Characterization and Correction of GOES-16 ABI Solar diffuser Residual BRDF

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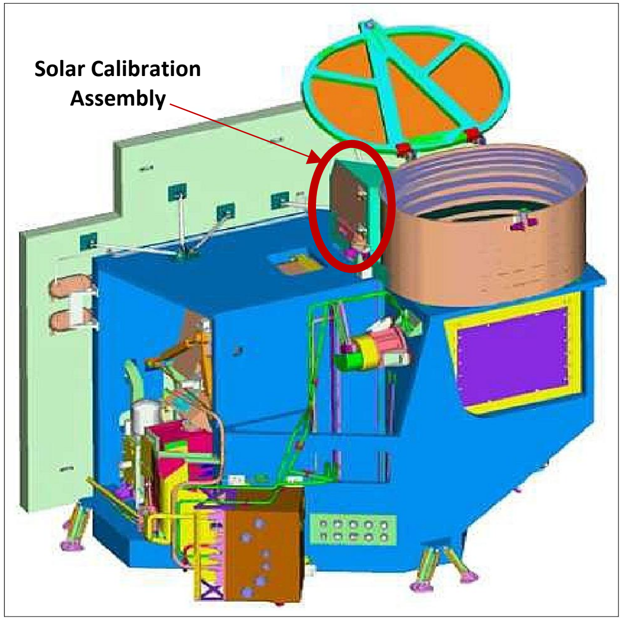
Outlines

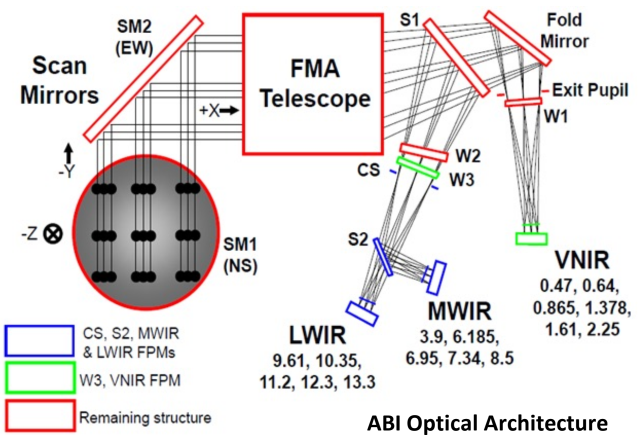
- **Introduction**
  - GOES-R Series ABI VNIR bands solar calibration
- **Dataset and Method**
  - Issues in long-term performance of Operational (OE) ABI solar calibration in addressing its instrument degradation
  - CWG in-house solar calibration experiments
- **Results**
  - Characterize the dependence of the solar calibration angles on the seasonal variation of VNIR bands gains for G16.
  - Quantify and derive the angle correction coefficients.
  - Correct these impacts of the dependence on ABI.
  - Compare our results after we apply the angles bias correction
- **Summary**

Introduction

- **GOES-R ABI** is a primary weather instrument on board the NOAA GOES-R series satellites, and consists of six visible and near-infrared (VNIR) and 10 infrared(IR) channels for accurate weather forecasting and environmental monitoring
- For VNIR bands, it utilizes a solar diffuser as its solar calibration target (**SCT**) to generate the gain coefficients for the Earth scene calibration. Cadence of the solar calibration starts every other day and increases to every 90 days over the first 12-18 months of operation as designed. Currently, it is conducted biweekly by a reschedule.
- The solar calibration can only be performed when a specific geometry between the SCT and the sun is achieved with the elevation angle near zero.



Schematic view of the ABI instrument (image credit: ITT)



ABI Optical Architecture
(Courtesy Paul Griffith and Harris Corp.)

GOES-16 ABI Major Solar Calibration Events

Major Solar Calibration Events	GOES-16	Impact on Mean Gain
Solar Cal. Algorithm (Rev. E)	01/15/2017	None –initial algorithm
G16 B02 Gain Set Change	03/19/2017	~11% increase
Optimal Solar Cal. Timing	12/12/2017	Removed the variation up to 2%
G16 Operational Date	**12/18/2017**	**Operational**
G16 B01-B03 Q LUT update	01/17/2018	Negligible, removed striping
Solar Cal. Algorithm update (Rev. F)	02/07/2018	G16 Striping removed
Solar Cal. Algorithm update (Rev. F')	12/26/2018	Negligible, <0.1%
Solar Cal. Algorithm update (Rev. G)	04/23/2019	B04-B06 gain 1%- 2.5% reduce
B02 solar cal. K LUT update	04/23/2019	~B02 7% reduced
Lunar rejection threshold LUT updates	06/24/2019	Gain corrected, B03-B06, striping removed
Biweekly Solar Calibration	**06/22/2021**	**More frequent solar calibration**

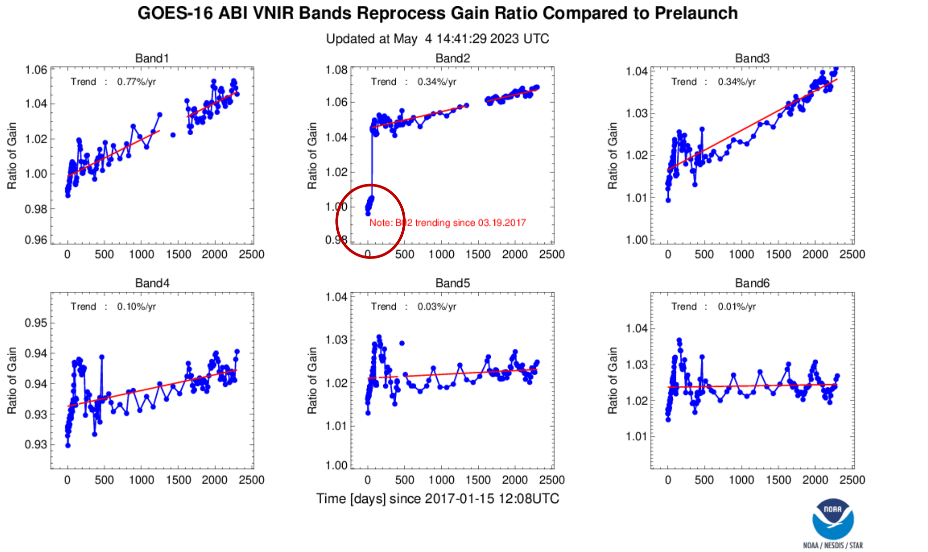
ABI VNIR Bands Solar Calibration

GOES-R ABI Reflective channel gain coefficient (for each channel): *m*

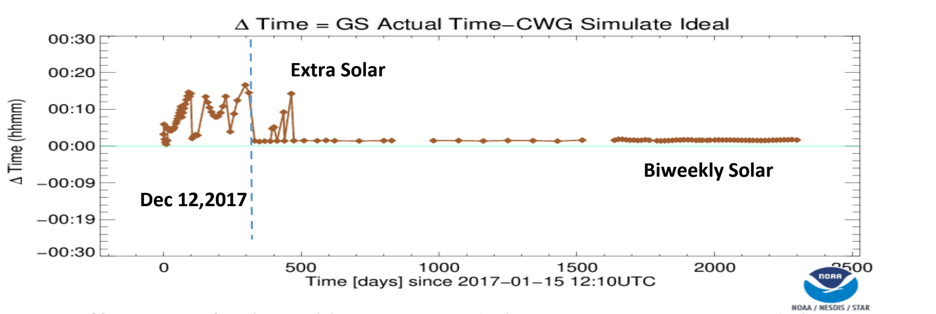
$$m = \frac{f_{int,ch} \cdot L_{SCT}^{eff}}{\left(\bar{x}_{SCT} - \bar{x}_{Solar\_Cal\_Space}\right)} - Q\frac{\left(\bar{x}_{SCT} - \bar{x}_{Solar\_Cal\_Space}\right)}{\left(f_{int,ch}\right)^{p-1}}$$

- $\bar{x}_{SCT}$ Average SCT counts, $\bar{x}_{Solar\_Cal\_Space}$ Average solar cal space counts, L_{SCT}^{eff} SCT effective channel average spectral radiance. The p is integration factor power term (per channel). Q is the nonlinearity quadratic term.
- L_{SCT}^{eff} is a function of scan mirror reflectance, 100% albedo Lambertian Scene, distance from earth to the Sun, Sun-to-SCT diffuser normal angle of incidence and bidirectional reflectance distribution function(function of beta angle).
- Thus the L_{SCT}^{eff} depends on the elevation angle and beta angle.

Issue: "Imperfect" Solar Timing of G16



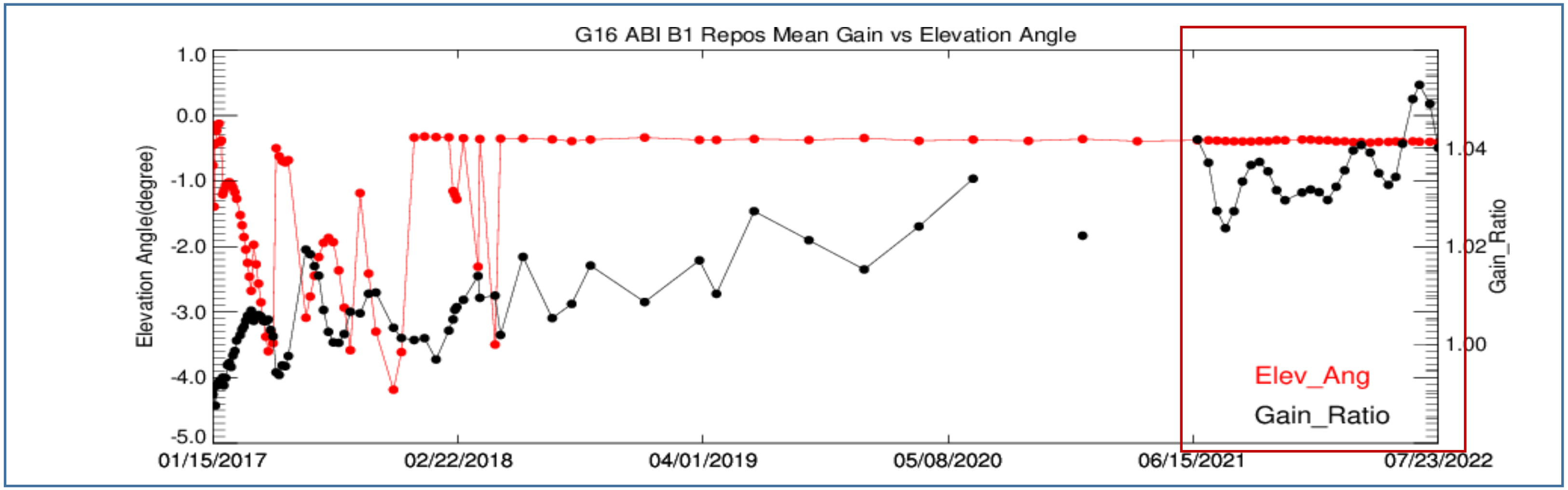
- CWG reprocessed solar calibration (repos) with CDRL-79 Rev N and CDRL-80 Rev G.

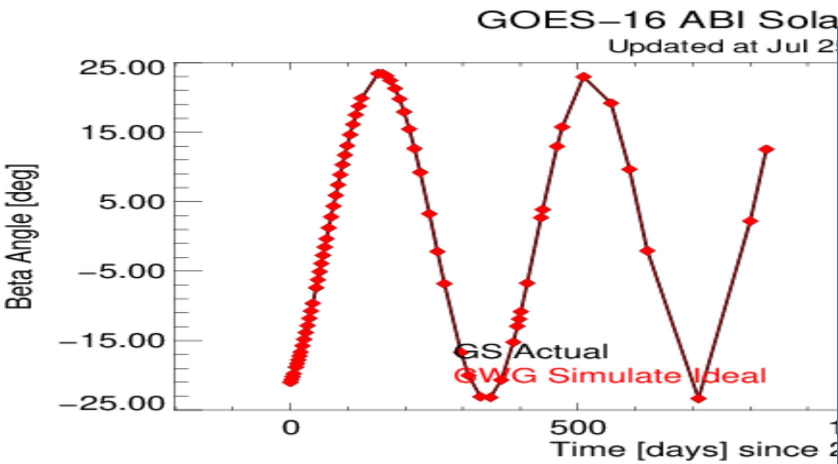


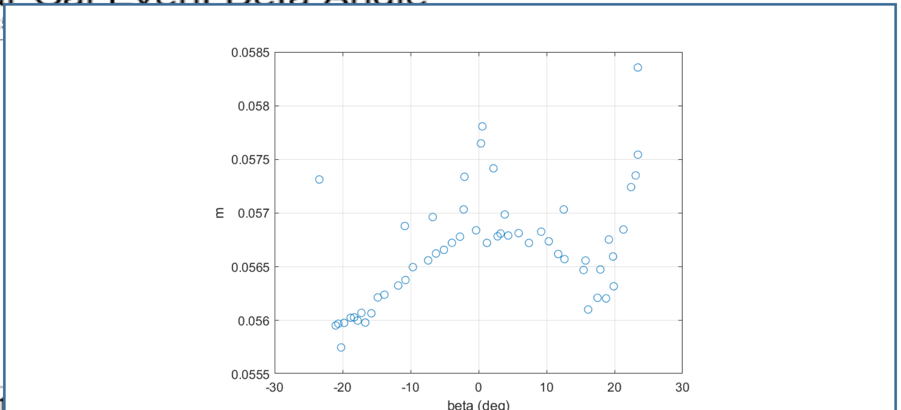
- Difference of solar calibration timing between operation and the simulation for best timing with the elevation angle equal to zero.

- Before correcting for these biases related to the solar elevation angle, we must account for gain variation due to the algorithm and LUT changes firstly. Thus we reprocessed G16 solar calibration with the CDRL-79 Rev N and CDRL-80 Rev G.
- There was a ~4% offset at the earlier stage in B02 before 03/19/2017 due to the reduction in the detector responsivity, which needs to be corrected.
- During the first year of its operation, calibrations for the GOES-16 ABI solar channels often occurred when the elevation angle of the Sun is not zero. This introduces bias in the derived gain.
- Variation in solar calibration gains can be caused by:
  - Instrument degradation, which is the signal we seek for;
  - Change of Solar Diffuser (SD) reflectance with elevation angle and beta angles
  - Noise, which can be reduced with multiple samples

GOES-16 Solar Angles vs Gain



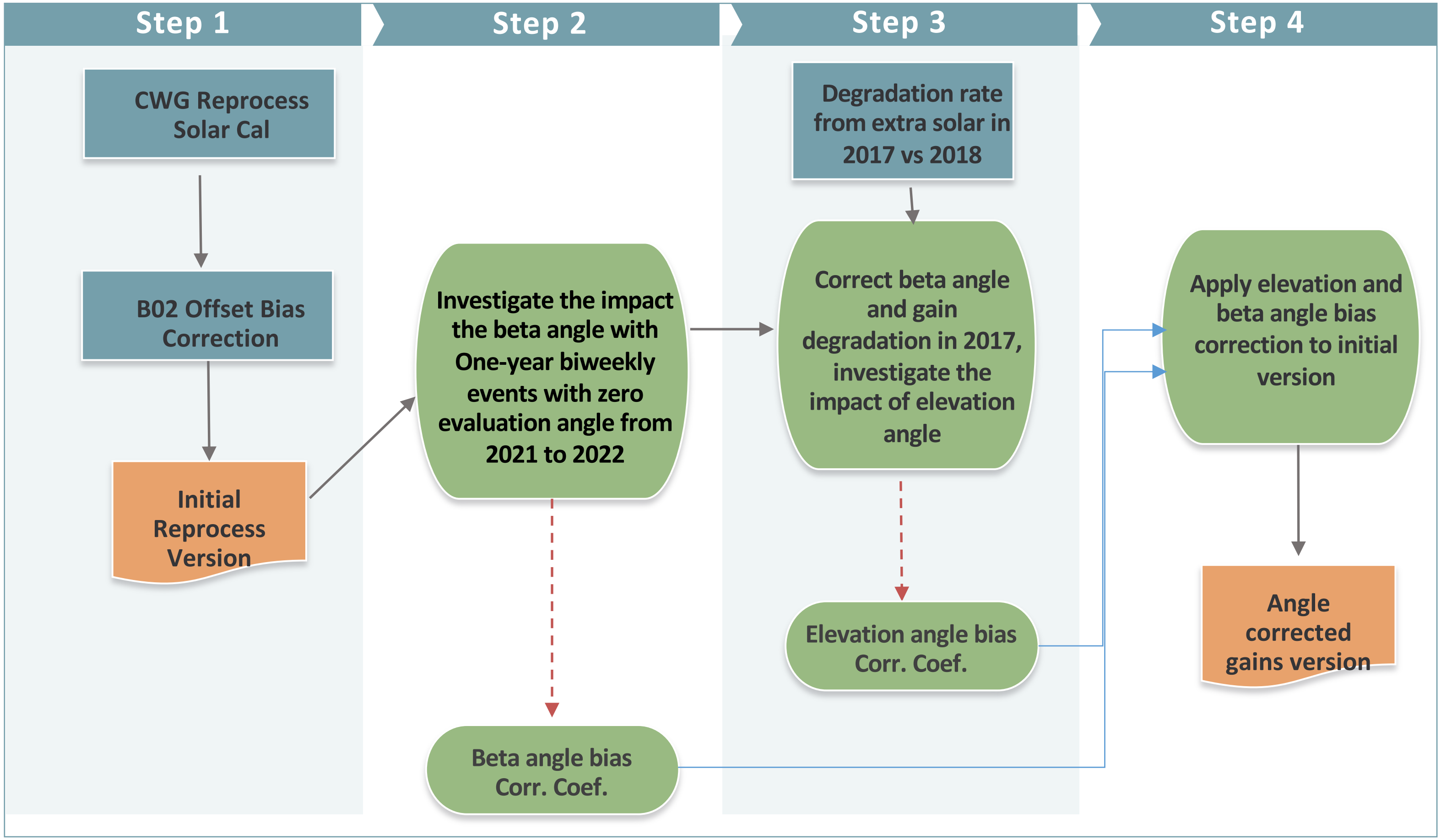




by A. Pearlman et al. 2021

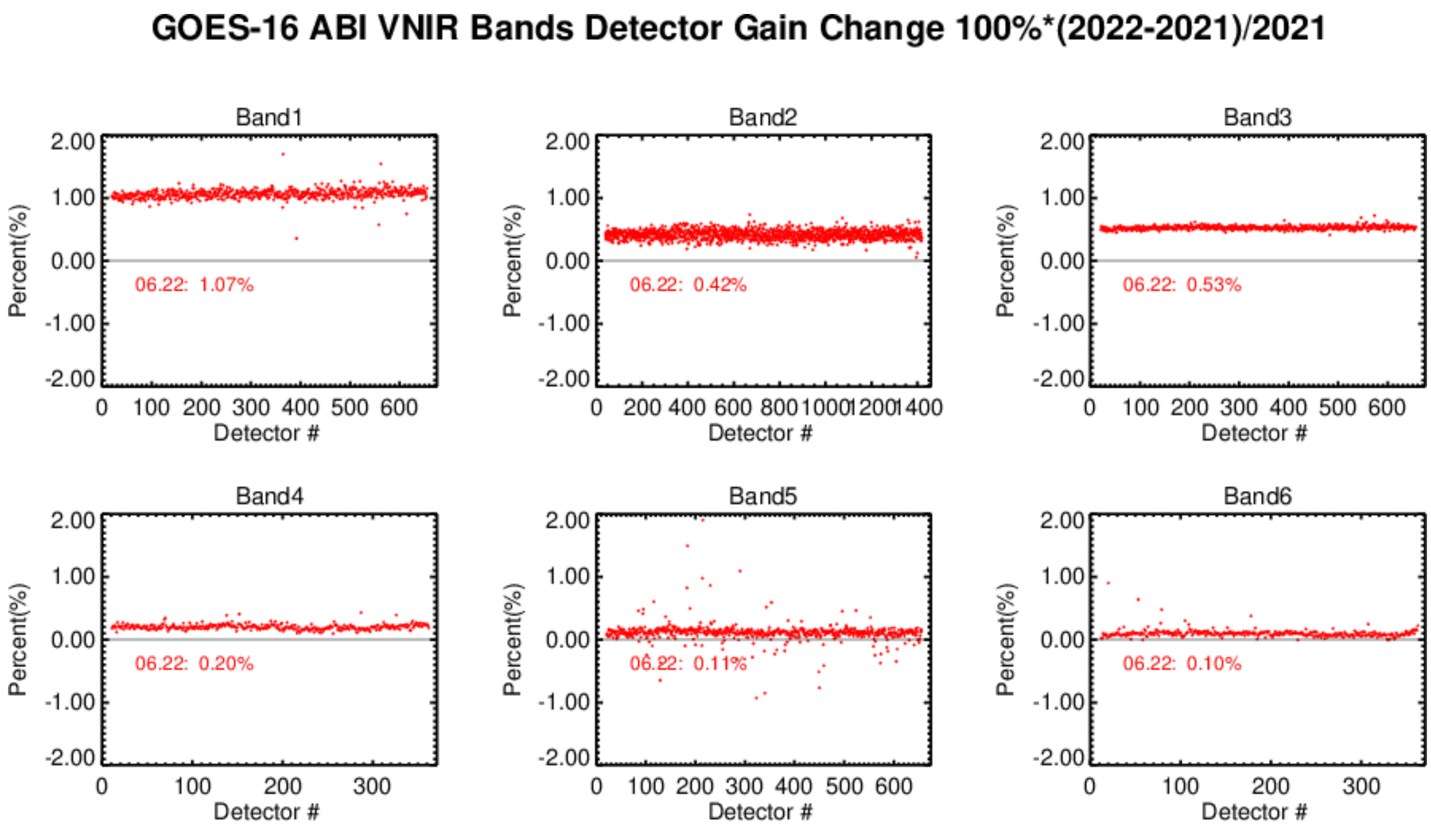
- The gains from the early stage were impacted by the beta angle, elevation angle and instrument degradation and it is hard to separate their individual impact.

Flowchart of Correcting the Bias of solar Beta/Elevation Angles



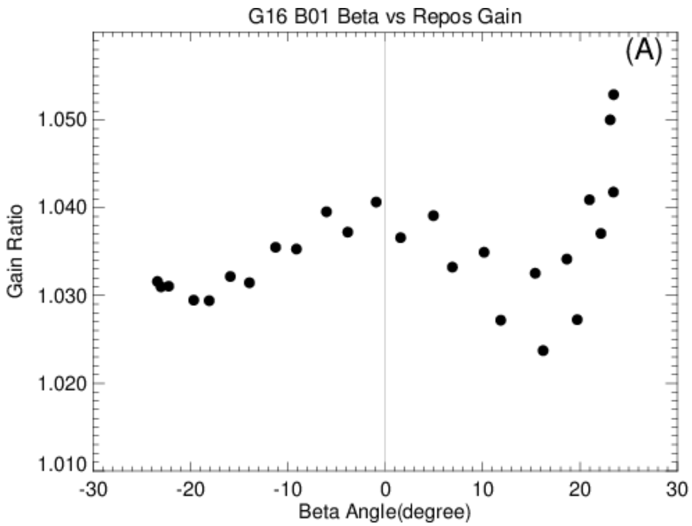
- **Flowchart to** correct the impact of solar angles (beta/elevation) for GOES-16 ABI VNIR bands gain with the CWG in-house solar calibration reprocessing.

Result Parts:
Step 2: Detector Gain Degradation Rate from Biweekly Events of 2022 vs 2021



- The biweekly solar events during this period were conducted as the zero elevation angle, providing a golden opportunity to isolate the impact from beta angle.
- To quantify the impact of beta angle vs gain from 06/22/2021 to 06/21/2022, we need to estimate the gain degradation rate and correct the gain over time.

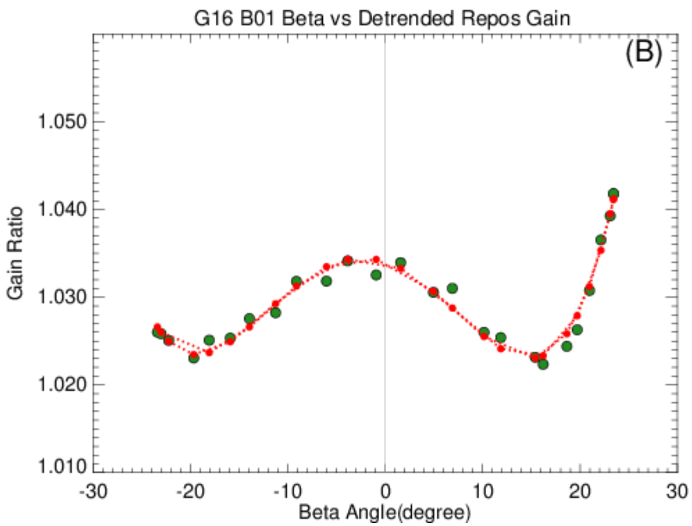
Beta Angle vs Gain in G16 B01

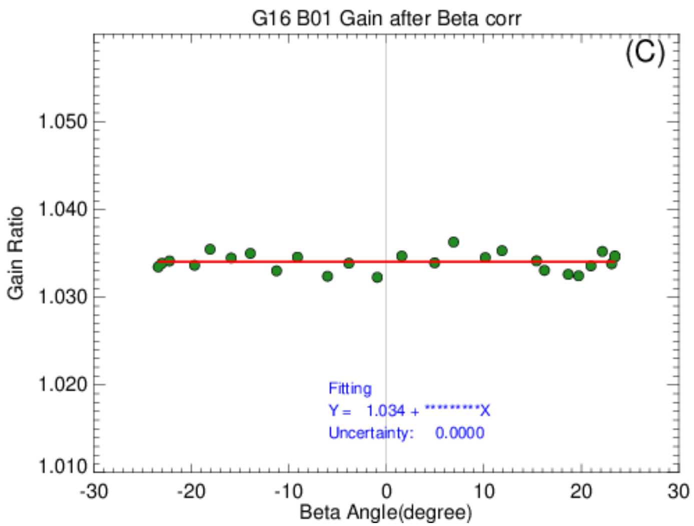


(A) Beta angle (1 year biweekly, 26 events vs mean gain in G16 B01).

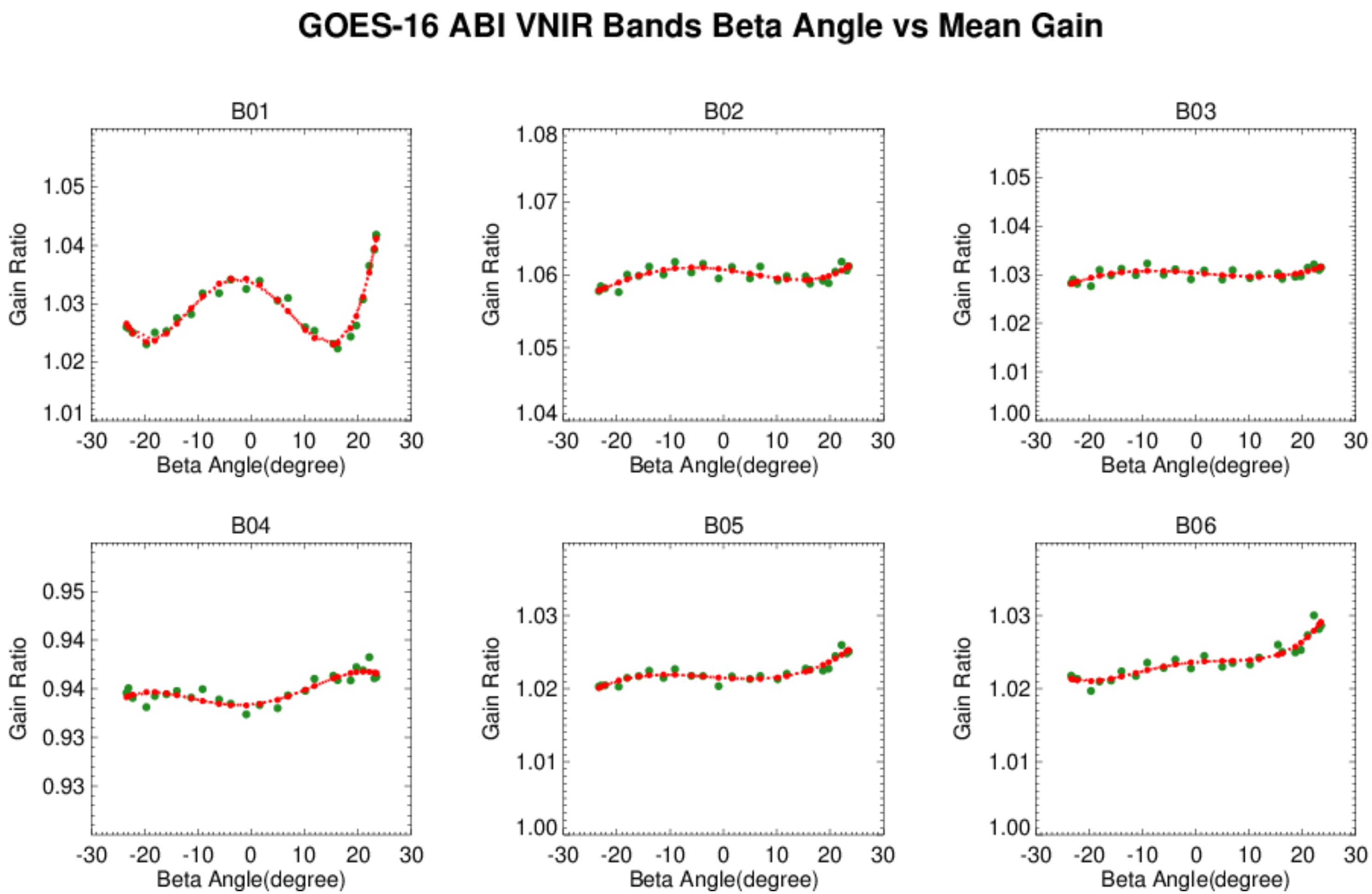
(B) The mean gain was corrected with degradation from the previous step on detector level in green. A Polynomial fitting with 4 degree is in red.

(C) Apply the correction coefficient to remove the dependence, then check the residual of beta angle dependence.



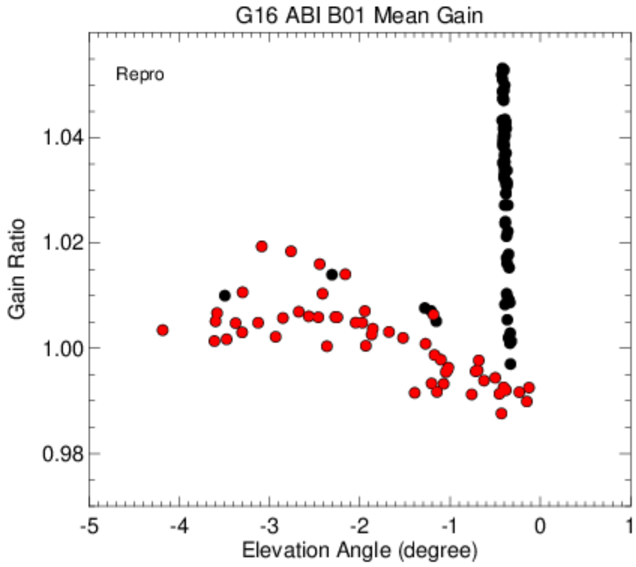


G16 VNIR Bands Dependence of Beta Angle vs Gain

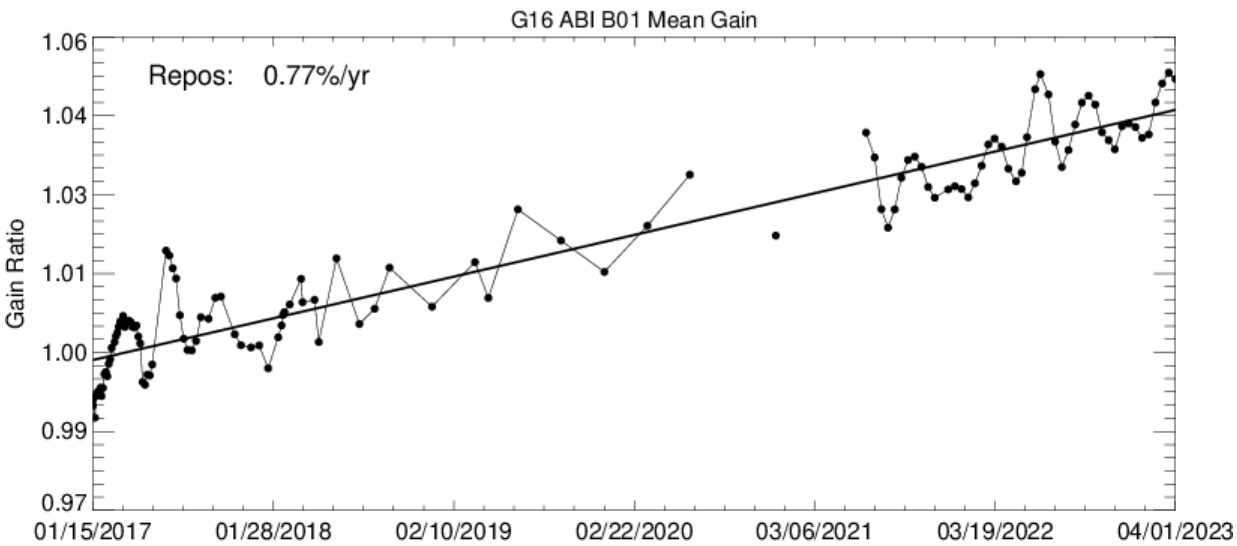


➢ The dependence of beta angle vs mean gain after degradation correction for each G16 VNIR bands based on the biweekly solar events from 06/22/2021 to 06/22/2022. A Polynomial fitting in red with 4 degrees is used to derive the dependence coefficient.

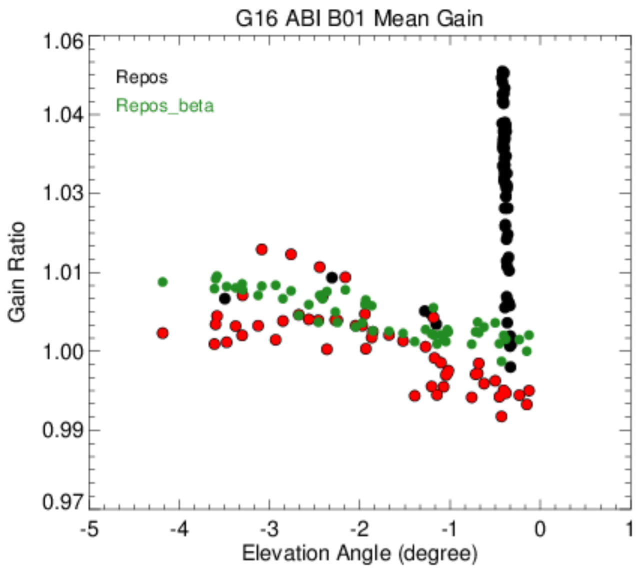
Step3: G16 B01 Mean Gain



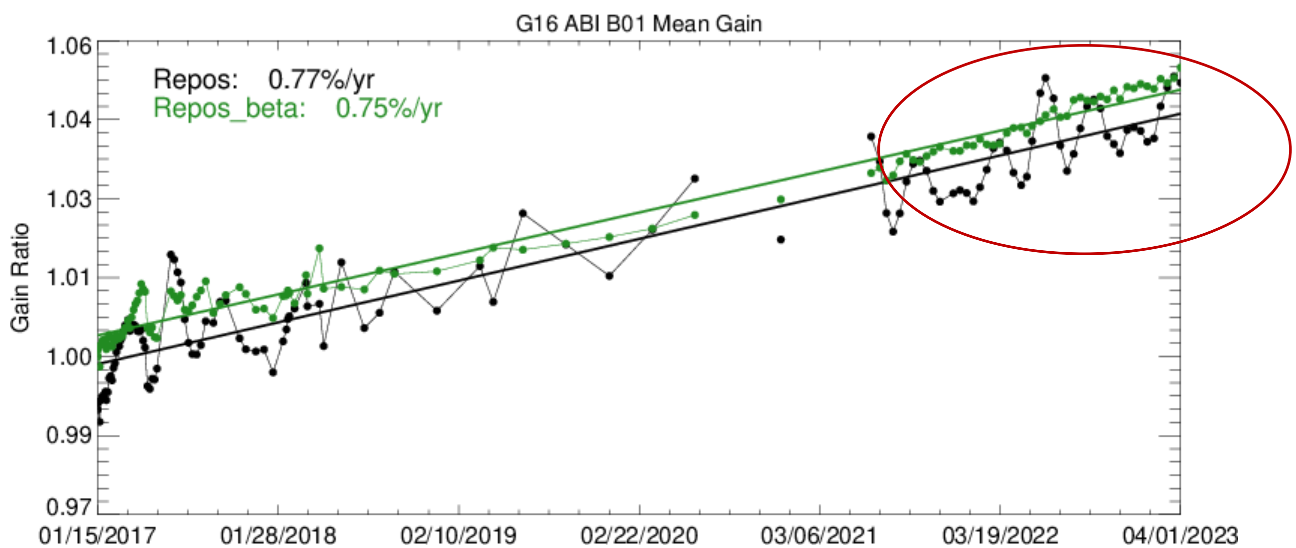
- Top left: The reprocessed mean gain vs actual elevation angle and the red points for the period from 01/15/2017 to 12/21/2017 and the black for the rest.
- Bottom: The trending of the reprocessed mean gain in black



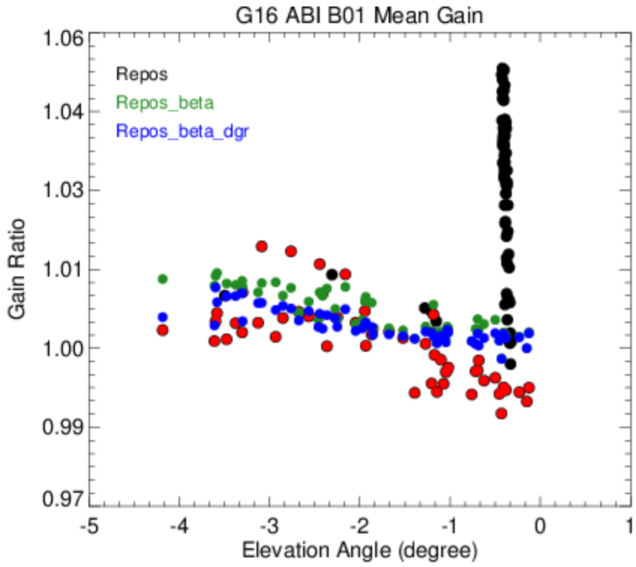
G16 B01 Mean Gain with Correction of Beta Angle



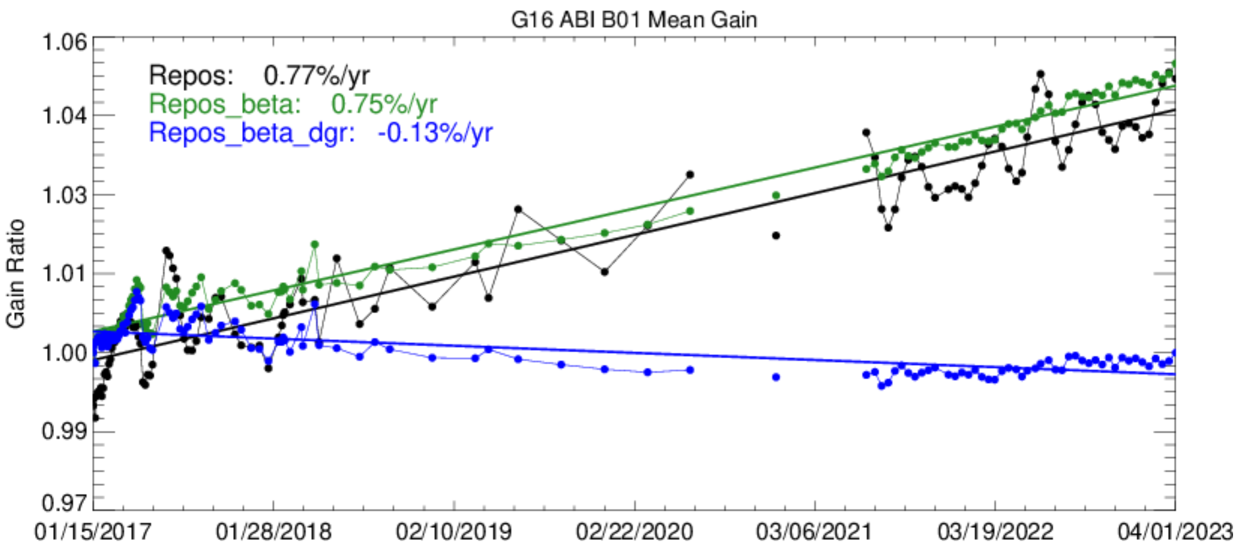
- Top left: The reprocessed mean gain vs actual elevation angle and the red points for the period from 01/15/2017 to 12/21/2017 and the black for the rest. Green: with beta correction for points in red.
- Bottom: The trending of the reprocessed mean gain in black, and for the one with the beta correction in green



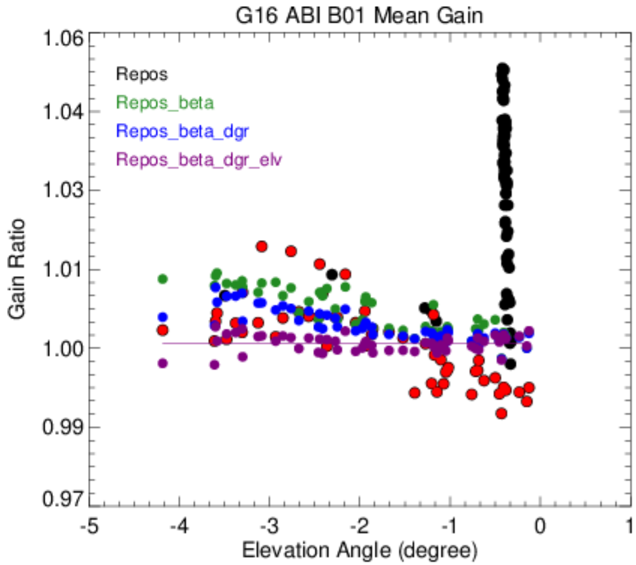
G16 B01 Mean Gain with Correction of Beta Angle/Degradation



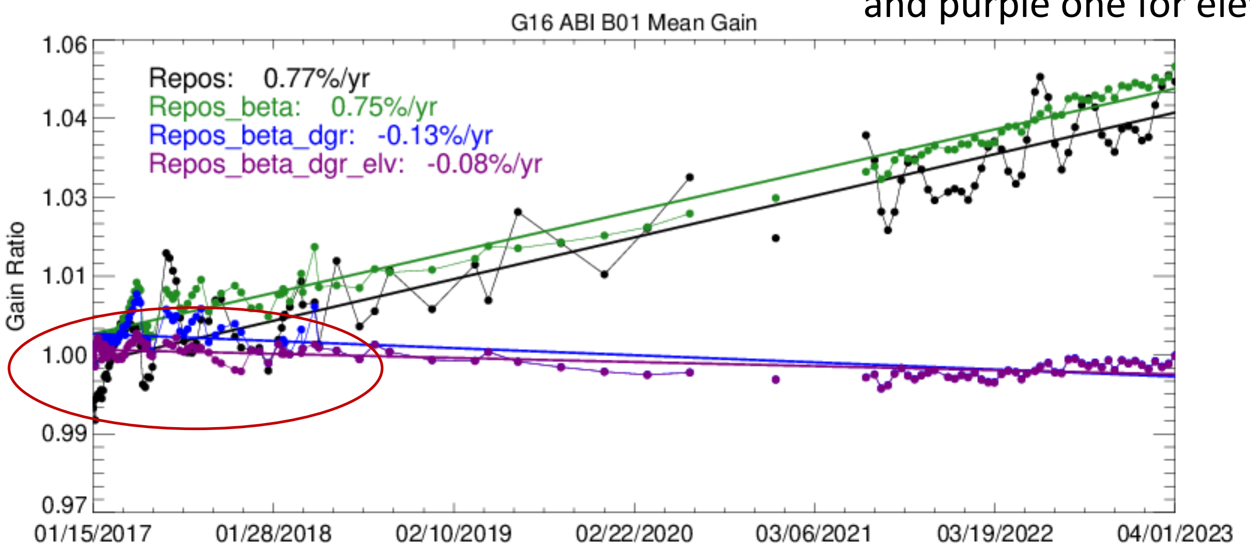
- Top left: The reprocessed mean gain vs actual elevation angle and the red points for the period from 01/15/2017 to 12/21/2017 and the black for the rest. Green: with beta correction for points in red. Blue: with removal the degradation for points in green.
- Bottom: The trending of the reprocessed mean gain in black, and for the one with the beta correction in green, and the one in blue removing the degradation trend (first guess)



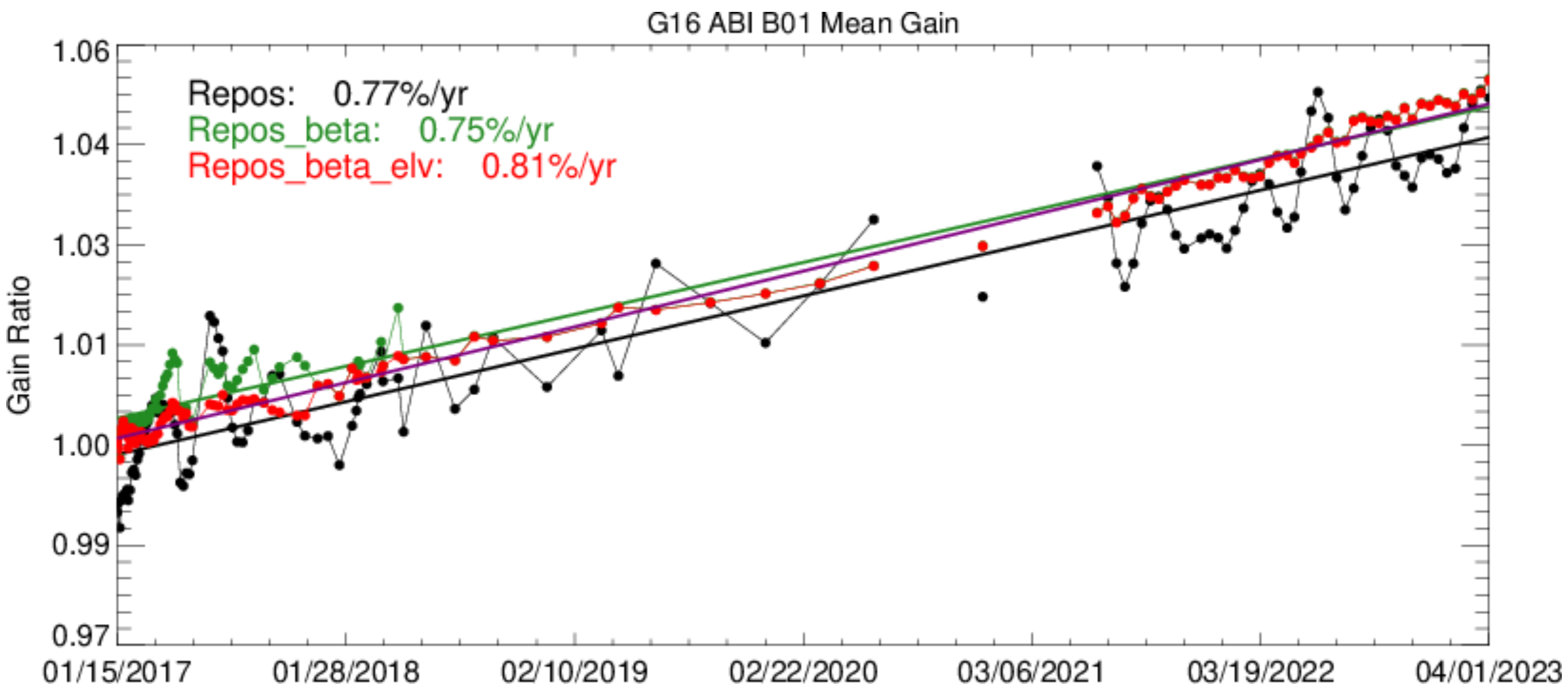
G16 B01 Mean Gain with Correction of Beta Angle/Degradation/Elevation



- Top left: The reprocessed mean gain vs actual elevation angle and the red points for the period from 01/15/2017 to 12/21/2017 and the black for the rest. Green: with beta correction for points in red. Blue: with removal the degradation for points in green. Purple: Elevation correction.
- Bottom: The trending of the reprocessed mean gain in black, and for the one with the beta correction in green, and the one in blue removing the degradation trend (first guess) and purple one for elevation angle correction.

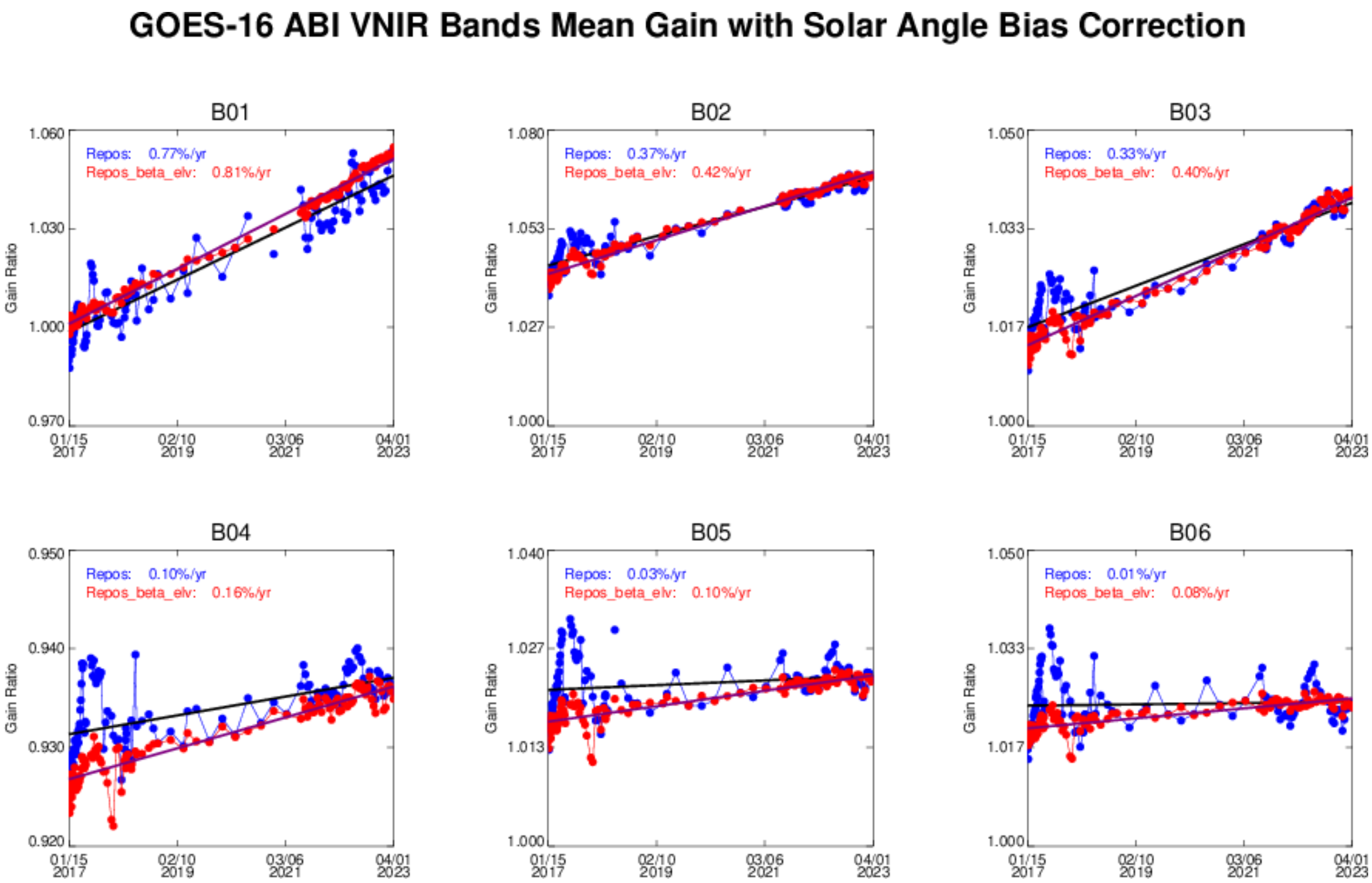


Step 4: G16 B01 Mean Gain with Correction of Beta/Elevation Angles



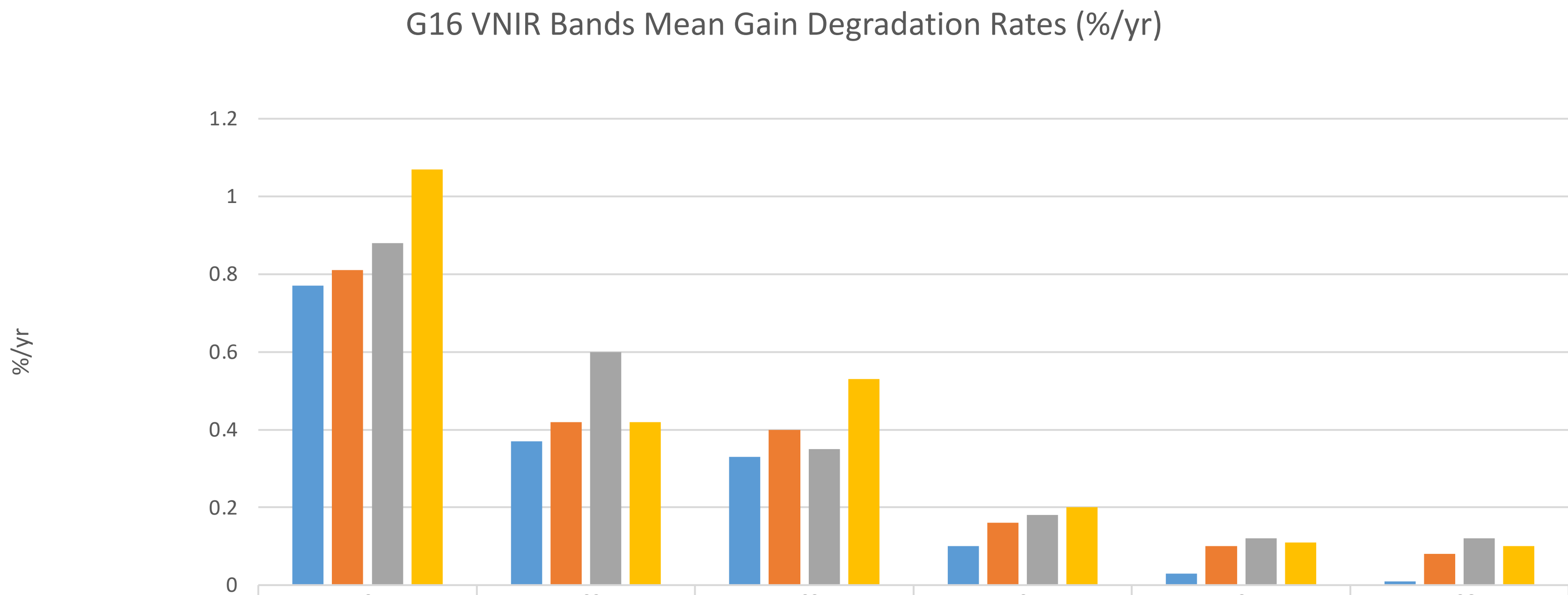
- The trending of he reprocessed mean gain in black, the one with the beta correction in green, and the red one for beta and elevation angle correction.
- This result shows that the large seasonal variation of gain was significantly corrected with the beta and further improved with elevation angles for the early stage.
- Overall, the result did improve the assessment of long-term gain degradation.

G16 VNIR Mean Gain with Correction of Beta/Elevation Angles



- The trending of he reprocessed mean gain in blue, the one with the beta correction and elevation angle correction in red.
- The linear fitting is used to calculate the long-term gain degradation rate.

Degradation Rates Comparison



	B01	B02	B03	B04	B05	B06
Repos	0.77	0.37	0.33	0.1	0.03	0.01
Repos_beta_elv_corr	0.81	0.42	0.4	0.16	0.1	0.08
Extra_solar_2018-2017	0.88	0.6	0.35	0.18	0.12	0.12
Extra_solar_2022-2021	1.07	0.42	0.53	0.2	0.11	0.1

Band

Repos Repos_beta_elv_corr Extra_solar_2018-2017 Extra_solar_2022-2021

Summary

- This study aimed to rely on CWG in-house solar calibration to quantify and remove the bias of G16 solar beta/elevation angles on the VNIR bands gain performance.
- The dependence of beta angle on the gain was quantified with the golden biweekly solar calibration from 06/2021 to 06/2022.
- The dependence of elevation angle on gain due to " imperfect" solar calibration timing was quantified with the events in early stage in 2017.
- Overall, our result shows that the beta/elevation angle correction can significantly reduce the large seasonal variation of mean gain and improve our assessment of it long-term performance. After correction, the largest degradation registered in the B01 with 0.81%/year, with least one in B06 with 0.08%/year.
- The characterization method of dependence of beta angle in gain seasonal variation in G16 VNIR bands can be referred to support the investigation for recent G18 VNIR variation after we reprocess it.

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- The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the authors and do not necessarily reflect those of NOAA or the Department of Commerce