GOCI Radiometric Calibration

: On-ground characterization and in-orbit calibration status

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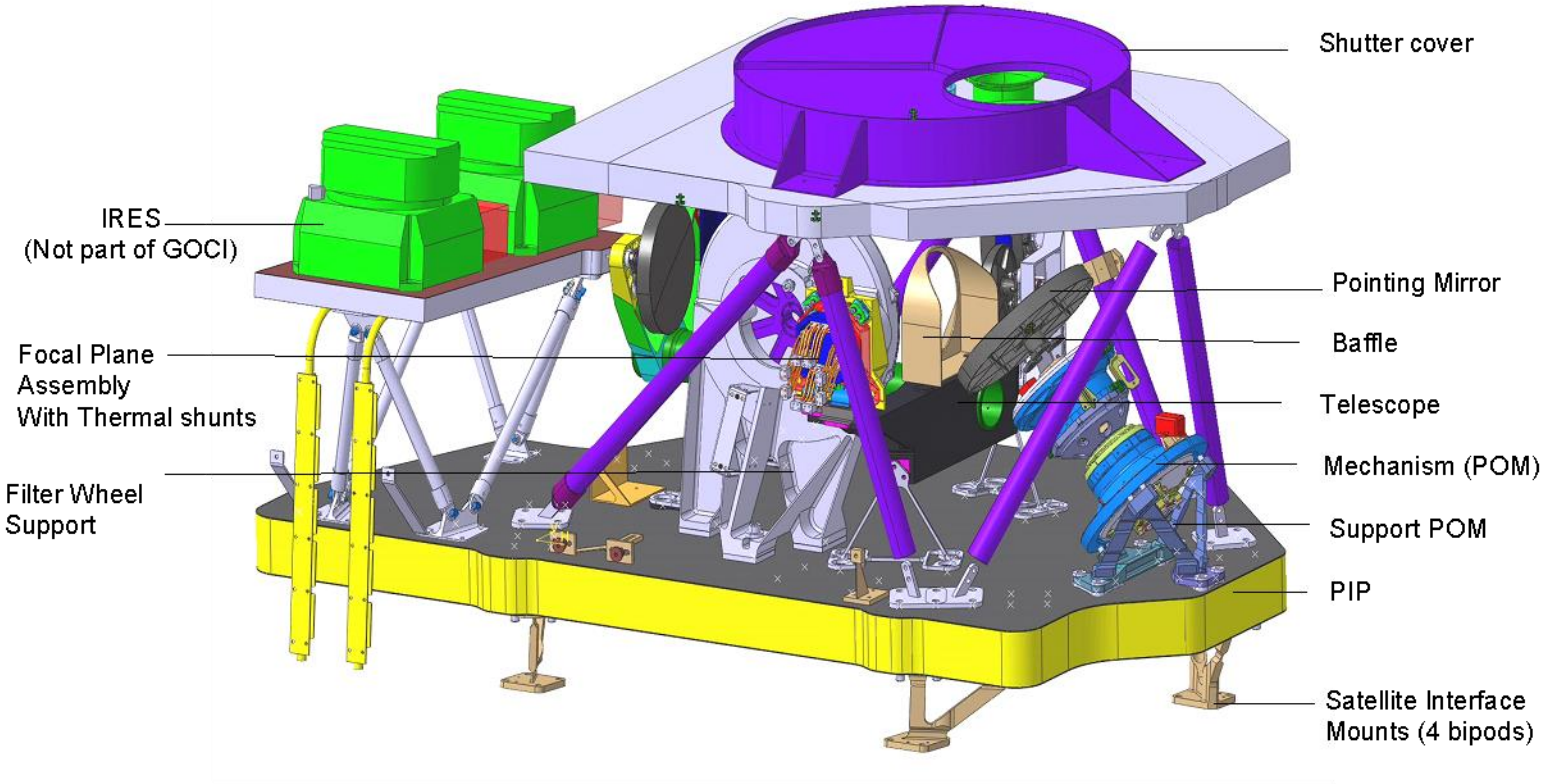
GOCI : Overview

- GOCI(Geostationary Ocean Color Imager)
  - 8 Spectral Bands (6 VIS, 2 NIR)
  - 500m GSD @ Center of Coverage (~375m GSD @ Nadir)
  - Coverage Area : 2,500km x 2,500km @ 130E 36N



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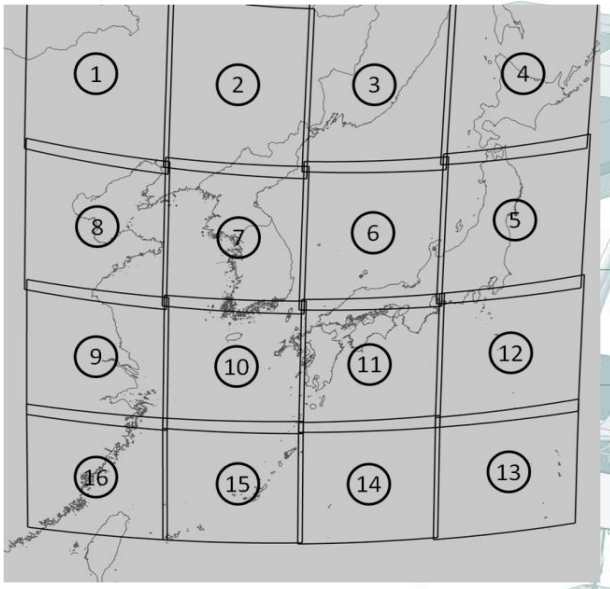
  - Temporal Resolution : 8 times / day



GOCI Coverage Area and Slot Imaging Sequence

Shutter cover

Movie File

GOCI
8 times / day

LEO
1 times / day

GOCI In-Orbit Calibration

- **In-orbit Solar Calibration Procedure**

Input Data for Radiometric Calibration

- Solar Diffuser ImageLV0C Image Data
- **Solar Incident Angle** calculated from Ephemerides data
- **Solar Irradiance(Thuillier, 2004)** after Sun-Earth Distance Correction(Spencer, 1971)
- **LV0C Secondary Header** Data
- **Diffuser Aging Factor using DAMD**

Pre-processing for Radiometric Calibration

- Pseudo averaging factor compensation for HG(High Gain, Image Averaging(a.k.a. Stacking) for better SNR)
- Offset Correction (Dark Current Correction)

In-orbit Radiometric Gain parameters calculation based on pixel-level Radiometric Model

Input from video data (image data)
$S^A_{dark\_T_n}, S^B_{dark\_T_n}$: Two dark image sets
$S^A_{SD\_T_n}, S^B_{SD\_T_n}$: Two sun image sets
Inputs from secondary header of each image data
T = *integration time*
n = *number of accumulated image*
p=*pseudo averaging coefficient*

Solar incident angle computation: $\theta^A_{SD}, \theta^B_{SD}$
(Refer to Section 4.6)

Input from in-orbit calibration: $\Delta\rho$

1) p factor compensation for high gain data (pixel gain (high or low) is indicated in each pixel data)

$$\bar{S}^A_{dark\_T_n} = \frac{1024}{np} S^A_{dark\_T_n}, \quad \bar{S}^B_{dark\_T_n} = \frac{1024}{np} S^B_{dark\_T_n}$$

$$\bar{S}^A_{SD\_T_n} = \frac{1024}{np} S^A_{SD\_T_n}, \quad \bar{S}^B_{SD\_T_n} = \frac{1024}{np} S^B_{SD\_T_n}$$

2) Offset parameter estimation

$$O_{T_n} = \frac{\bar{S}^A_{dark\_T_n} - \bar{S}^B_{dark\_T_n}}{T^A_{dark\_T_n} - T^B_{dark\_T_n}}$$

$$F_{T_n} = \frac{T^B_{dark\_T_n}\bar{S}^A_{dark\_T_n} - T^A_{dark\_T_n}\bar{S}^B_{dark\_T_n}}{T^B_{dark\_T_n} - T^A_{dark\_T_n}}$$

3) Offset correction for two sun images

$$\bar{S}^A_{SD\_T_n} = \bar{S}^A_{SD\_T_n} - O_{T_n} T^A_{SD\_T_n} - F_{T_n}$$

$$\bar{S}^B_{SD\_T_n} = \bar{S}^B_{SD\_T_n} - O_{T_n} T^B_{SD\_T_n} - F_{T_n}$$

4) Calculation of absolute gain parameters

$$G(T_n) = \frac{\pi}{E_s} \frac{(x^A_{SD\_T_n})^3 \bar{S}^B_{SD\_T_n} - (x^B_{SD\_T_n})^3 \bar{S}^A_{SD\_T_n}}{x^A_{SD\_T_n}(x^B_{SD\_T_n})^3 - (x^A_{SD\_T_n})^3 x^B_{SD\_T_n}}$$

$$b(T_n) = \left(\frac{\pi}{E_s}\right)^3 \frac{(x^A_{SD\_T_n})^3 \bar{S}^B_{SD\_T_n} - (x^B_{SD\_T_n})^3 \bar{S}^A_{SD\_T_n}}{x^A_{SD\_T_n}(x^B_{SD\_T_n})^3 - (x^A_{SD\_T_n})^3 x^B_{SD\_T_n}}$$

where $x^p_{SD\_T_n} = T^p_{SD\_T_n} \rho_{SD\_T_n}(\theta^p_{SD\_T_n}) \cos\theta^p_{SD\_T_n}, \quad p = A, B$

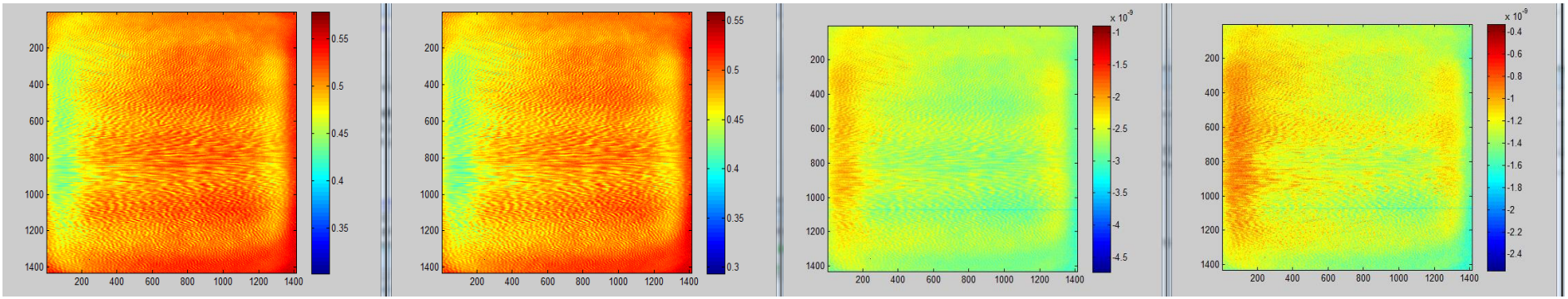
$$\rho_{SD\_T_n}(\theta^p_{SD\_T_n}) = \rho_{SD\_T_0}(\theta^p_{SD\_T_n}) \Delta\rho(\theta^p_{SD\_T_n}), \quad p = A, B$$

GOCI Radiometric Model

- GOCI Radiometric Model : 3rd-Order Polynomial

$$S = G \times T_{\text{int}} \times L + b \times T_{\text{int}}^3 \times L^3 + T_{\text{int}} \times O + F$$

  - L : Spectral Radiance(W/m^2/um/sr) measured by GOCI
  - G, b : Linear & Non-linear Gain of GOCI, respectively
  - Tint : Integration Time
  - O, F : Offset parameters (i.e. dark current)

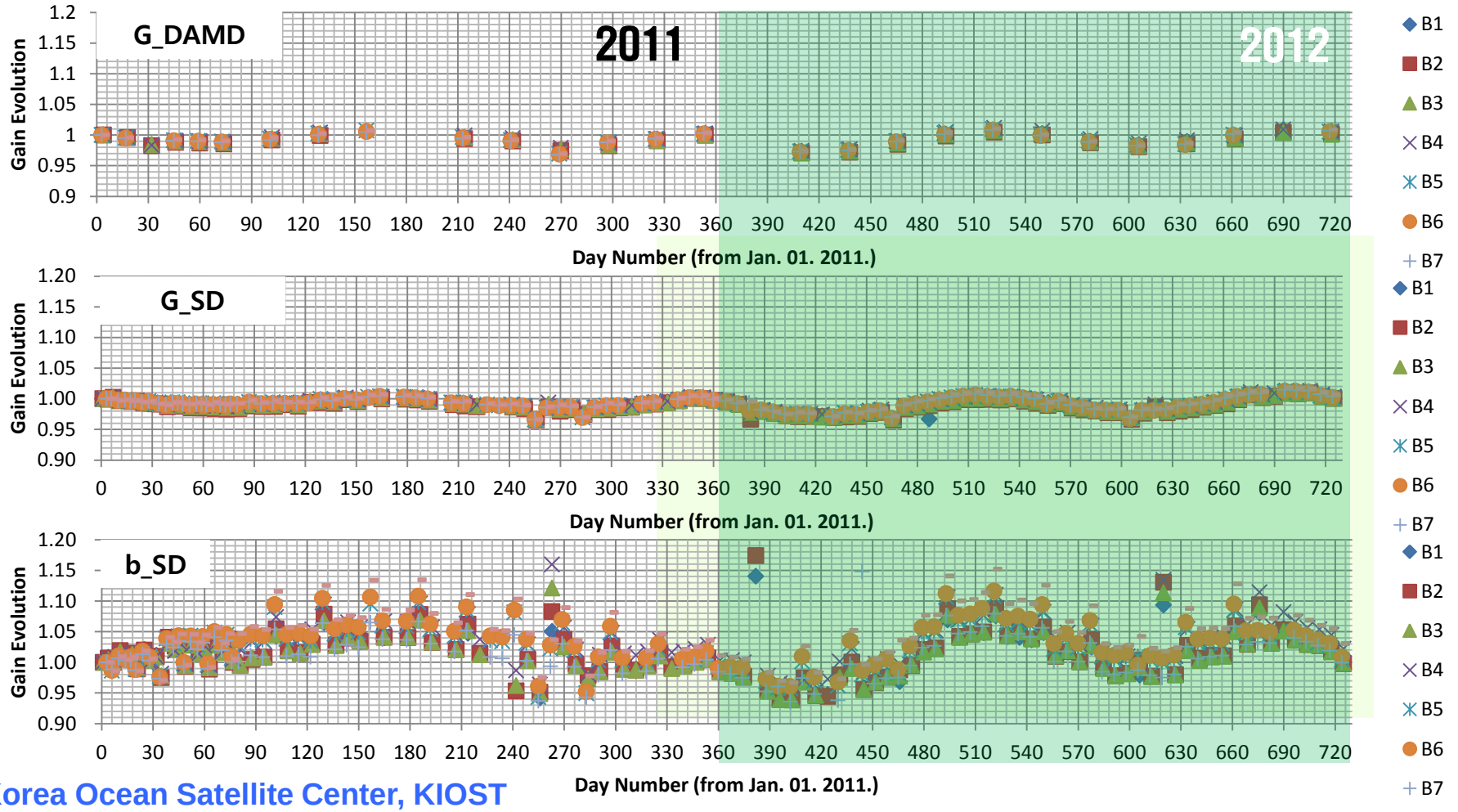


Linear Gain(G)

Non-linear Gain(b)

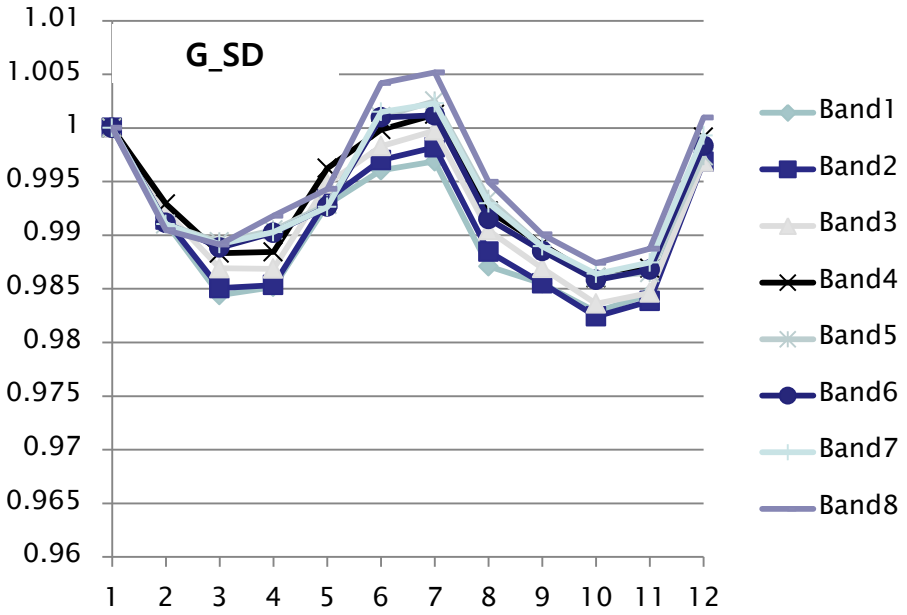
In-Orbit Calibration Results

- **Evolution of GOCI Radiometric Gain**
  - Monitoring of Linear Gain(G), Non-linear Gain(b) using SD & DAMD

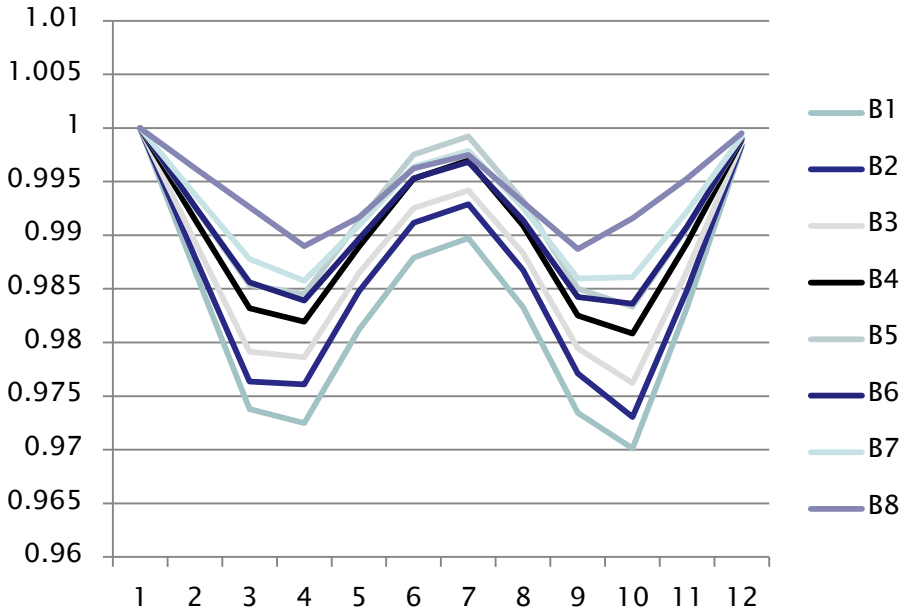


Discussion for Gain Evolution

- **Evolution of GOCI Radiometric Gain (2011.~2012.)**
  - Sinusoidal Variation of Radiometric Gain : ~ 2.5% (2011.)
  - Gain Evolution with same solar Azimuth/Elevation angle
    - ~0.51% (G_SD, Weekly Obs.) , ~0.14% (G_DAMD, Monthly Obs.)
    - Annual Solar angle variation : 108.4°/10.5° (AZ/EL)
  - Gain Variation(Uniformity) over FPA : ~5% (CV; STDEV/Mean)



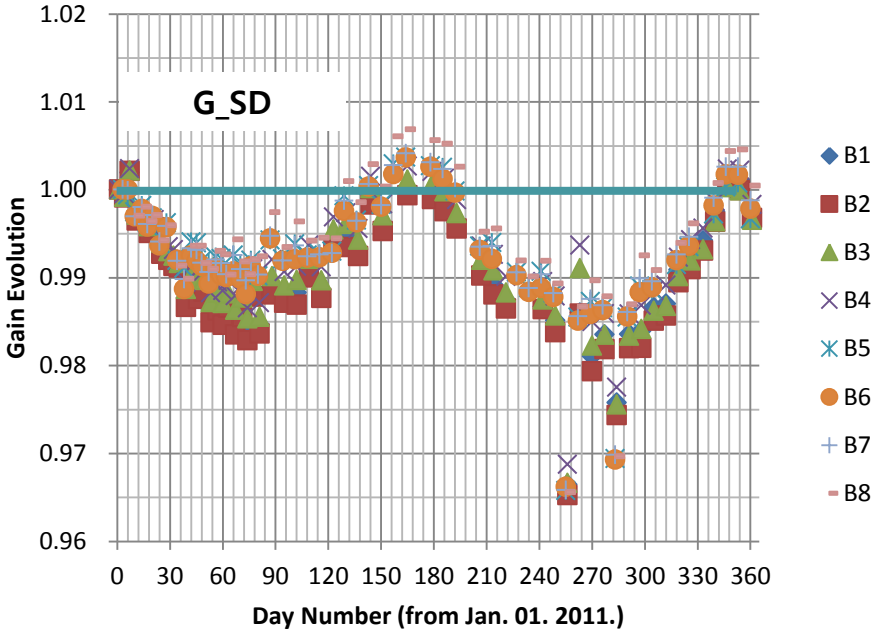
Evolution of Radiometric Gain (2011)



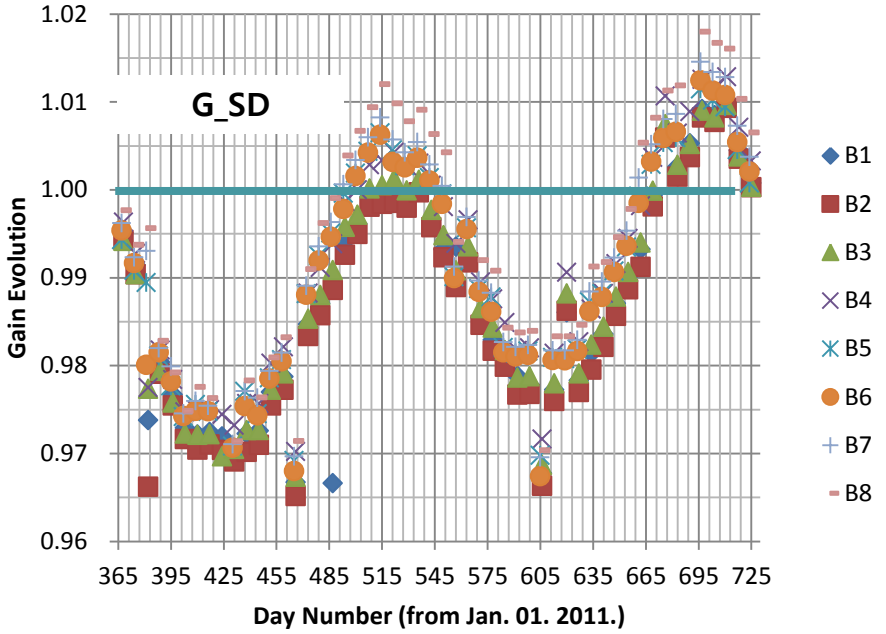
Diffusion Factor Variation
w.r.t. Solar azimuth **angle measured in pre-flight test**

Discussion for Gain Evolution

- **Evolution of Radiometric Gain (2011. vs. 2012.)**
  - Radiometric Gain Variation(2012) : ~ 4% (from '11./01./01.)
  - Amplitude of variation is larger than year of 2011.
    - Might be the contribution of aging of diffusion factor
    - Might be required the enhancement of Solar Irradiance Model



Evolution of Radiometric Gain (2011)



Evolution of Radiometric Gain (2012)

Issues and Concerns

- **Issues**
  - **Diffuser Characterization Model shall be updated**
    - Based on the Solar elevation angle only.
    - Unfortunately, diffuser BSDF test results over Solar azimuth angle is very poor measured at pre-flight test.
  - **Solar Irradiance Model shall be updated**
    - Solar irradiance variation model with 11-year solar cycle or other radiometric model independent to the Solar Irradiance are required
  - **Concerns**
    - Is Solar Calibration the optimal solution for the in-orbit calibration in GEO?
    - Solar angle variation is quite larger, and it is quite hard to control the Solar angle on diffuser (without satellite maneuver) in GEO.

GOCI-II Radiometric Calibration

- **GOCI-II Radiometric Calibration plan**
  - **derived by lessons learned from GOCI operation**
  - **Solar Diffuser with Lambertian Characteristics is preferred**
  - **In any case, highly accurate solar diffuser characterization model is required**
    - Diffuser BSDF characterization over all Sun angle(AZ/EL) range
    - Diffuser Aging Model(w.r.t. Sun angle) shall be characterized at on-ground test
  - **Lunar Calibration is planned for GOCI-II calibration**
    - Moon(even in 100% phase) may not cover the whole GOCI-II 2D FPA region
    - Required dedicated Calibration Algorithm(based on ROLO)
  - **2nd Diffuser (DAMD on GOCI) will be implemented**
    - For the monitoring of Diffuser aging and contingency plan (redundancy of diffuser)