

# Satellites Stability & Inter Comparison Using PICS and Extended PICS

*Trending Analysis: L7, L8, L9, S2A, S2B*

&

*Cross Calibration: L8-S2A (PICSCAR), L8-L9*

IVOS-2022

31 August 2022

USGS Headquarters

By

M. Kaewmanee, L. Leigh

South Dakota State University, Image Processing Laboratory



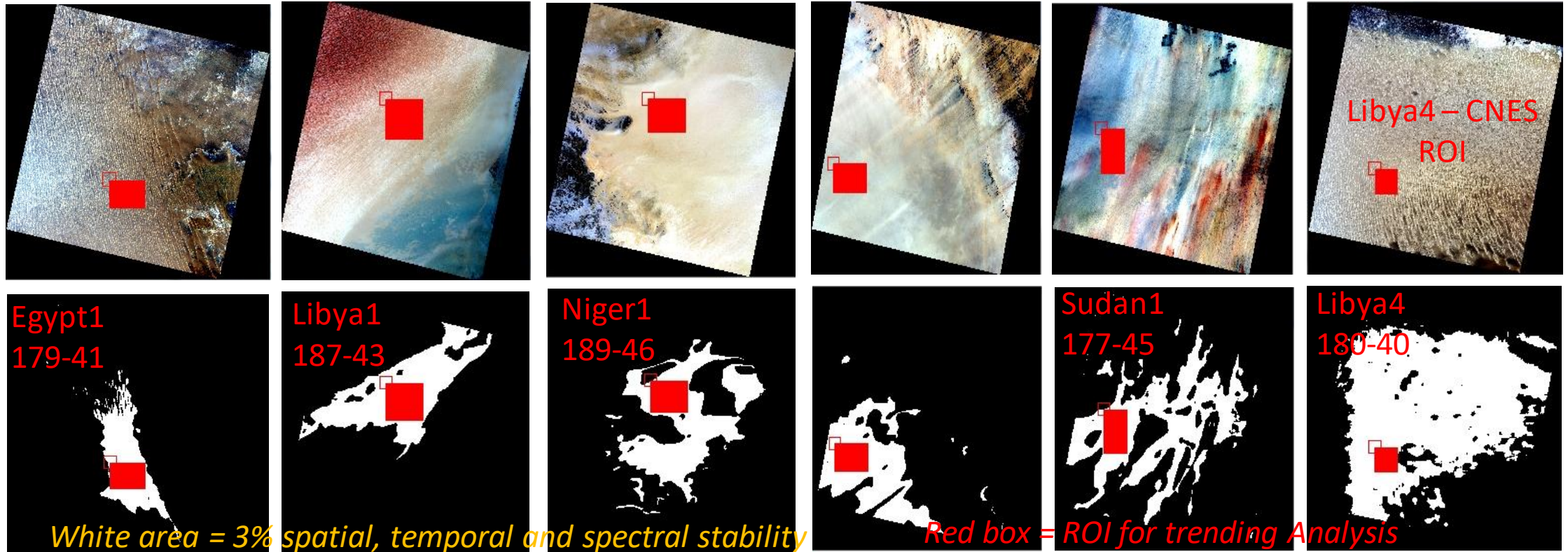
# Outline

- Identify Stable pixels/regions –PICS to Extended PICS ( EPICS)
  - PICS
  - North African desert sites: EPICS-NA
  - EPICS-Global
- Trending Analysis
  - L7, L8, L9, S2A, S2B
- PICSCAR Results: L8-S2A Cross calibration –Libya4 PICS
- Satellites Inter comparison : L8-S2A, L8-L9
  - Cross Calibration– EPICS-NA, EPICS-Global

# PICS to EPICS in A Nutshell



# Limitations of traditional PICS



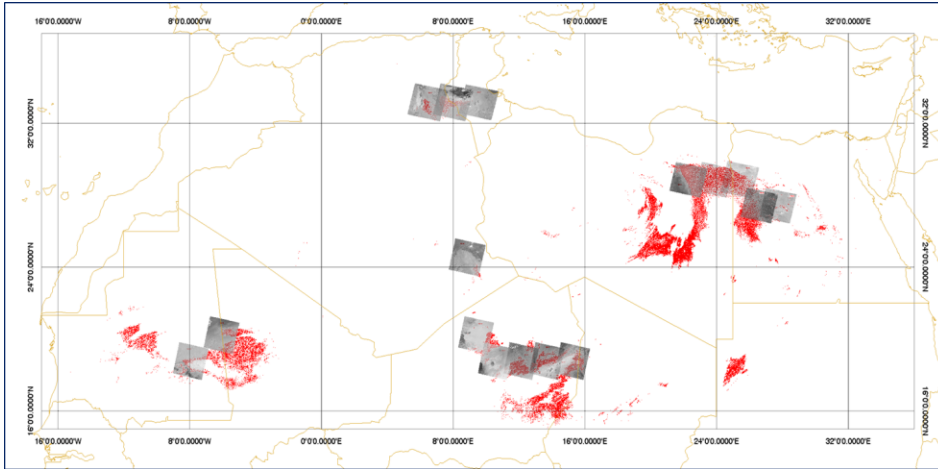
## Limitations when using these sites:

1. 2014, Absolute Calibration of Optical Satellite Sensors Using Libya 4 Pseudo Invariant Calibration : <https://doi.org/10.3390/rs6021327>
2. 2016, 2017, PICS Normalization Process: <https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1287&context=calcon>

- Cloud coverage can reduce number of observations.
  - i.e. Landsat 8 acquisition every 16 days. It may take 2-3 years to have enough dataset to detect drifts
- Reliability on a single site to be invariant – potential of false drift detection.

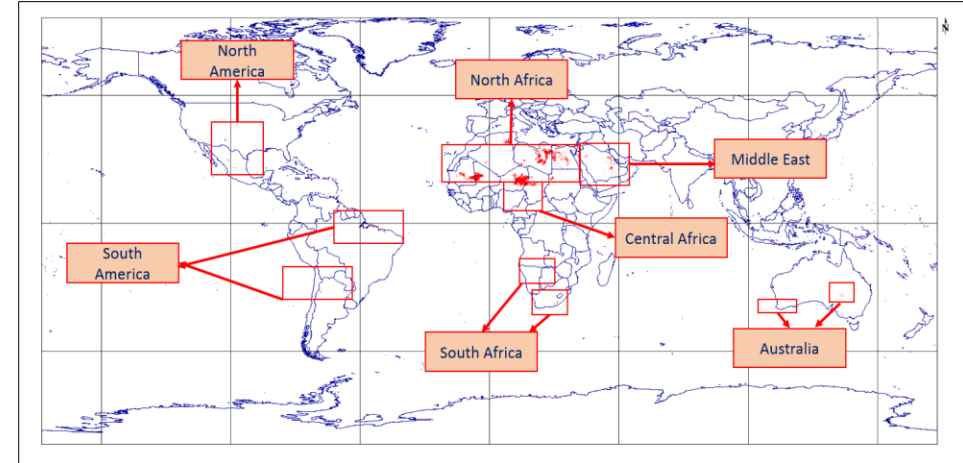
# Continental EPICS -North Africa vs Global EPICS

*North Africa: EPICS-NA*



- K-means clustering technique used. **19 clusters identified**.
- Performed over **North Africa** Latitude : -15° to 36°, Longitude : 18° to 35°.
- **300 m spatial resolution** data cubes containing temporal mean TOA reflectance – 8 Landsat 8 bands, temporal standard deviation, temporal uncertainty and pixel count (input to the clustering technique).
- **Filters applied**: Pixels with temporal uncertainty (ration of standard deviation and mean TOA reflectance) larger than 5% and with pixel count lower than 25 were excluded for further analysis.
- Focused on **bright targets**.
- **16 WRS-2 Path/Row** over North Africa.

*Global: EPICS-Global*



- K-means clustering technique used. **300 clusters identified**.
- Performed **on a global scale** Latitude : -50° to 50°, Longitude : -180° to 180°.
- **30 m spatial resolution** data cubes containing temporal mean TOA reflectance – 8 Landsat 8 bands, temporal standard deviation, temporal uncertainty and pixel count (input to the clustering technique).
- **No filters were applied** to allow the classification of pixels with different spectral characteristics, waterbodies, dark targets and more variable sites.
- **No constraints** in the spectral characteristics of the target.
- **33 WRS-2 Path/Rows** over North Africa, Central Africa, Middle East, North America and Australia.

# Libya4 vs EPICS-North Africa vs EPICS-Global



		Landsat 8 bands						
		CA	Blue	Green	Red	NIR	SWIR1	SWIR 2
<b>Libya 4 - ROI</b>	<b>Mean TOA reflectance</b>	<b>0.229</b>	<b>0.249</b>	<b>0.340</b>	<b>0.468</b>	<b>0.594</b>	<b>0.694</b>	<b>0.619</b>
	<b>Temp. standard deviation</b>	0.002	0.002	0.003	0.004	0.004	0.005	0.011
<b>North Africa EPICS</b>	<b>Mean TOA reflectance</b>	0.234	0.251	0.341	0.467	0.587	0.674	0.581
	<b>Temp. standard deviation</b>	0.007	0.008	0.006	0.010	0.007	0.012	0.017
<b>Global EPICS</b>	<b>Mean TOA reflectance</b>	0.227	0.242	0.328	0.454	0.573	0.664	0.576
	<b>Temp. standard deviation</b>	0.007	0.007	0.008	0.014	0.013	0.016	0.022

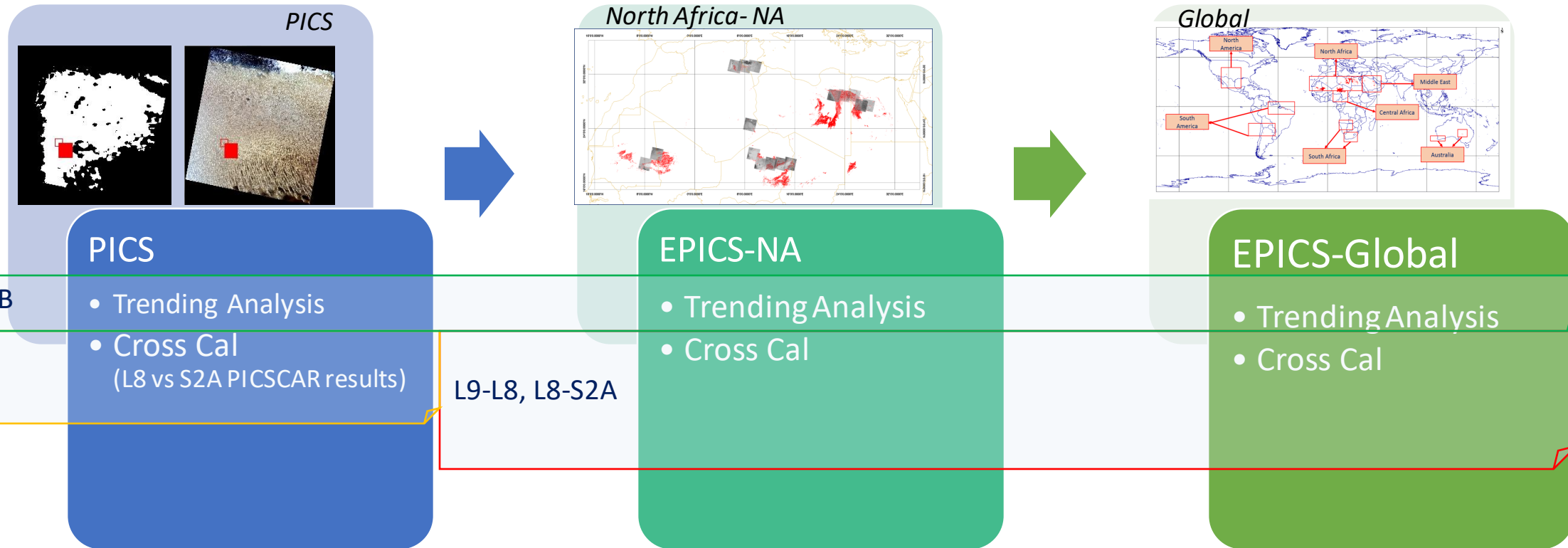
- Using Libya4 – ROI, One image every 19 days on average.

- Using North Africa EPICS, One image every 3 days on average

- Using Global cluster, One or more scenes every day on average!



# Stable Pixels: PICS to Extended PICS at Global Scale (EPICS) in Satellite Calibration Methodology



L7,L8,L9, S2A,S2B

L8-S2A

L9-L8, L8-S2A

*Temporal Resolution*

1 point Every 16 days

1 point every 2-3 days

2-3 points daily

**Evaluation L8/L9 & L8/S2A**



# Trending Analysis

6 PICS, EPICS-NA, EPICS-Global

# Trending Analysis:

## Targets

- SDSU stable region 6 PICS
  - Libya1, Libya4, Niger1, Niger2, Egypt1, Sudan1
- EPICS-NA or (C13-NA): 16 Path/Row
- EPICS-Global or (C13-Global): 33 Path/Row

## Satellites

- Landsat: L7, L8, L9
- Sentinel: S2A, S2B
  - *TOA Reflectance conversion equation changed in Jan 2022*

**Expectation:**  
*Do we get Similar trending results from these targets for each satellite ???!*



# Trending Analysis Process

## Data

- Toa Reflectance, data until May 2022
- EPICS- NA, Global & 6 PICS ( L1,L4,N1,N2,E1,S1)
- L7, L8, L9 and S2A, S2B

## BRDF Normalization

- 4 Angle BRDF Model, Spherical to Cartesian coordinates  $\Rightarrow \begin{aligned} x_1 &= \sin(SZA) * \sin(SAA) ; y_1 = \sin(SZA) * \cos(SAA) , \\ x_2 &= \sin(VZA) * \sin(VAA) ; y_2 = \sin(VZA) * \cos(VAA) , \end{aligned}$
- BRDF Normalization:

$$Reflectance = \beta_0 + \beta_1 y_1^2 + \beta_2 x_1^2 + \beta_3 y_2^2 + \beta_4 x_2^2 + \beta_5 x_1 y_1 + \beta_6 x_1 y_2 + \beta_7 x_2 y_2 + \beta_8 x_2 y_1 + \beta_9 y_1 y_2 + \beta_{10} x_1 x_2 + \beta_{11} x_1 + \beta_{12} y_1 + \beta_{13} x_2 + \beta_{14} y_2$$

## Trending Analysis

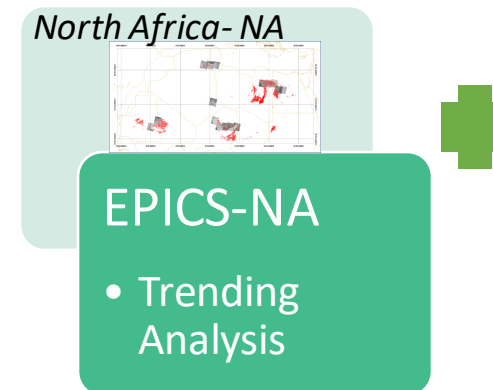
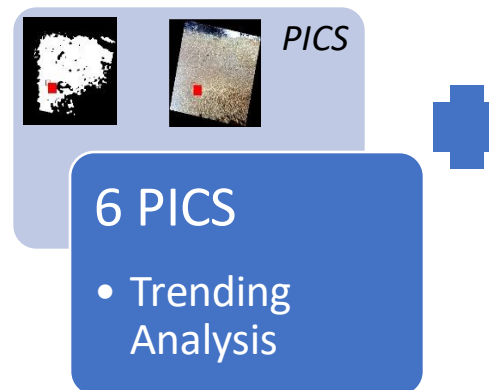
- Linefit with Uncertainties ( Monte Carlo Simulation): Spatial Standard deviation and Satellite Calibration Uncertainty
- Determine Drift per year
  - 6 PICS results and Weighted Average
  - EPICS NA, Global

# Trending Analysis Results

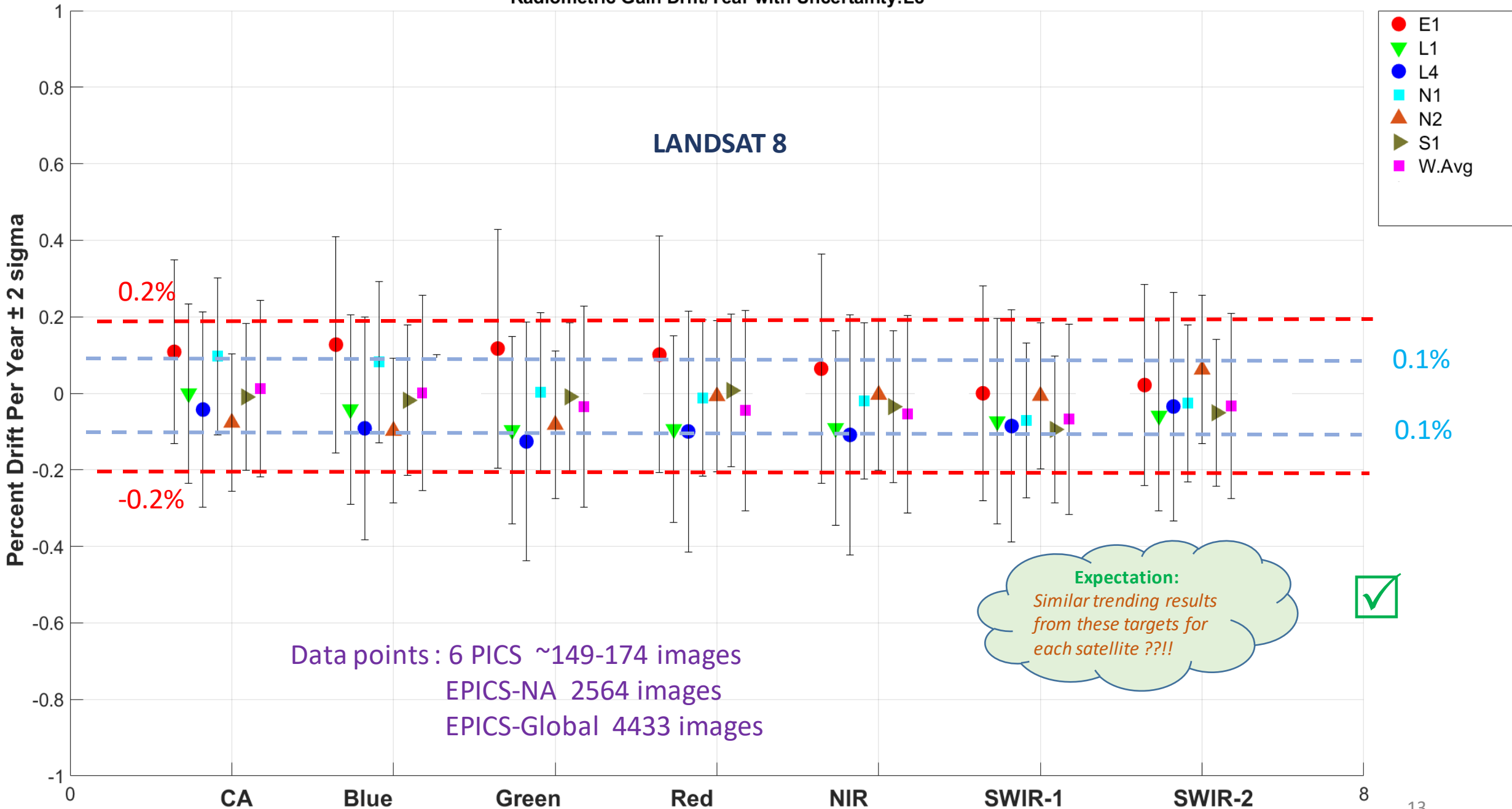
L7, L8, L9, S2A, S2B

Results from each target:

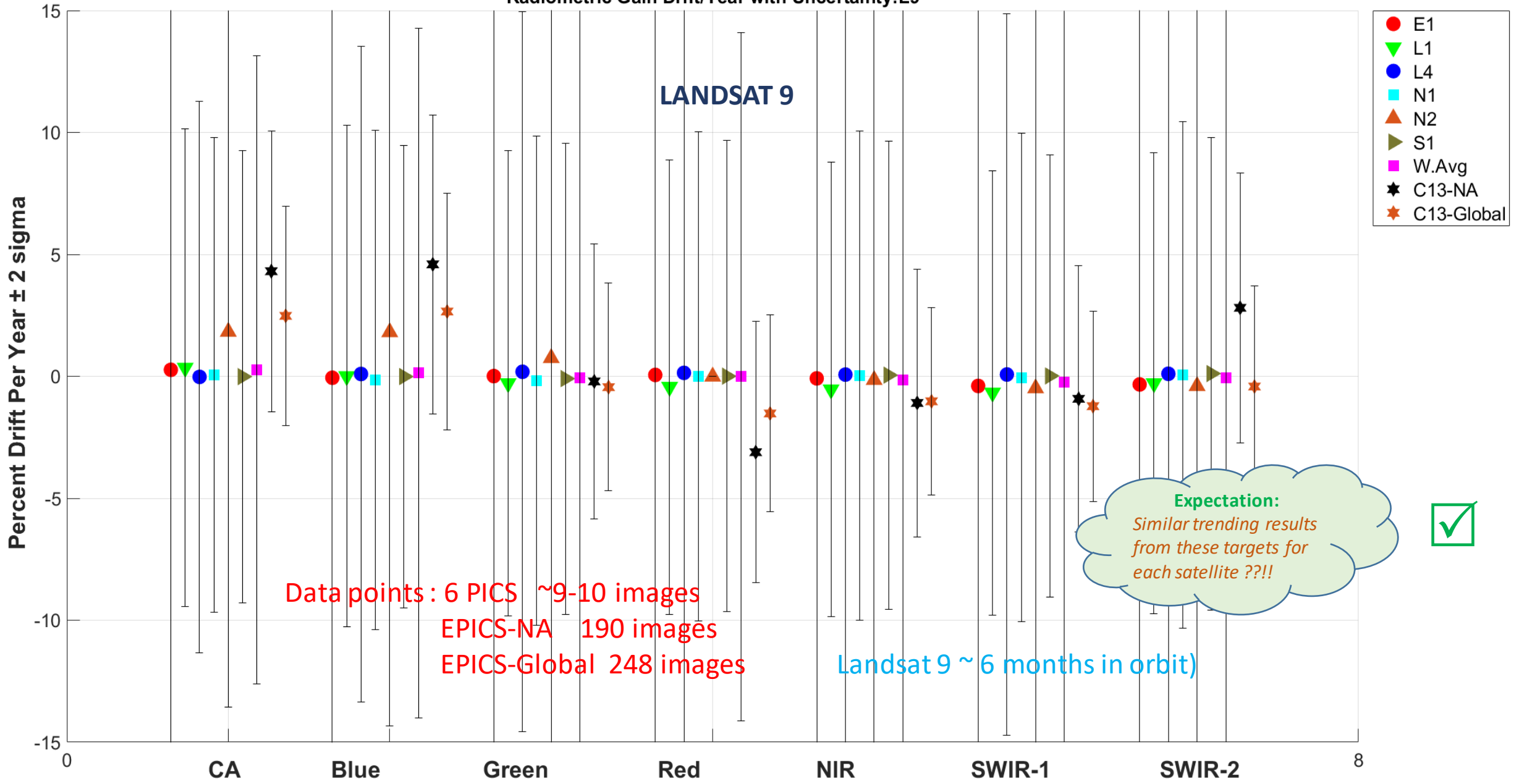
*E1, L1, L4, N1, N2, S1, W. Average, EPICS-NA, EPICS-Global*



# Radiometric Gain Drift/Year with Uncertainty:L8

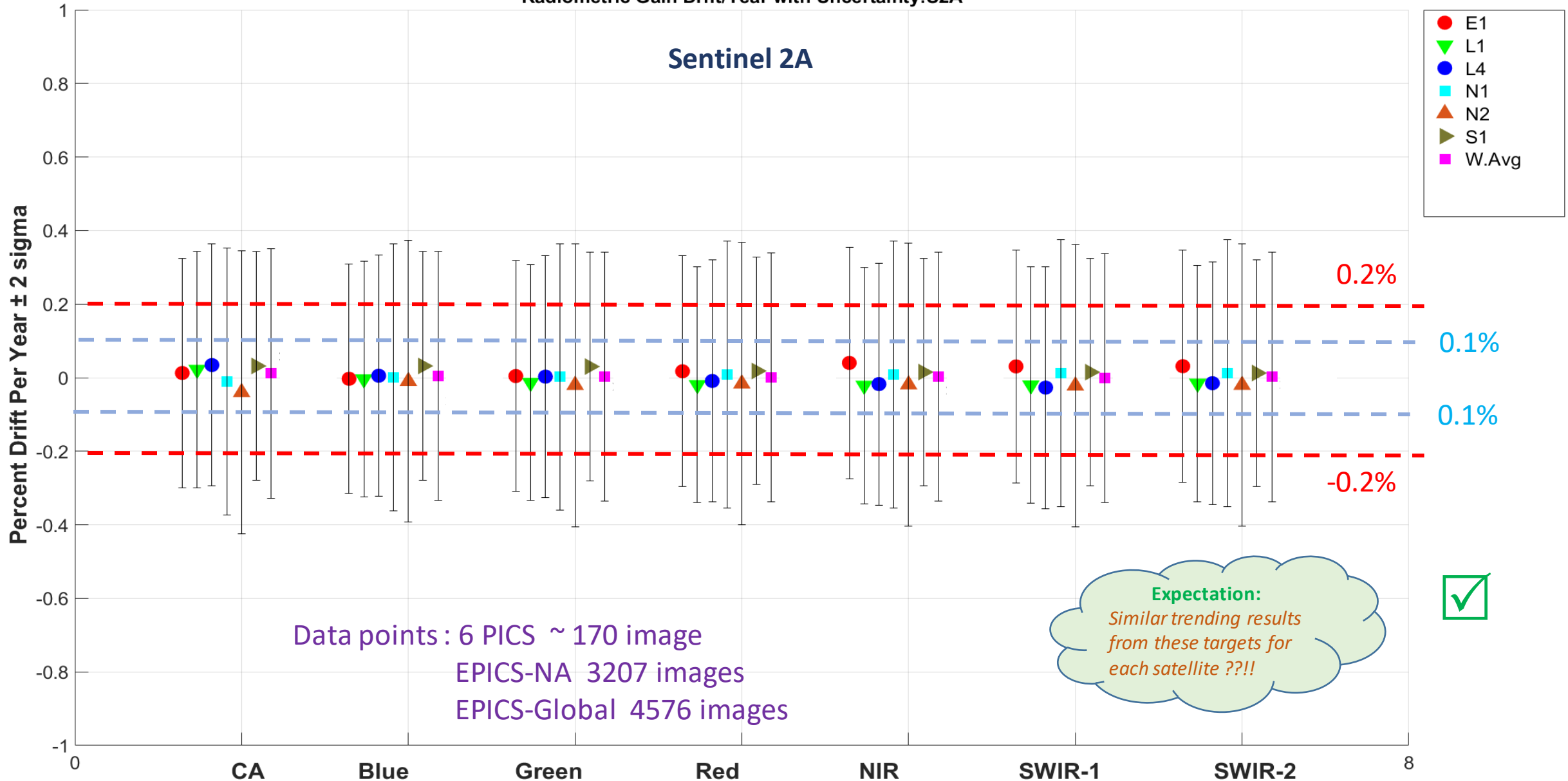


Radiometric Gain Drift/Year with Uncertainty:L9



# Radiometric Gain Drift/Year with Uncertainty:S2A

## Sentinel 2A



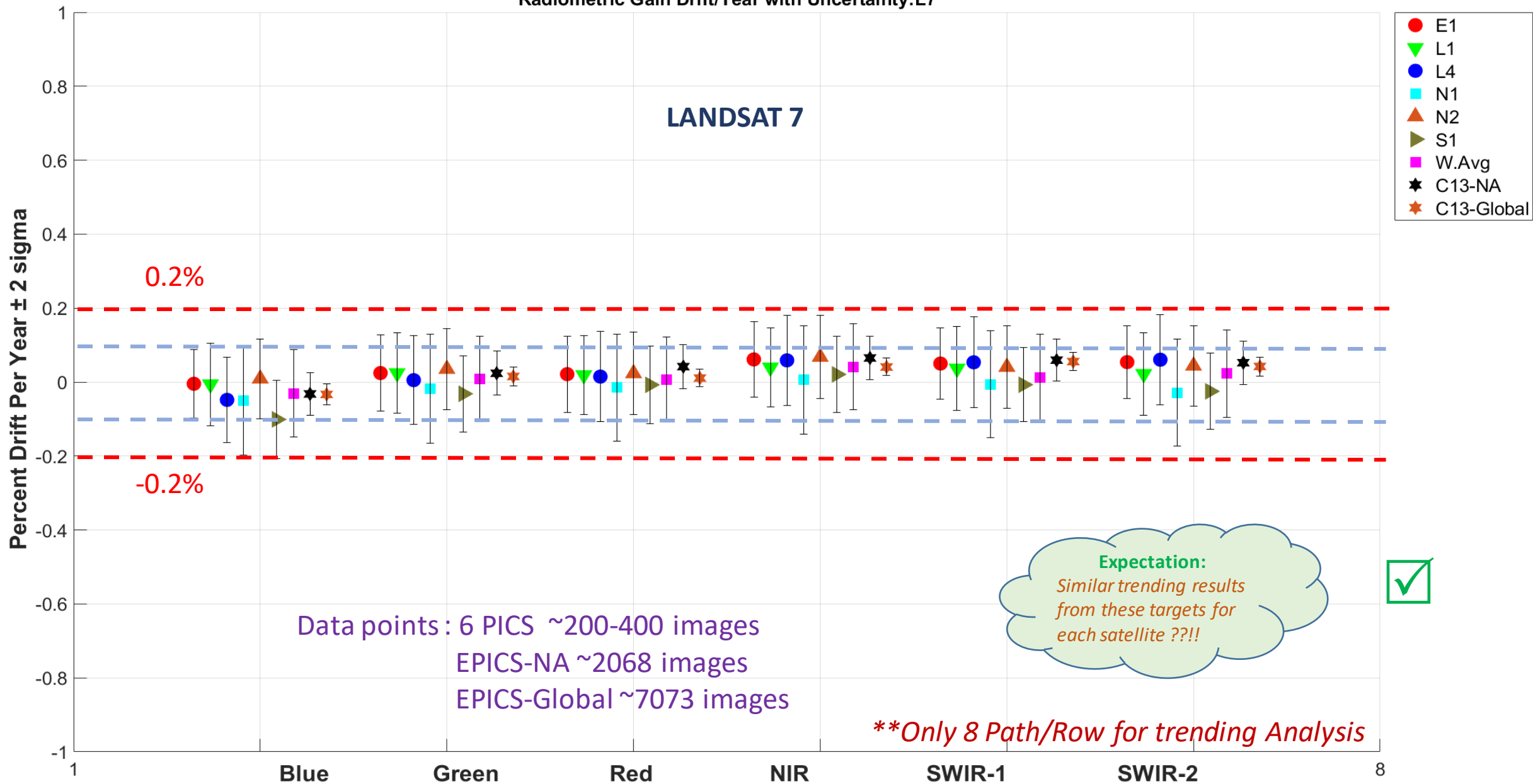
Data points: 6 PICS ~ 170 image  
EPICS-NA 3207 images  
EPICS-Global 4576 images

**Expectation:**  
Similar trending results  
from these targets for  
each satellite ???!



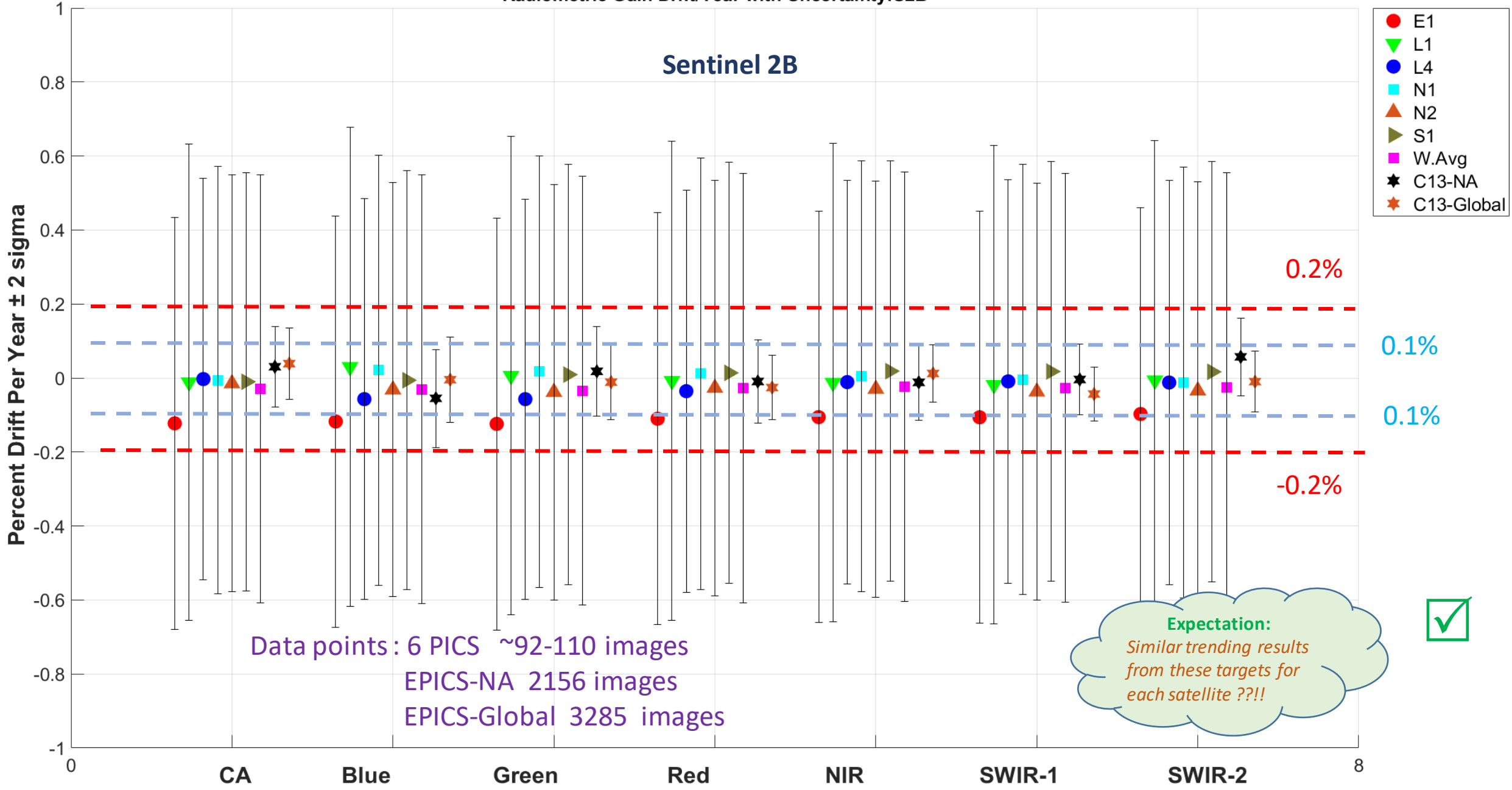


### Radiometric Gain Drift/Year with Uncertainty:L7



# Radiometric Gain Drift/Year with Uncertainty:S2B

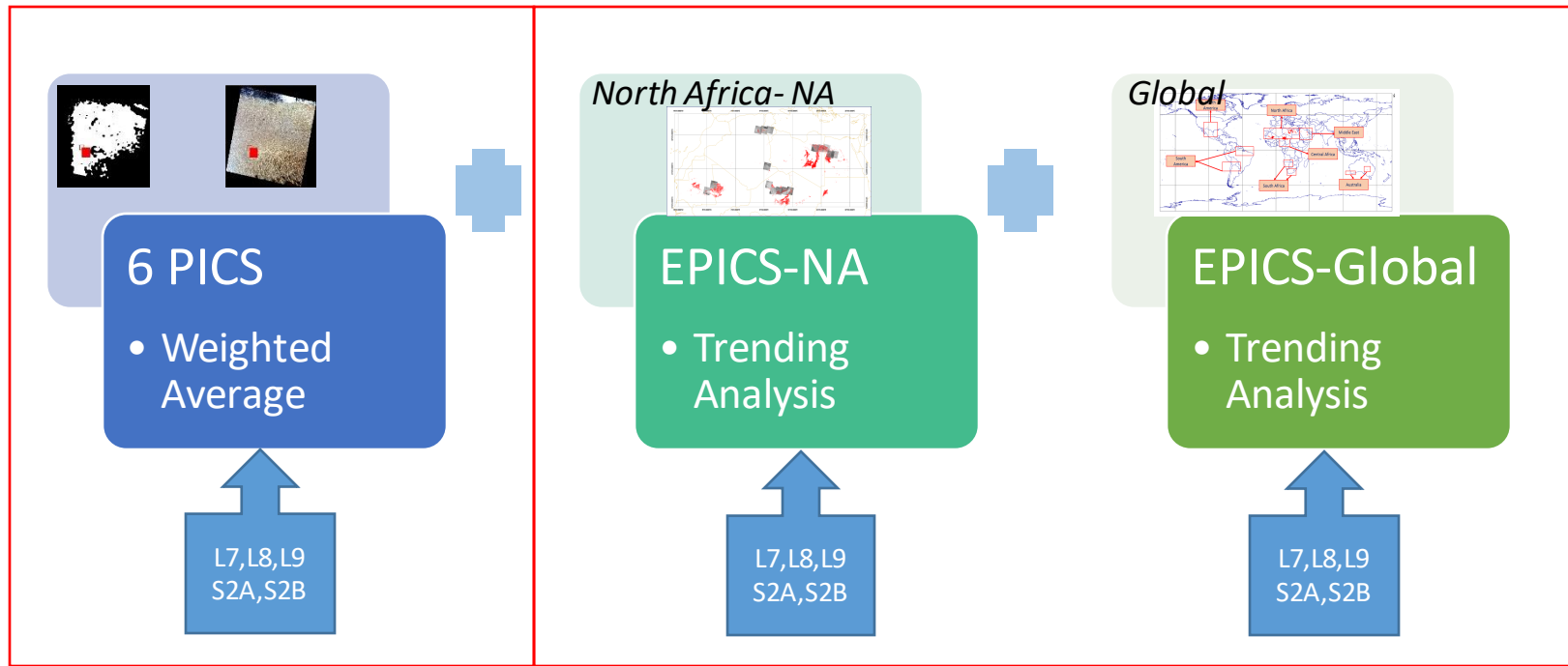
## Sentinel 2B



Data points : 6 PICS ~92-110 images  
EPICS-NA 2156 images  
EPICS-Global 3285 images

**Expectation:**  
Similar trending results  
from these targets for  
each satellite ???!





L7, L8, L9, S2A, S2B

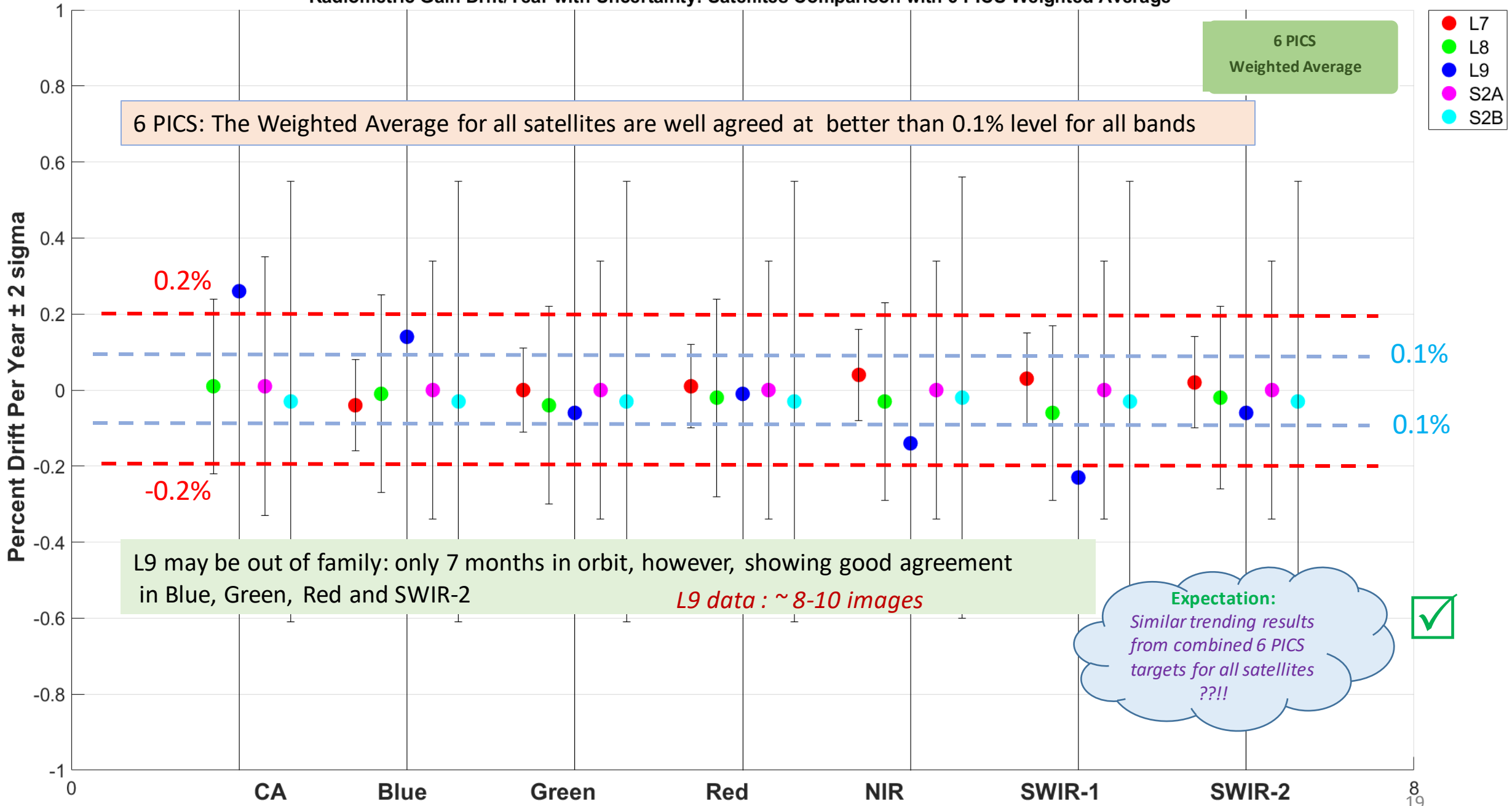
Results from each satellite on same target:

*EPICS-NA, EPICS-Global*

*6 PICS-W. Average,*

# Trending Analysis Summary

Radiometric Gain Drift/Year with Uncertainty: Satellites Comparison with 6 PICS Weighted Average



### Radiometric Gain Drift/Year with Uncertainty: Satellites Comparison with EPICS-NA & EPICS-Global

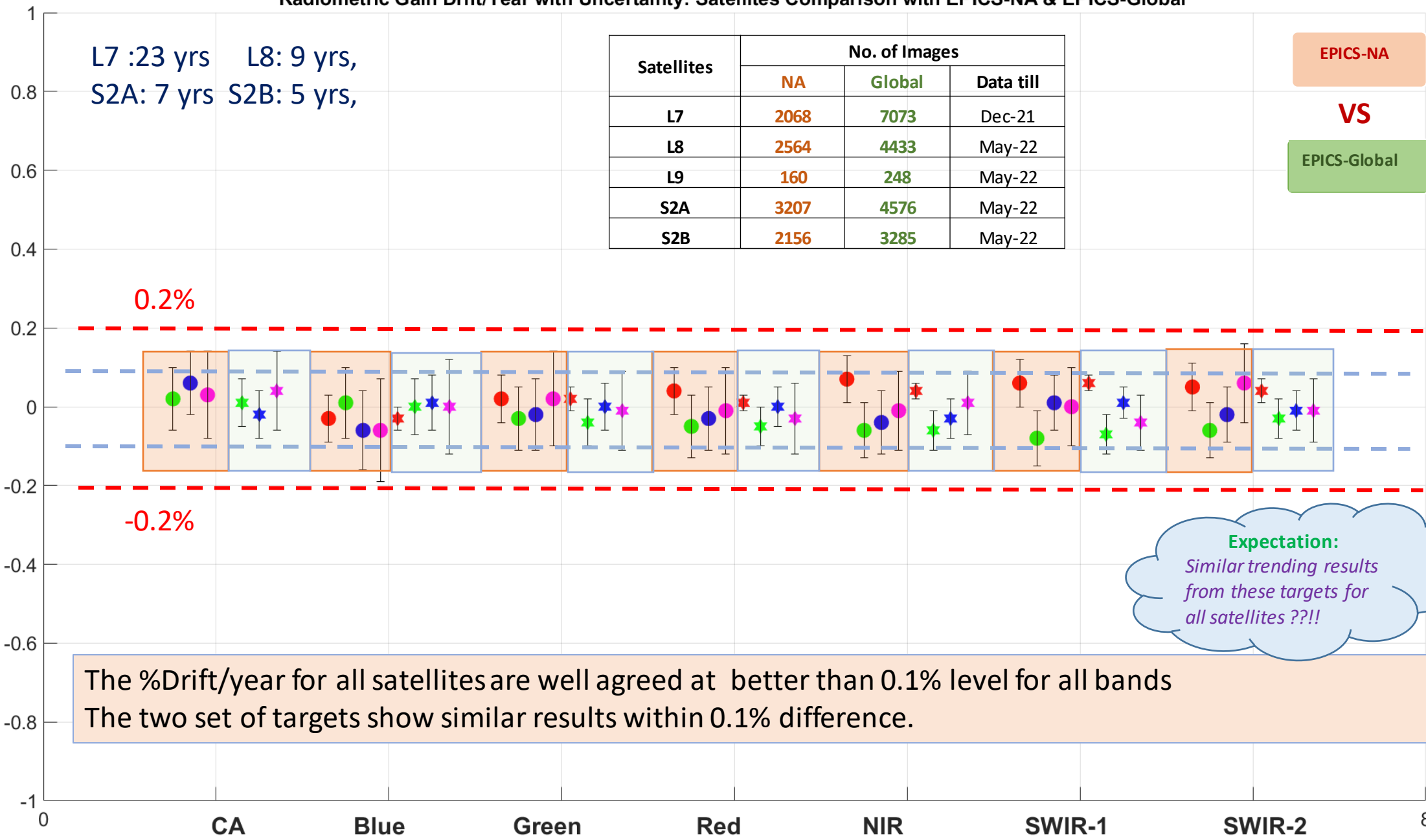
L7 :23 yrs L8: 9 yrs,  
S2A: 7 yrs S2B: 5 yrs,

Satellites	No. of Images		
	NA	Global	Data till
L7	2068	7073	Dec-21
L8	2564	4433	May-22
L9	160	248	May-22
S2A	3207	4576	May-22
S2B	2156	3285	May-22

EPICS-NA  
**VS**  
EPICS-Global

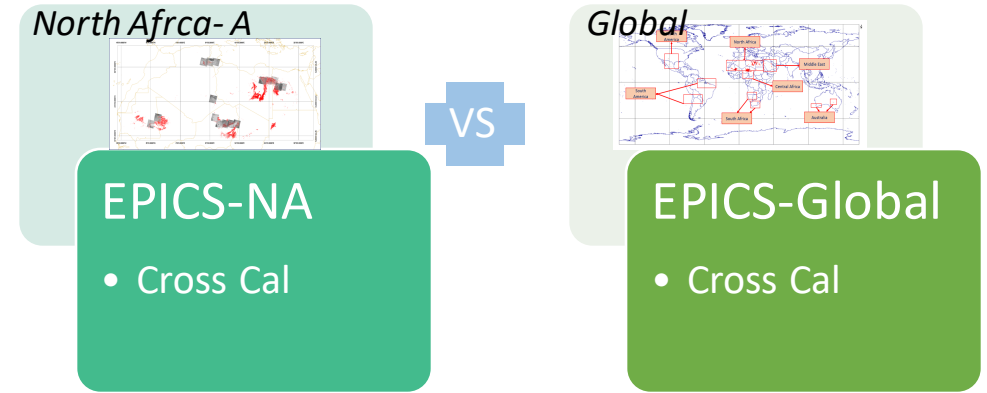
- L7NA
- L8NA
- S2ANA
- S2BNA
- ★ L7G
- ★ L8G
- ★ S2AG
- ★ S2BG

Percent Drift Per Year  $\pm 2$  sigma



The %Drift/year for all satellites are well agreed at better than 0.1% level for all bands  
The two set of targets show similar results within 0.1% difference.

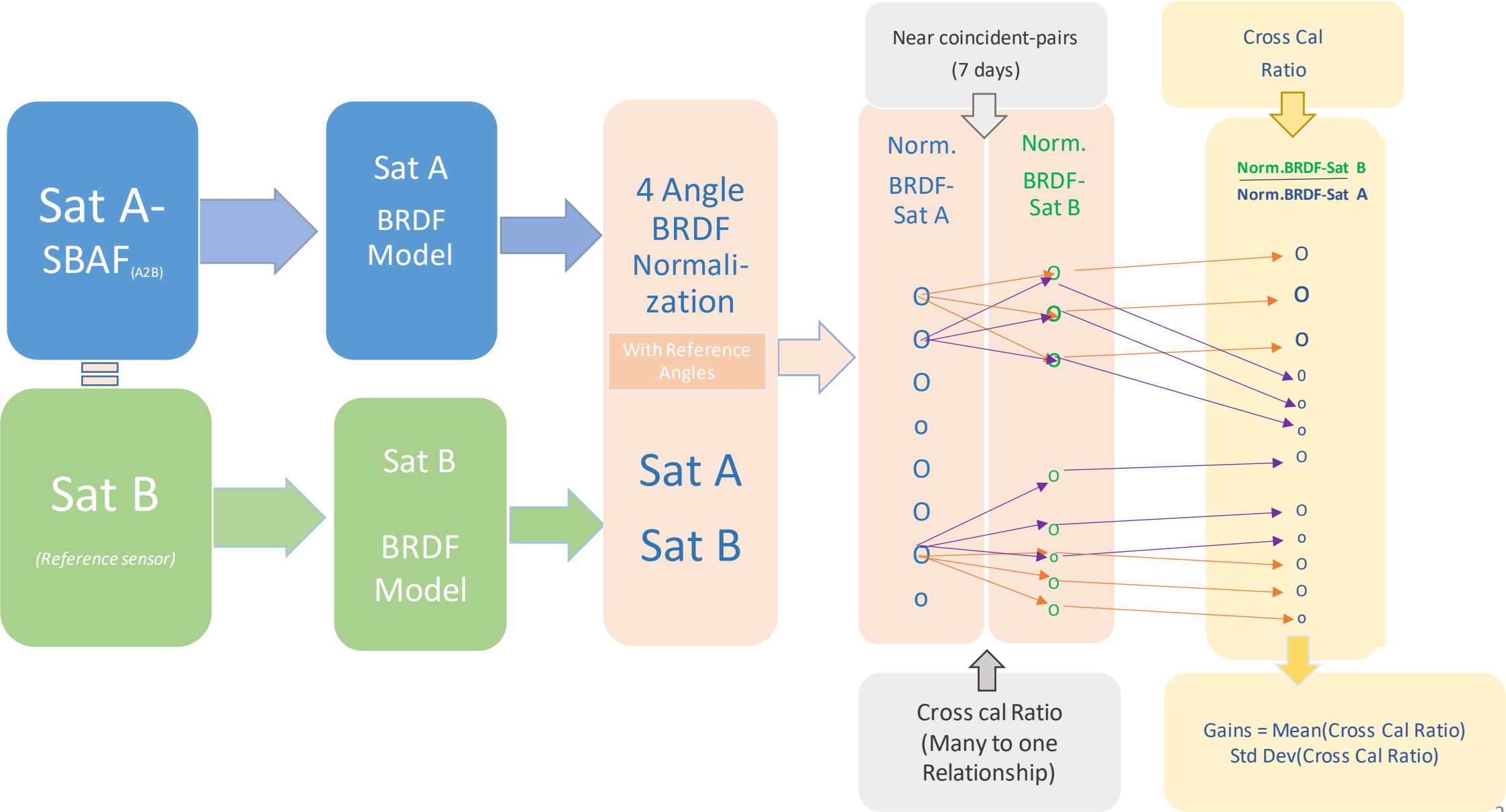
**Expectation:**  
Similar trending results  
from these targets for  
all satellites ???!



# Traditional EPICS Cross Calibration Analysis

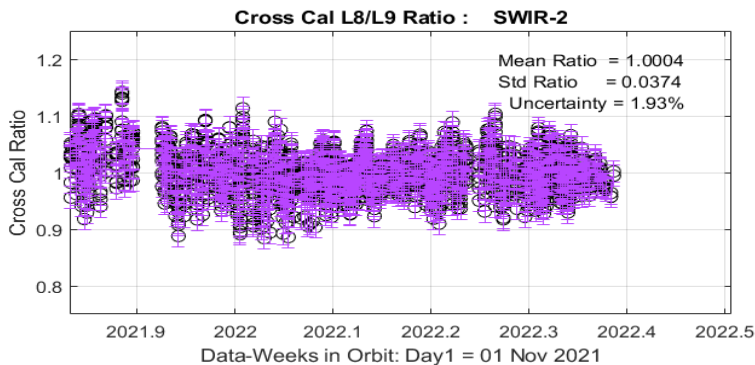
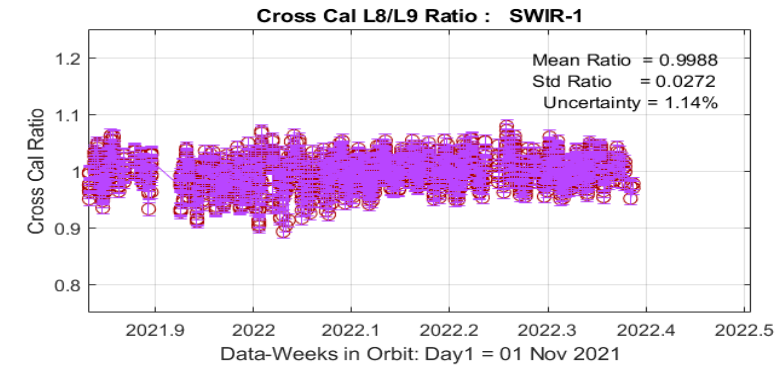
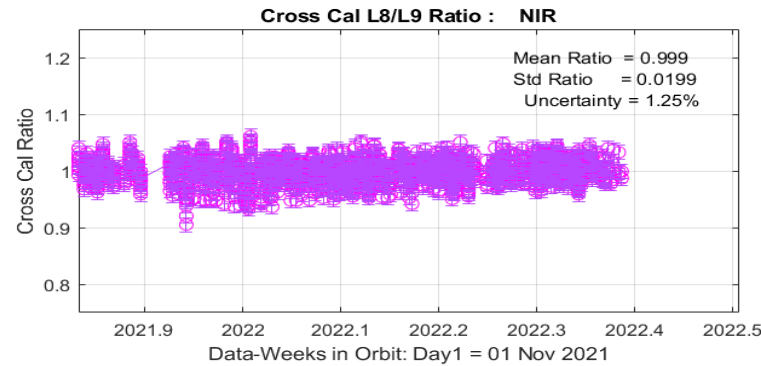
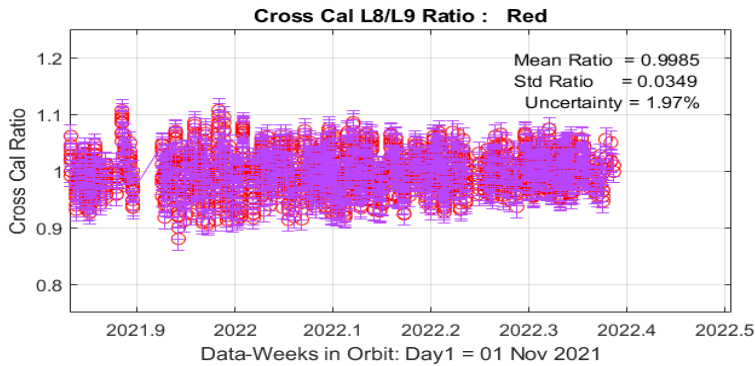
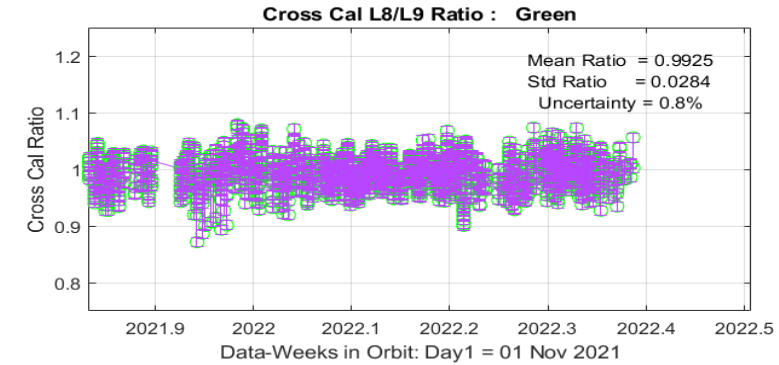
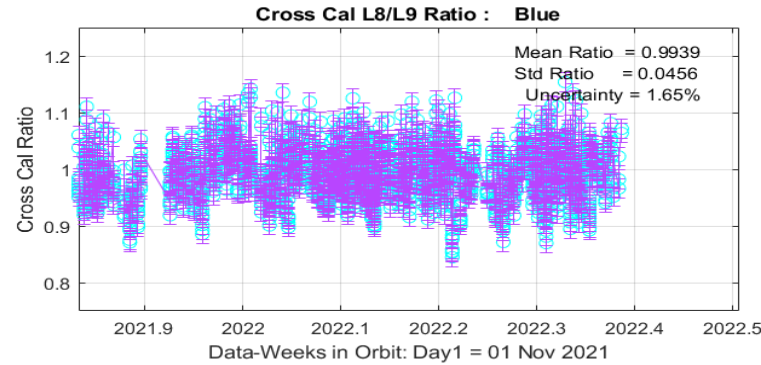
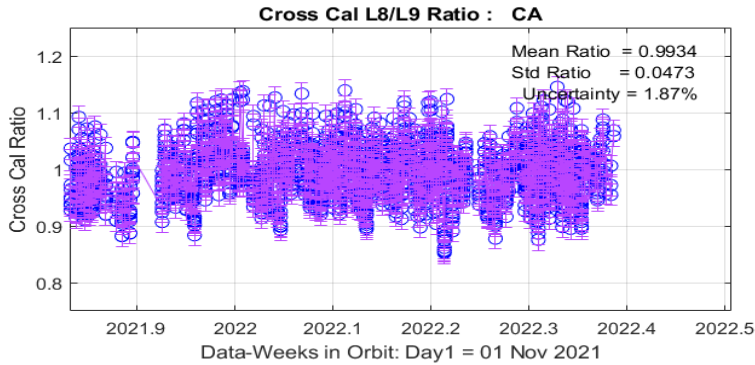
L8/L9, L8/S2A  
EPICS-NA,  
EPICS-Global

# Traditional Cross Calibration Process EPICS





# Traditional Cross Cal L8/L9 results: **NA**- May2022



L8 = 169 images, L9 = 173 images

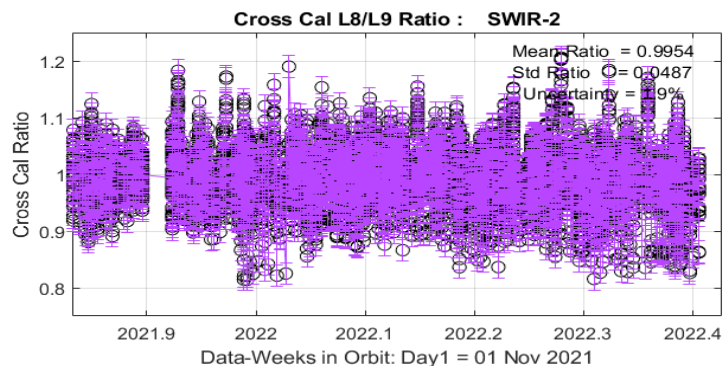
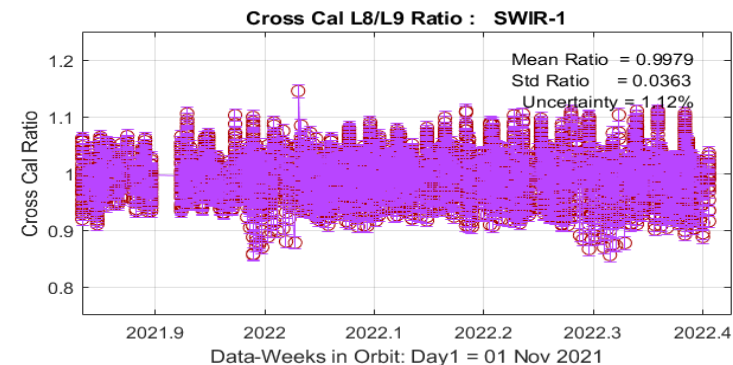
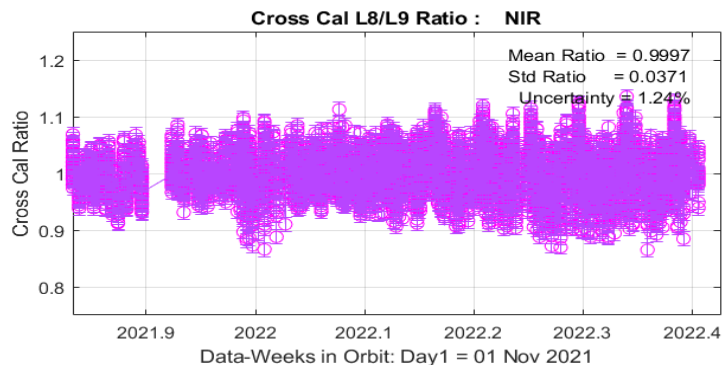
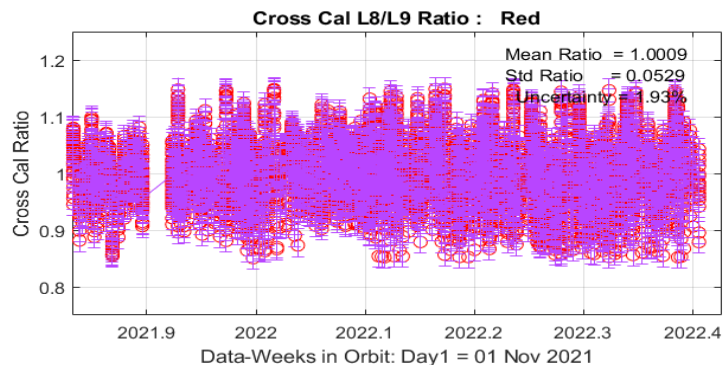
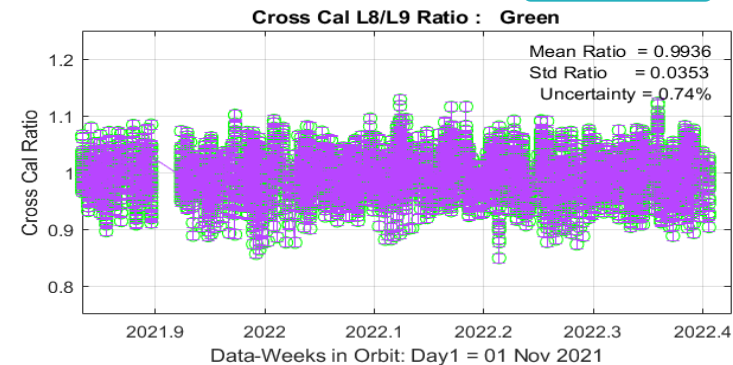
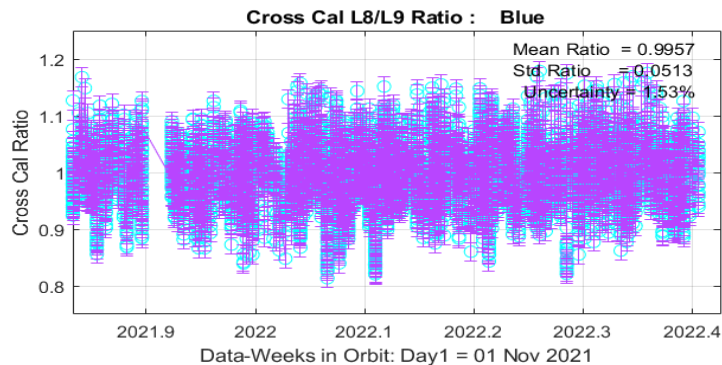
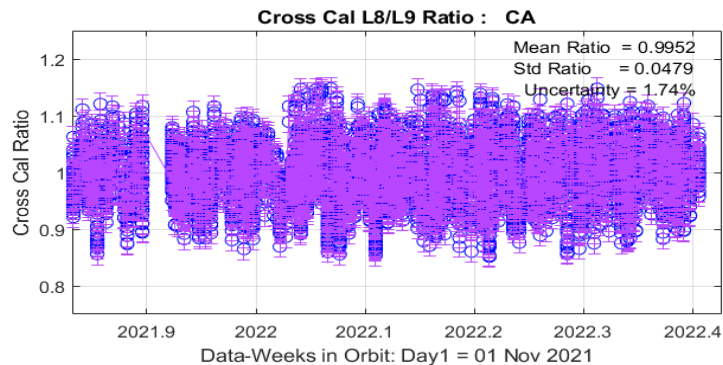
~0.5% Deviation from unity for all bands

GAINS	CA	Blue	Green	Red	NIR	SWIR1	SWIR2	
<b>Cross Cal</b>	<b>0.9934</b>	<b>0.9939</b>	<b>0.9925</b>	<b>0.9985</b>	<b>0.9990</b>	<b>0.9988</b>	<b>1.0004</b>	
Std.Dev	0.0473	0.0456	0.0284	0.0349	0.0199	0.0272	0.0374	
Xcal Unc.%	1.74%	1.53%	0.74%	1.93%	1.24%	1.12%	1.90%	

# Traditional Cross Cal L8/L9 results: Global- May2022



• Cross Cal



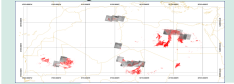
L8 = 335 images, L9 = 291 images

~0.5% Deviation from unity for all bands

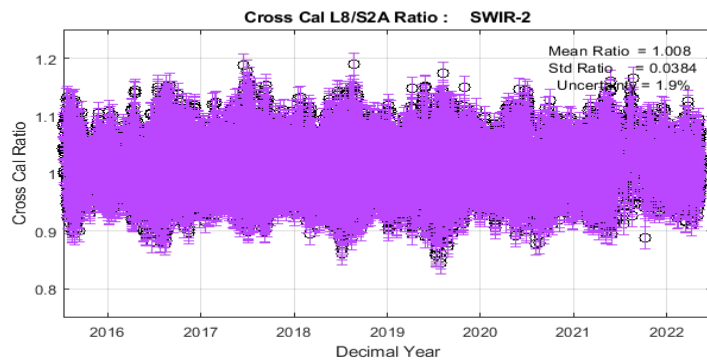
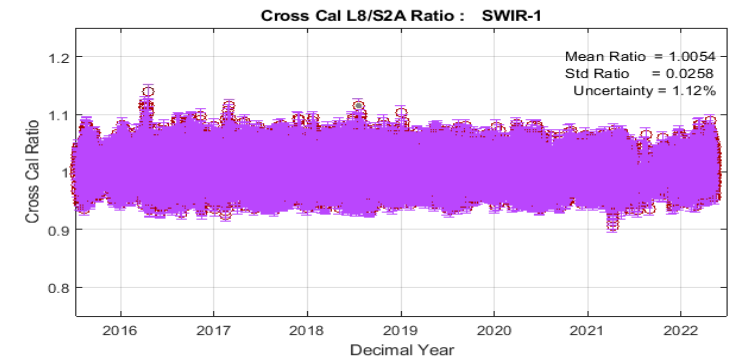
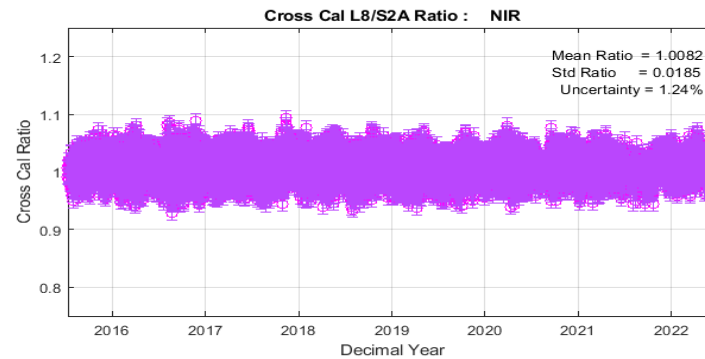
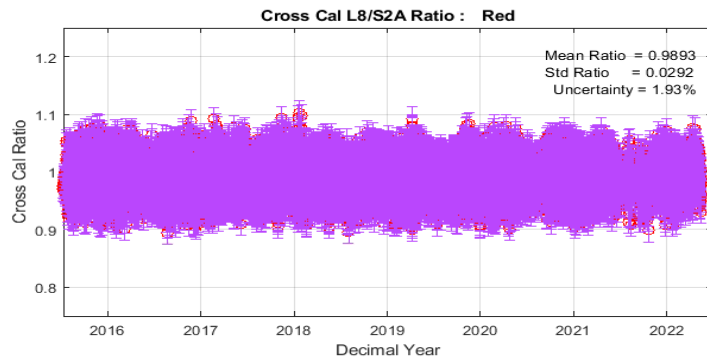
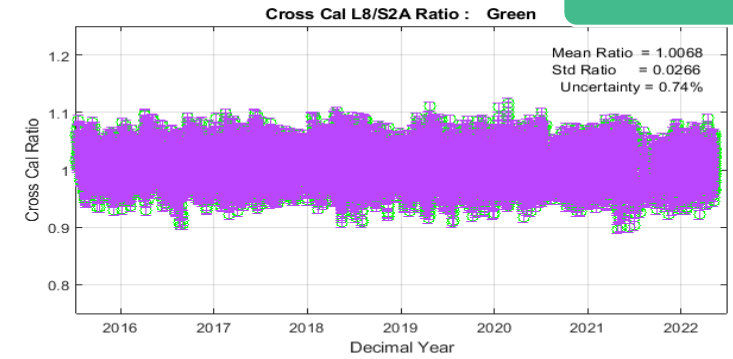
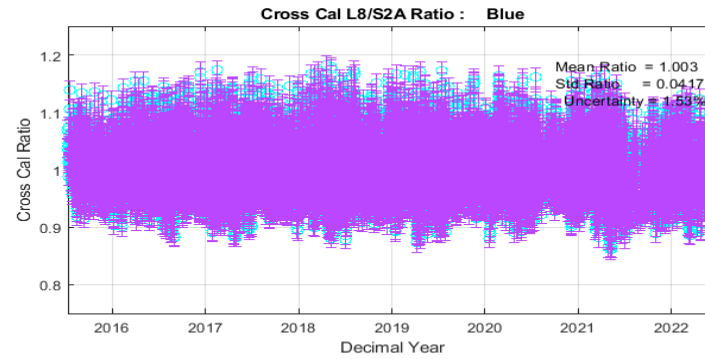
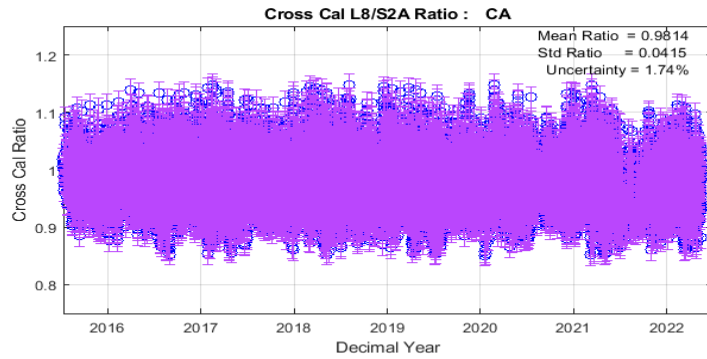
GAINS	CA	Blue	Green	Red	NIR	SWIR1	SWIR2	
<b>Cross Cal</b>	<b>0.9952</b>	<b>0.9957</b>	<b>0.9936</b>	<b>1.0009</b>	<b>0.9997</b>	<b>0.9979</b>	<b>0.9954</b>	
Std.Dev	0.0479	0.0513	0.0353	0.0529	0.0371	0.0363	0.0487	
Xcal Unc.%	1.74%	1.53%	0.74%	1.93%	1.24%	1.12%	1.90%	

# Traditional EPICS Cross Cal L8/S2A

# Traditional EPCIS Cross Cal L8/S2A results: **NA**- May2022



EPCIS-NA  
• Cross Cal



*L8 = 2564 images, S2A = 3281 images*

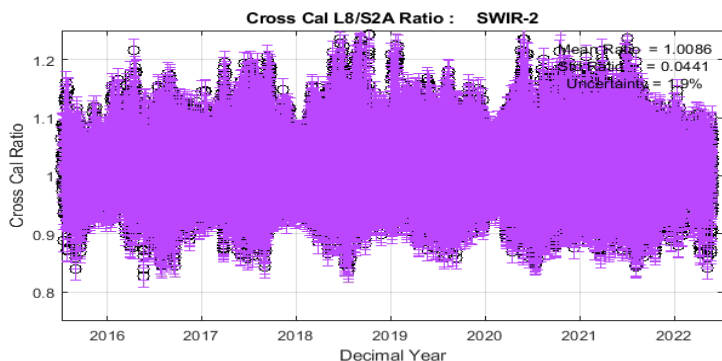
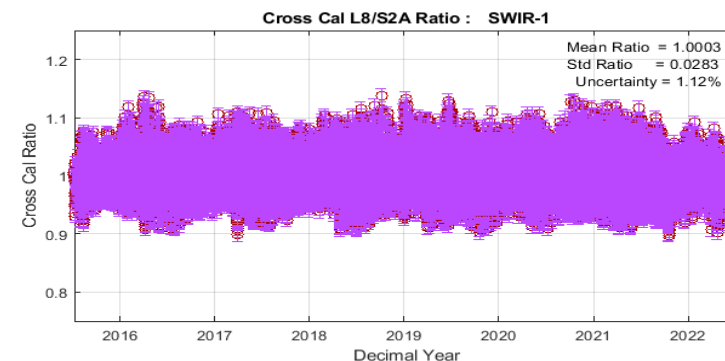
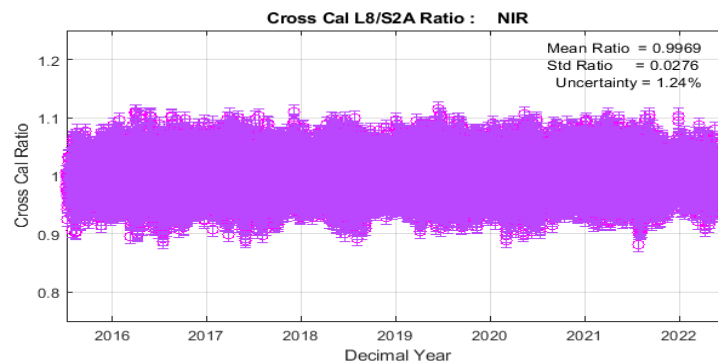
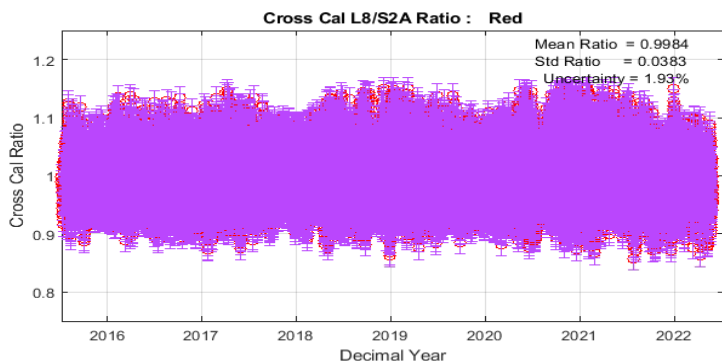
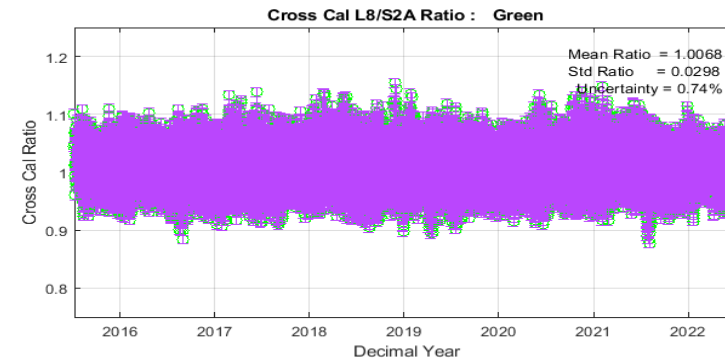
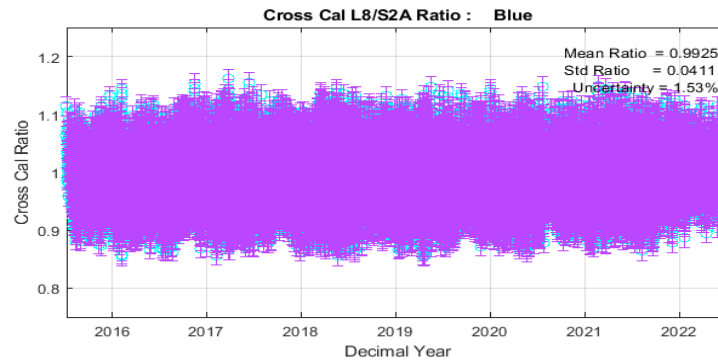
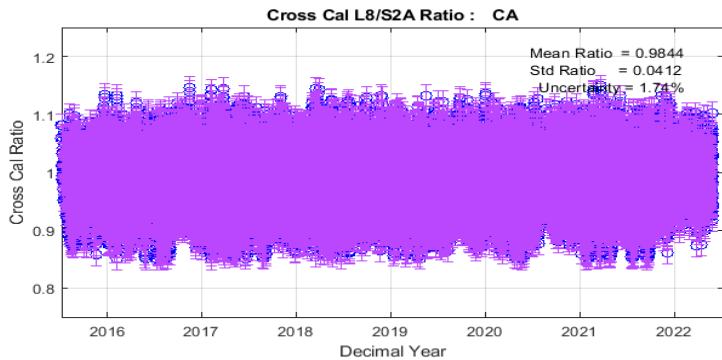
GAINS	CA	Blue	Green	Red	NIR	SWIR1	SWIR2	
<b>Cross Cal</b>	<b>0.9814</b>	<b>1.0030</b>	<b>1.0068</b>	<b>0.9893</b>	<b>1.0082</b>	<b>1.0054</b>	<b>1.0080</b>	
Std.Dev	0.0415	0.0417	0.0266	0.0292	0.0185	0.0258	0.0384	
Xcal Unc.%	1.74%	1.53%	0.74%	1.93%	1.24%	1.12%	1.90%	

*~1% Deviation from unity for all bands except CA & Red ~1-2%*

# Traditional EPICS Cross Cal L8/S2A results: **Global**- May2022



• Cross Cal

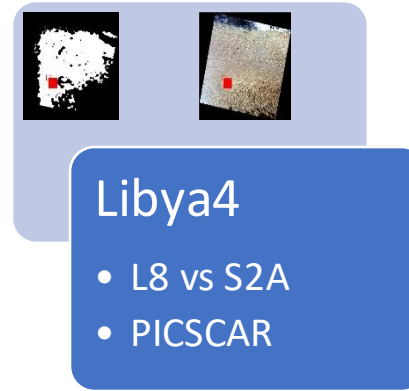


*L8 = 4433 images, S2A = 5085 images*

GAINS	CA	Blue	Green	Red	NIR	SWIR1	SWIR2	
<b>Cross Cal</b>	<b>0.9844</b>	<b>0.9925</b>	<b>1.0068</b>	<b>0.9984</b>	<b>0.9969</b>	<b>1.0003</b>	<b>1.0086</b>	
Std.Dev	0.0412	0.0411	0.0298	0.0383	0.0276	0.0283	0.0441	
Xcal Unc.%	1.74%	1.53%	0.74%	1.93%	1.24%	1.12%	1.90%	

*~Sub 1% Deviation from unity for all bands except CA ~Sub 2%*





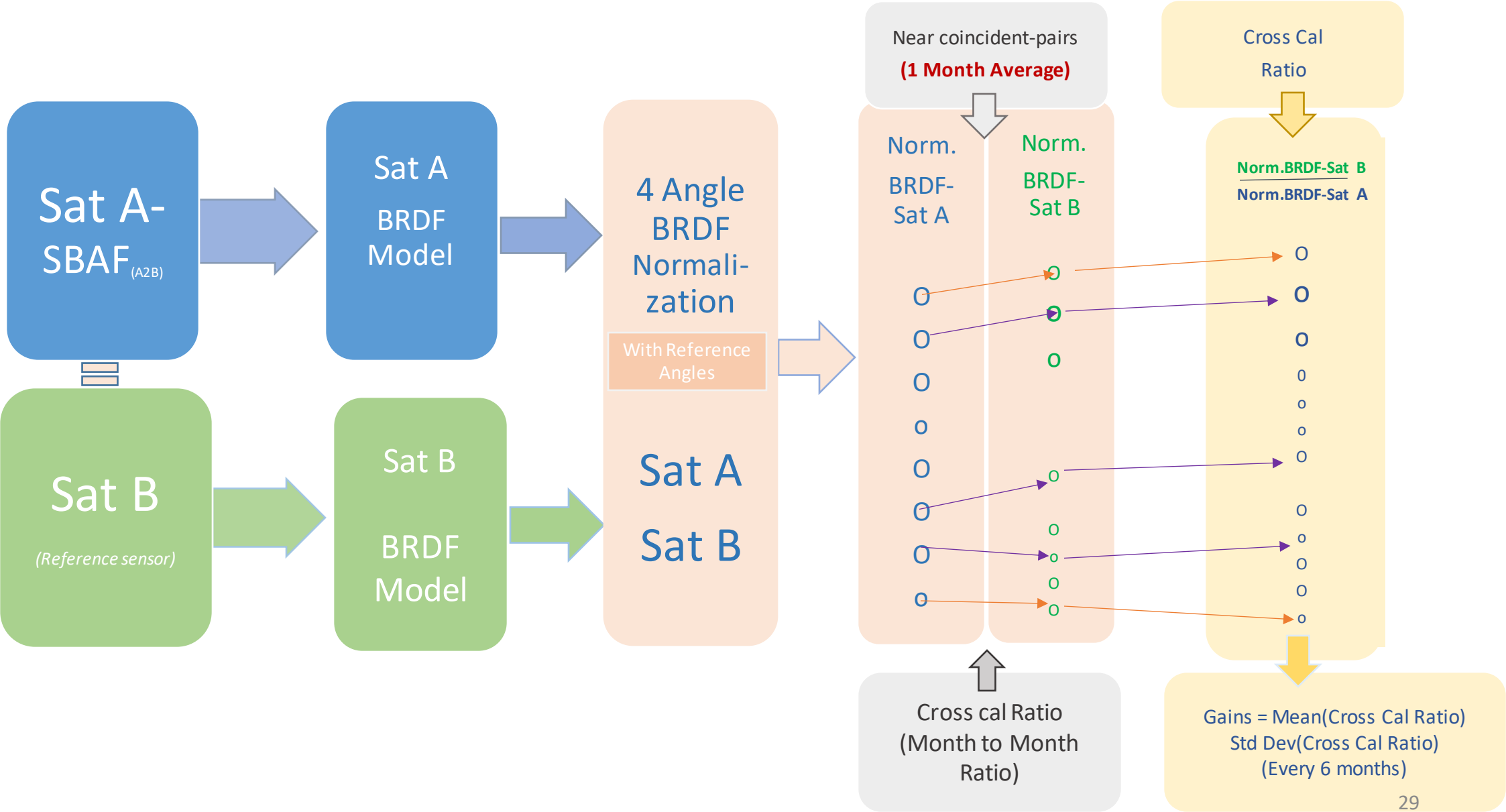
# Traditional PICS Cross Calibration Analysis

L8/S2A

Libya4

(PICSCAR Result)

# Traditional Cross Calibration Process : PICSCAR

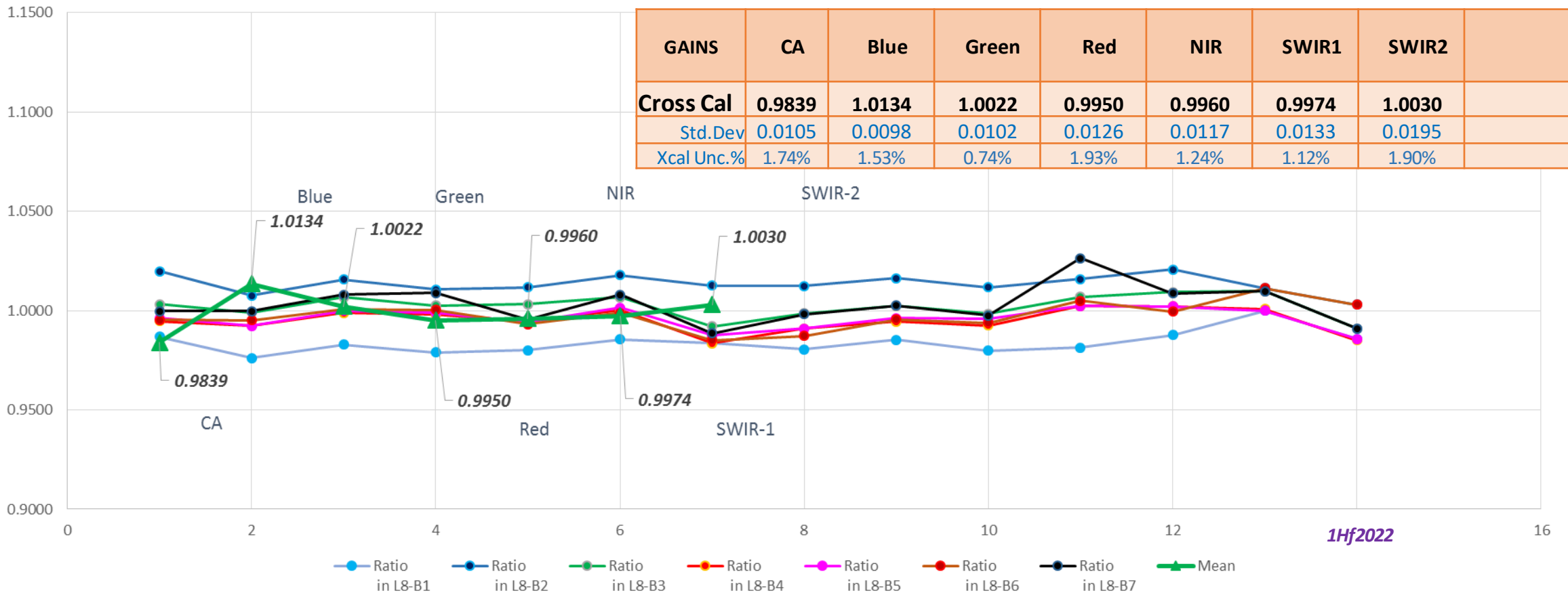




# PICSCAR Results: End June 2022 (ratio L8/S2A)

Summary chart: L8/S2A Ratio

	GAINS	CA	Blue	Green	Red	NIR	SWIR1	SWIR2	
<b>Cross Cal</b>		<b>0.9839</b>	<b>1.0134</b>	<b>1.0022</b>	<b>0.9950</b>	<b>0.9960</b>	<b>0.9974</b>	<b>1.0030</b>	
Std.Dev		0.0105	0.0098	0.0102	0.0126	0.0117	0.0133	0.0195	
Xcal Unc.%		1.74%	1.53%	0.74%	1.93%	1.24%	1.12%	1.90%	



# Summary Cross Cal Results:

*Traditional Cross Cal,  
EPICS NA vs EPICS Global*

*L8 vs L9*

*L8 vs S2A*

# Summary Satellite Inter comparison

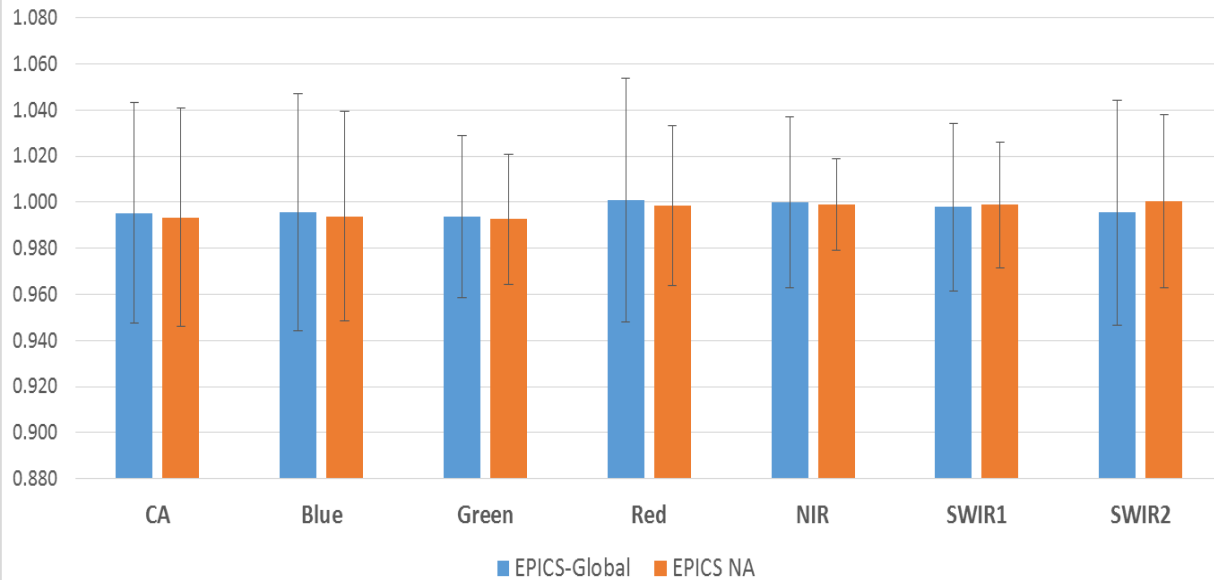
## L8/L9

- Better than 0.5% for all bands, Green band ~ Sub 1%

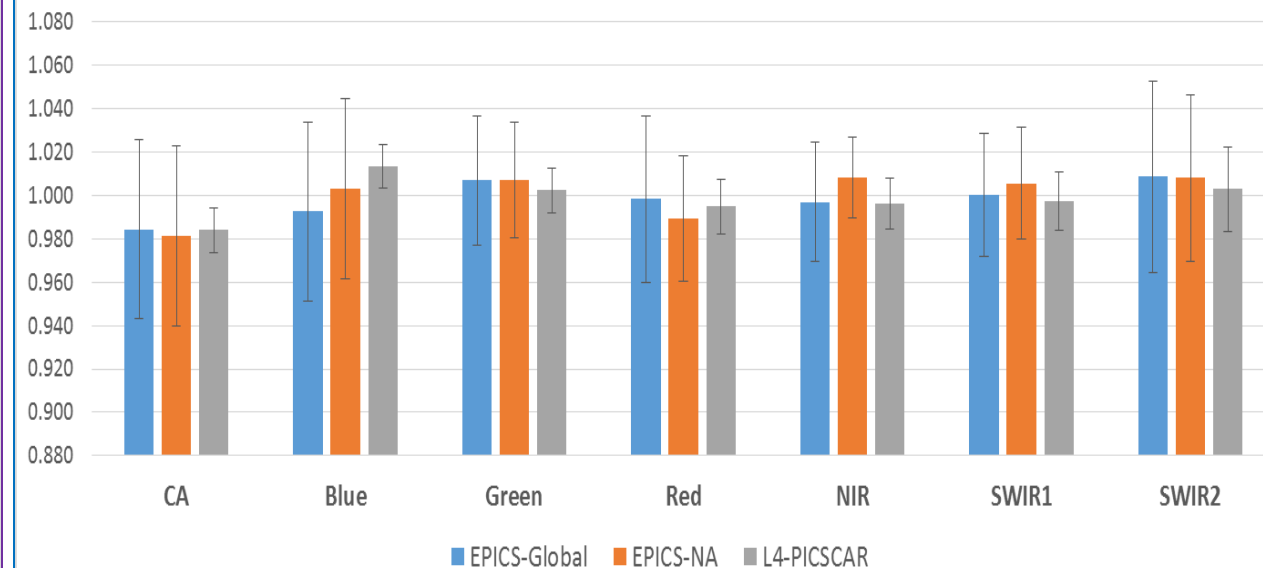
## L8/S2A

- ~1-2% for CA, Blue and Red bands, Green, NIR and SWIRS bands are sub 0.5%

Cross Calibration Ratio Comparison: L8/L9






Cross Calibration Ratio Comparison: L8/S2A



# Conclusion



- Trending Analysis
  - Satellites [ L7, L8, L9, S2A, and S2B] are performing well in orbit and stable with degradation better than 0.1% per year for all bands,
  - all targets [6 PICS, EPICS-NA, EPICS-Global] confirmed same level of degradation better than 0.1% 
- Cross Calibration: Traditional Cross Cal
  - L8/L9**
    - L8 and L9 are at sub 0.5% agreement for all bands except green band 
    - Only green band shows difference at ~1% level
  - L8/S2A**
    - CA, Blue and Red ~1-2% agreement between L8 and S2A
    - All other bands are better than 0.5%
- EPICS give consistent cross calibration results; 
  - Applicable to all satellites taking advantage of stable pixels on a continental and global scale
  - Obtain dense dataset for calibration: a daily basis

*Thank you  
for you Attention*