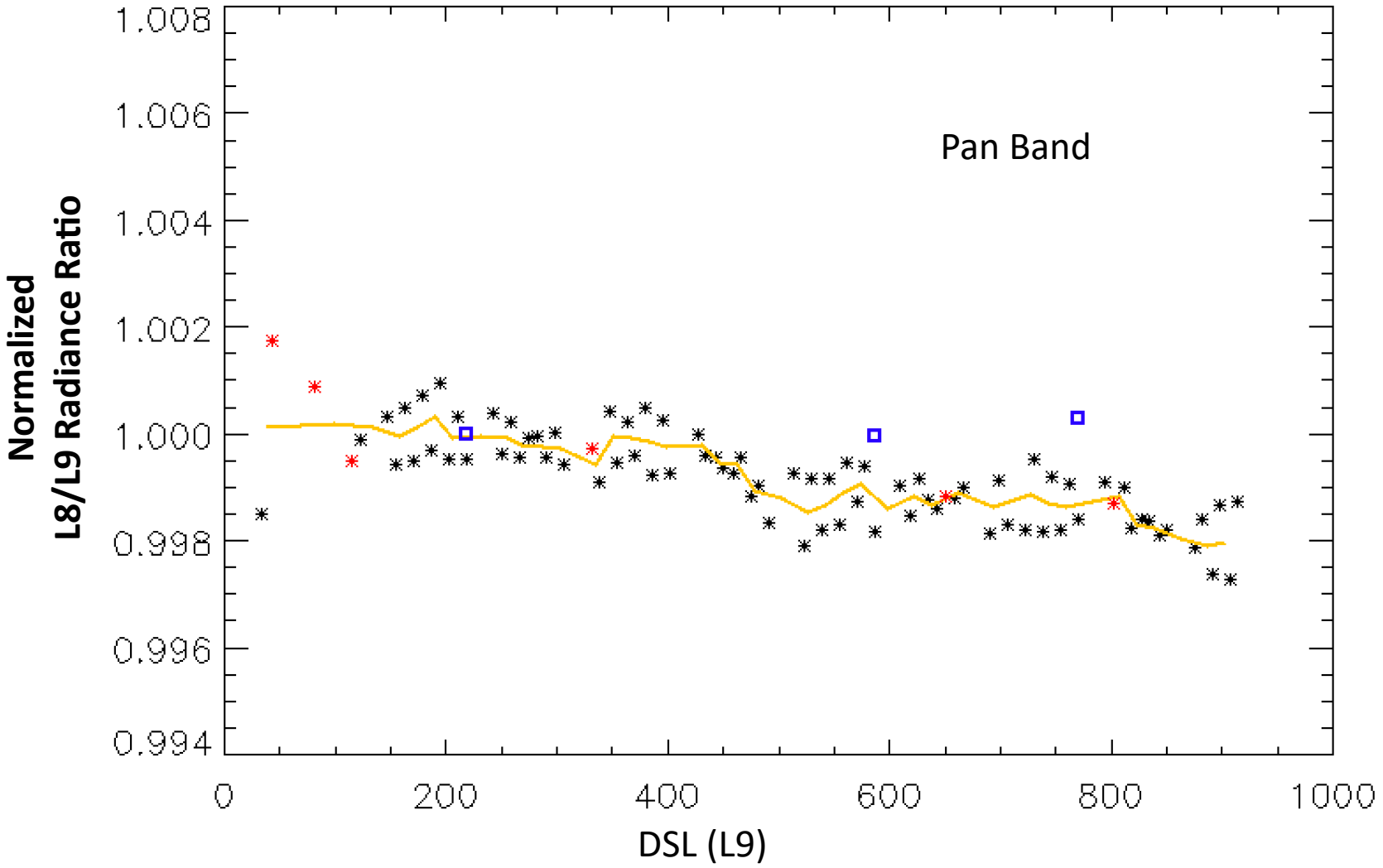

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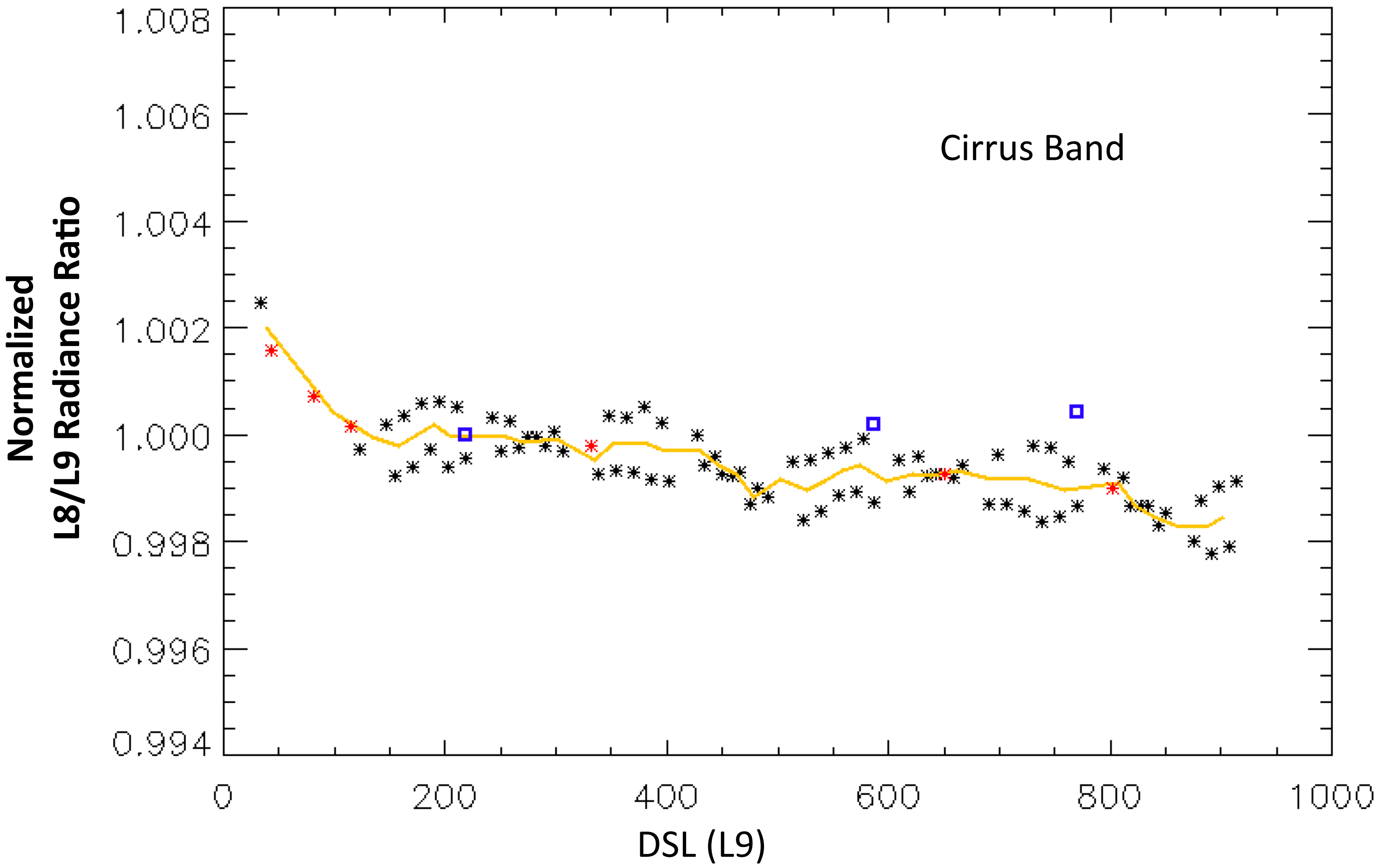

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