Evaluation of GCOM-C/SGLI Lunar Calibration Using GIRO

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This work is based on a contract with JAXA (JX-PSPC-501115), and complies with GIRO usage policy, "Global Satellite Inter-Calibration System, GIRO and GSICS Lunar Observation Dataset Usage Policy", Version 1.0, May 2015, GSICS-RD005.

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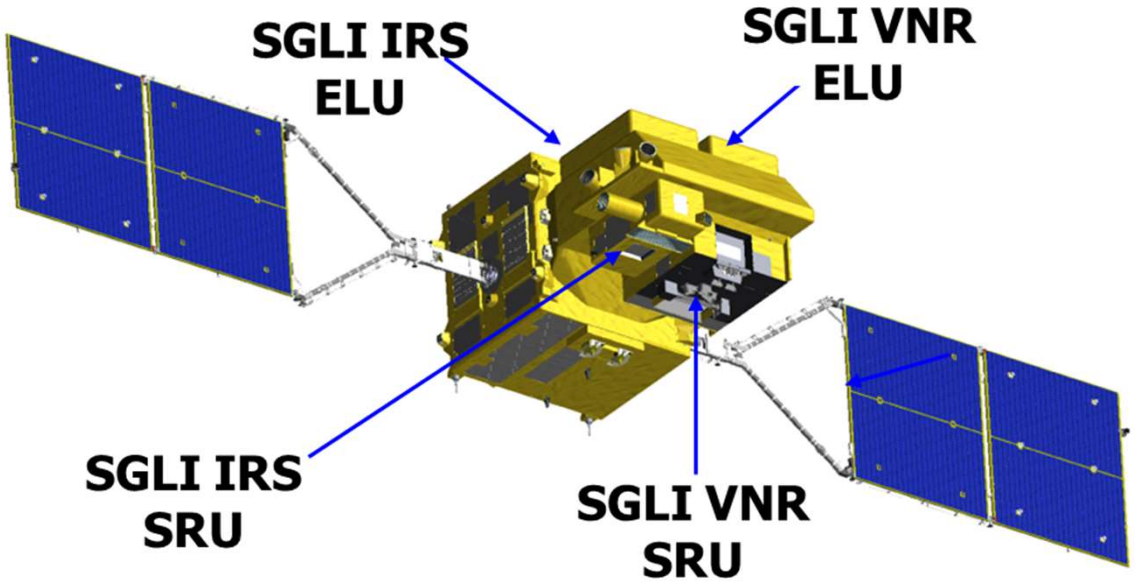
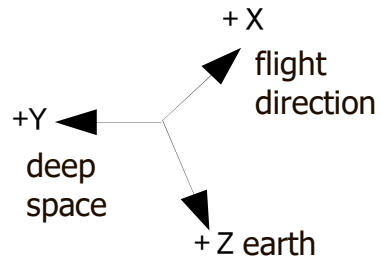
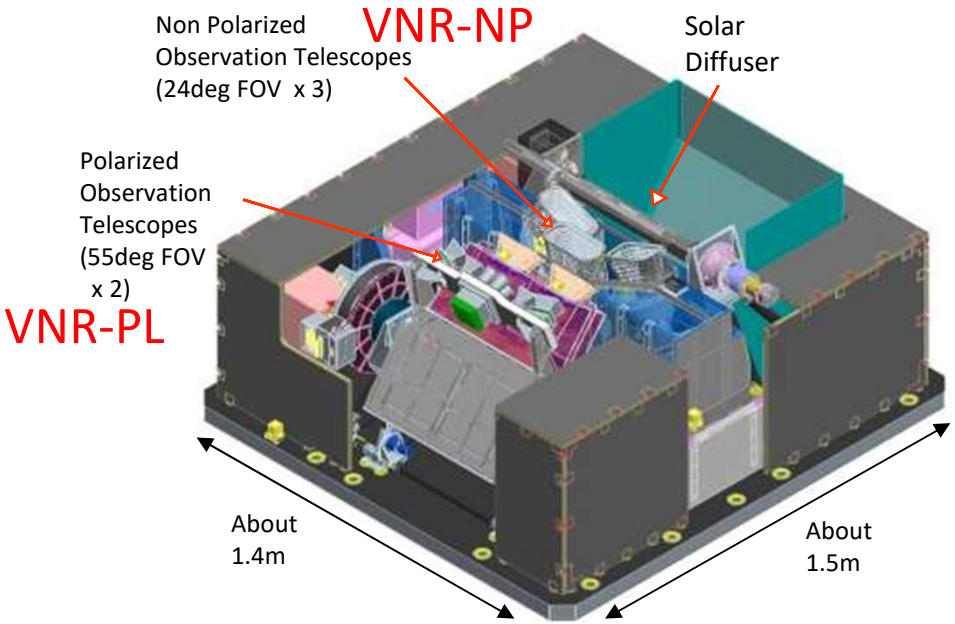




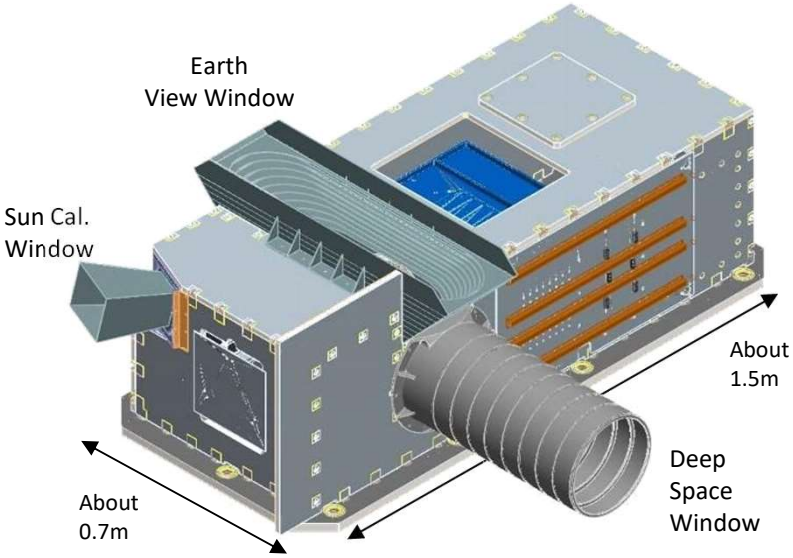
SGLI	**Second-generation Global Imager**
VNR	**Visible and Near Infrared Radiometer**
IRS	**Infrared Scanning Radiometer**
SRU	**Scanning Radiometer Unit**
ELU	**Electronic Unit**

- GCOM-C was successfully launched on December 23, 2017 and completed the one-year initial calibration activities.
- The various GCOM-C scientific products have been released to public since December, 2018. [Data access --> https://gportal.jaxa.jp/]

Second-generation Global Imager (SGLI) Overview



Visible and Near Infrared Radiometer
(SGLI-VNR)



Infrared Scanning Radiometer
(SGLI-IRS)

- VNR-NP consists of three 24-degree-FOV telescopes configured in cross track direction to realize the wide FOV (70 degrees).
- VNR-PL has the tilting mechanism to observe around ±45 degrees in along track direction.

- The combination of the 45 degrees tilting scanning mirror and Ritchey-Chretien type telescope realize the wide 80 degrees FOV observation swath.

SGLI Specification

- The SGLI features are **250m (VNR-NP & SW3) and 250/500m (TIR) spatial resolution** and **polarization/along-track slant view** channels (VNR-PL), which will improve land, coastal, and aerosol observations.

GCOM-C SGLI characteristics	
Orbit	Sun-synchronous (descending local time: 10:30) Altitude 798km, Inclination 98.6deg
Mission Life	5 years
Scan	Push-broom electric scan (VNR) Wisk-broom mechanical scan (IRS)
Scan width	1150km cross track (VNR-NP & VNR-PL) 1400km cross track (IRS-SWI & IRS-TIR)
Digitalization	12bit
Polarization	3 polarization angles for VNR-PL
Along track direction	Nadir for VNR-NP, IRS-SWI and IRS-TIR, +45 deg and -45 deg for VNR-PL
On-board calibration	VNR-NP, VNR-PL: Solar diffuser, LED, Lunar cal. maneuvers, and dark current by masked pixels and nighttime obs. IRS-SWI: Solar diffuser, LED, Lunar, and dark current by deep space window IRS-TIR: Black body and dark current by deep space window

250m over the Land or coastal area, and 1km over offshore

Multi-angle obs. for 673.5nm and 868.5nm

SGLI channels						
CH	λ	Δλ	L_{std}	L_{max}	SNR at Lstd	IFOV
	VNR-NP, VNR-PL, IRS-SWI: nm IRS-TIR: μm		VNR-NP, VNR-PL, IRS-SWI :W/m²/sr/μm IRS-TIR: Kelvin		VNR-NP, VNR-PL, IRS-SWI : SNR IRS-TIR: NEΔT	m
VN1	380	10	60	210	250	250
VN2	412	10	75	250	400	250
VN3	443	10	64	400	300	250
VN4	490	10	53	120	400	250
VN5	530	20	41	350	250	250
VN6	565	20	33	90	400	250
VN7	673.5	20	23	62	400	250
VN8	673.5	20	25	210	250	250
VN9	763	12	40	350	1200	250/1000
VN10	868.5	20	8	30	400	250
VN11	868.5	20	30	300	200	250
P1	673.5	20	25	250	250	1000
P2	868.5	20	30	300	250	1000
SW1	1050	20	57	248	500	1000
SW2	1380	20	8	103	150	1000
SW3	1630	200	3	50	57	250
SW4	2210	50	1.9	20	211	1000
T1	10.8	0.7	300	340	0.2	250/1000
T2	12.0	0.7	300	340	0.2	250/1000

TIR: 500m resolution is also used

Calibration Types

SGLI Calibration Types

- ✓ On-board calibration of solar reflective bands (VNR and IRS-SWIR bands) is achieved by solar light and internal lamps.
- ✓ Radiometric calibration of the emissive infrared bands (IRS-TIR bands) is accomplished through two-point calibration using a temperature-monitored blackbody and view of deep space.

- ✓ GCOM-C has three kinds of dedicated maneuver operation
  - Lunar calibration pitch maneuver for sensor stability.
  - solar angle correction yaw maneuver for solar light calibration.
  - 90-degree yaw maneuver for pixel-to-pixel non-uniformities.

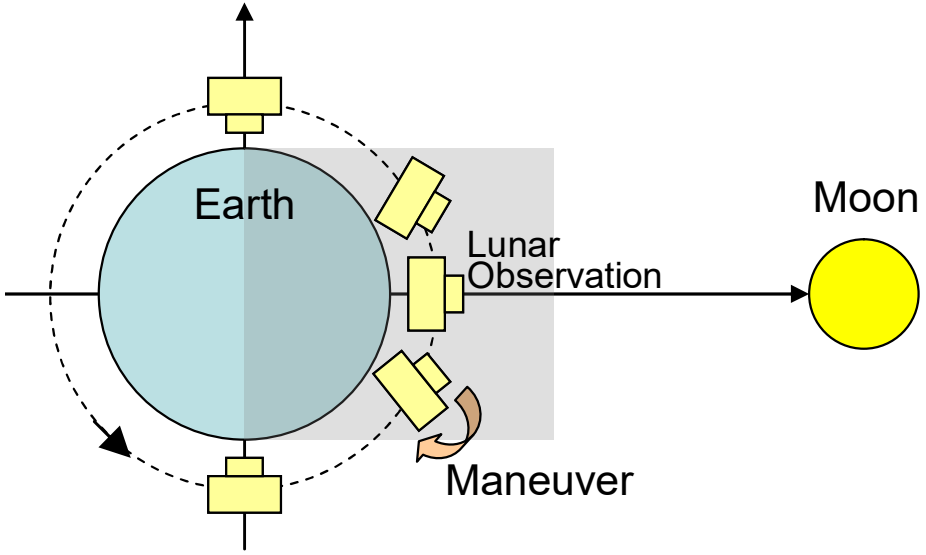
	On-orbit calibration					Calibration maneuver		
	Solar diffuser calibration	Internal lamp calibration	Dark image calibration	Black body calibration	Deep space calibration	Lunar calibration maneuver	Solar angle correction maneuver	90-degree yaw maneuver
VNR	○	○	○	-	-	□	△	△
SWIR	○	○	○	-	◇	□	△	-
TIR	-	-	-	◇	◇	□	-	-

○ : Once in 8 days ◇: Each scan □: Once in a month △: Once in a year

This presentation!!

Lunar Calibration Operation(1/2)

- ✓ The lunar observation images are captured by maneuvering GCOM-C attitude around the pitch axis.
- ✓ Pitch maneuver rate is 0.15 degree/second with high stability to obtain precise oversampled lunar image in along-track direction.



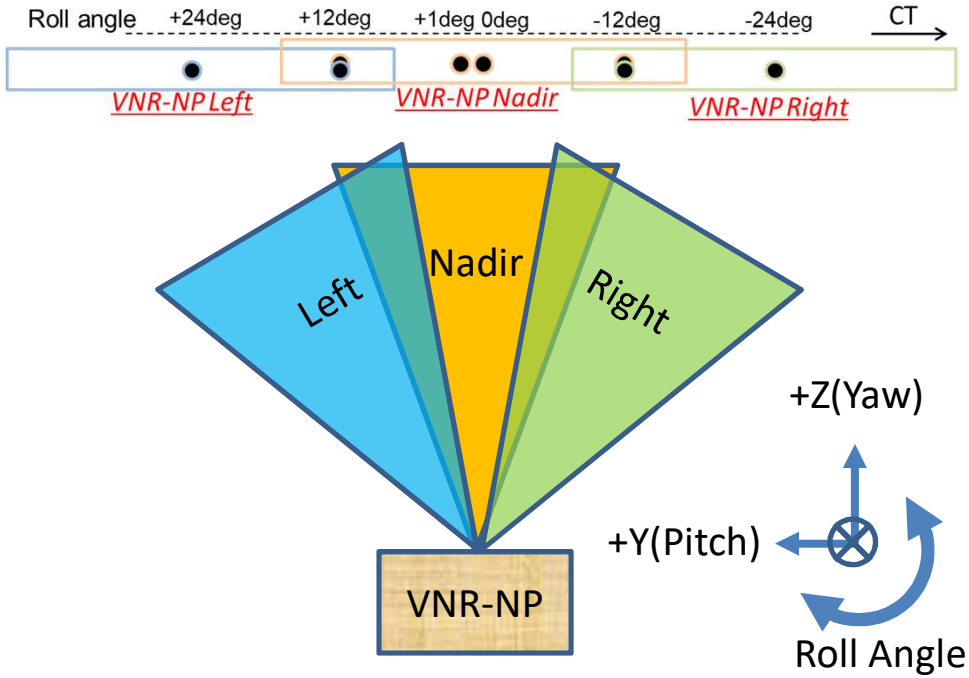
VNR-NP
R/G/B=VN08/VN05/VN03

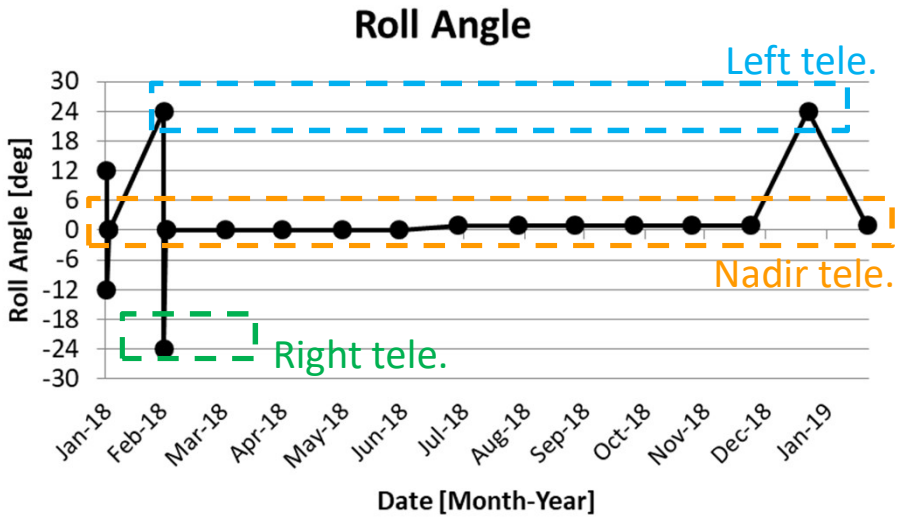
IRS-SW03

Lunar Calibration Operation(2/2)

- ✓ To evaluate the different telescope and view angle for VNR, the roll angle is selectable.
  - Normally, the roll angle is set to 1degree for VNR-Nadir telescope.
  - Once in a year, roll angle is set to +24/+12/-12/-24degree to evaluate VNR-Left/Right telescope.
  - Data in the case of +12/-12degree are used to simultaneously calibrate two telescopes.

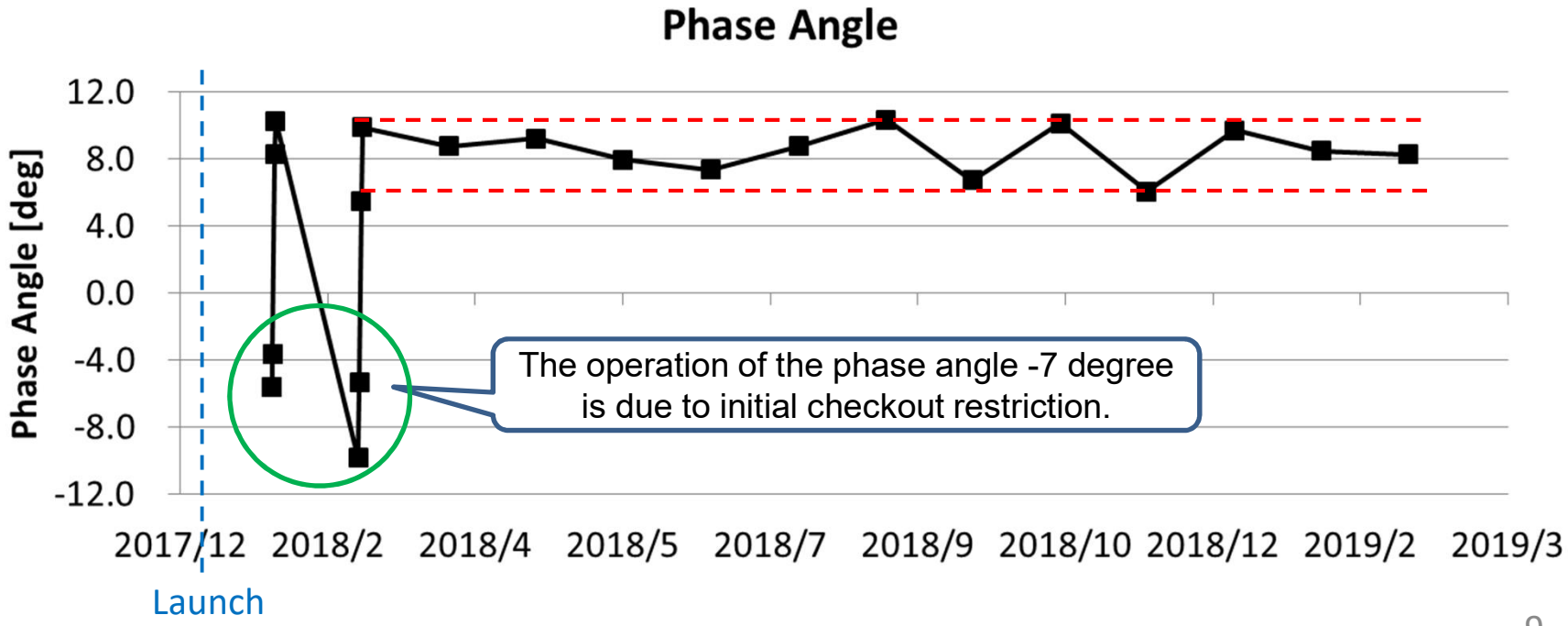
Footprint image





Lunar Calibration Timing

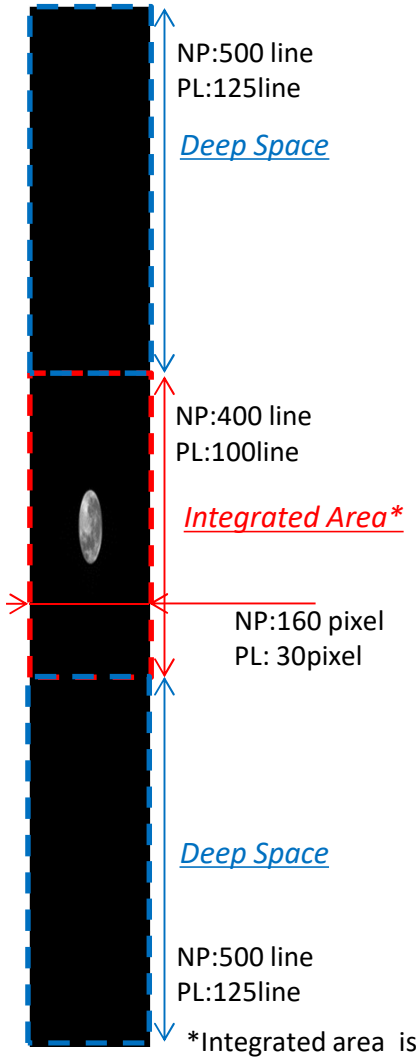
- Lunar calibration timing
  - ✓ The phase angle(Sun - Moon - Satellite) is around +7+/-3degree or -7+/-3deg.
    - Lunar calibration concept is similar to SeaWiFS.
  - ✓ Lunar calibration operations are planned to be performed every 29 day during 5 years mission.
    - SGLI acquired its first lunar image with pitch maneuver on January 31, 2018.
    - From Jan to Mar of 2018, SGLI lunar calibrations were performed several times in a month for initial checkout operation and since then it has observed the Moon once a month at a target phase angle.



Analysis Method (VNR)

➢ Analysis method of SGLI lunar calibration data

[Case of VNR-NP/PL]



*Integrated area is defined taking into account stray light.

- ✓ Removes dark noise using averaging deep space data per pixel.
- ✓ Converts to radiance image $L_{k,p}$ using radiometric parameter.
- ✓ To compare with lunar irradiance model, the radiance is converted to integrated lunar irradiance I_k using following equation.

$$I_k{}^{SGLI} = \left(\sum_{p=1}^{N} \Omega'_{k,p} L_{k,p} \right)$$

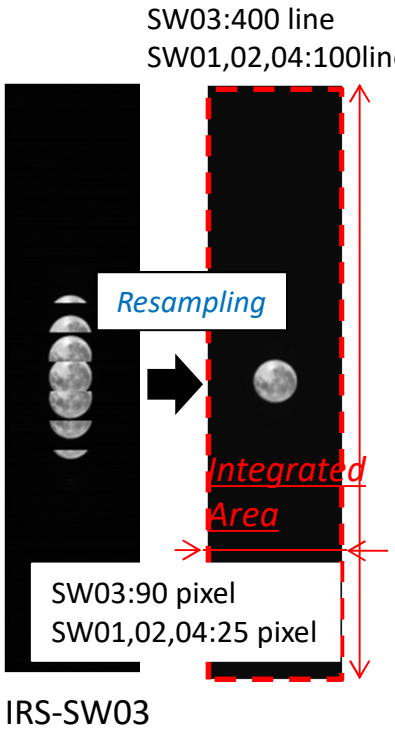
I_k : Lunar irradiance (k=ch1~11)
N : Total number of pixel
$\Omega'_{k,p}$: Solid angle per pixel include oversampling and $\sin\theta$ effect
θ : Angle between satellite-moon vector and satellite pitch axis

Analysis Method (IRS)

➢ Analysis method of SGLI lunar calibration data

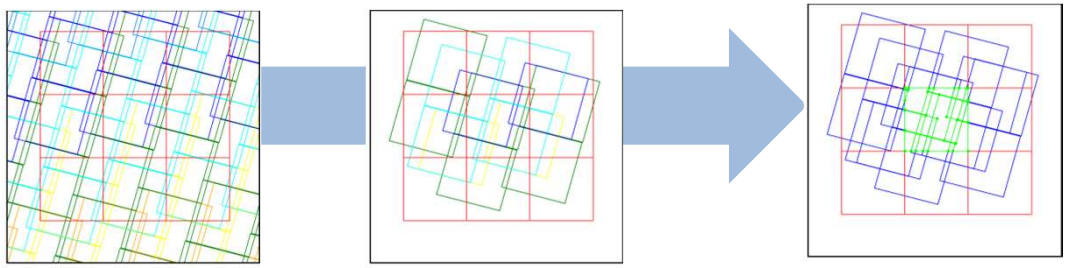
[Case of IRS-SWIR]

IRS discretely captures the moon because of whisk-broom type radiometer. Therefore, in order to obtain integrated lunar irradiance, it is necessary to round the lunar image.



IRS-SW03

- ✓Converts to radiance image $L_{k,p}$ using radiometric parameter.
- ✓The observed pixels of each detector are projected on the AT-CT plane in consideration of line-of-sight vector and the pitch maneuver.
- ✓ Converts to irradiance image $I_{k,p}$ using the solid angle for each pixel.
- ✓ Reconstructs the lunar irradiance image from the weighted average according to the a field of view of each detector in the resampling grid.
- ✓The lunar integrated irradiance ${I_k}^{SGLI}$ is calculated.



Red line: Resampling grid
※Colors show the observed pixel of each scan

Green : Weighted average pixel

Lunar Irradiance Model [GIRO]

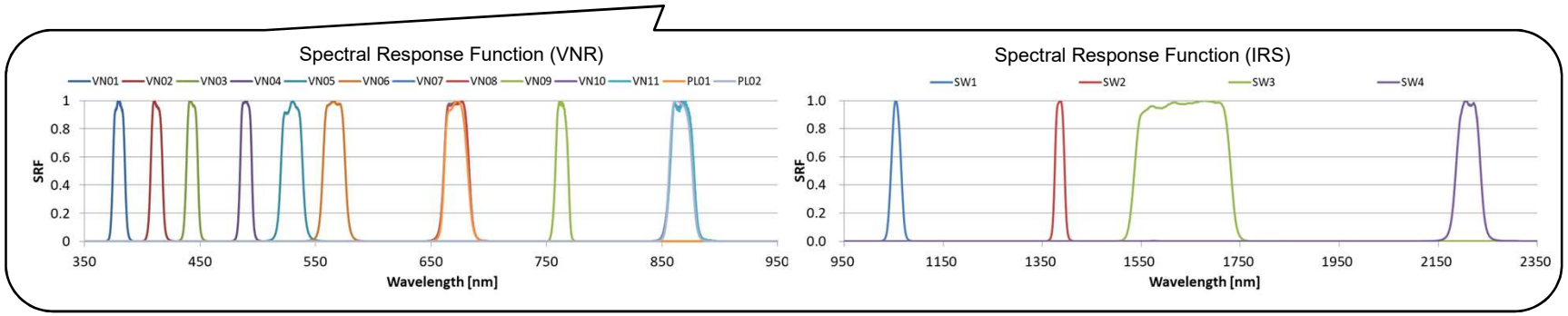
➢ Lunar irradiance model [GIRO]

✓ GSICS (Global Space-based Inter-Calibration System) Implementation of the ROLO* (GIRO) was developed by EUMETSAT in 2014 and provided access to the function of the ROLO lunar irradiance model for the international community.

ROLO* : the United States Geological Survey (USGS) Robotic Lunar Observatory (ROLO) model

GIRO ⟵ ☐ GIRO input NetCDF (according to GIRO rule)

- ✓ Moon center observation time & position.
- ✓ Image (Radiance & DN) of each band.
- ✓ Spectral Response Function of each band.



☐ Lunar irradiance of each band $I_k{}^{GIRO}$

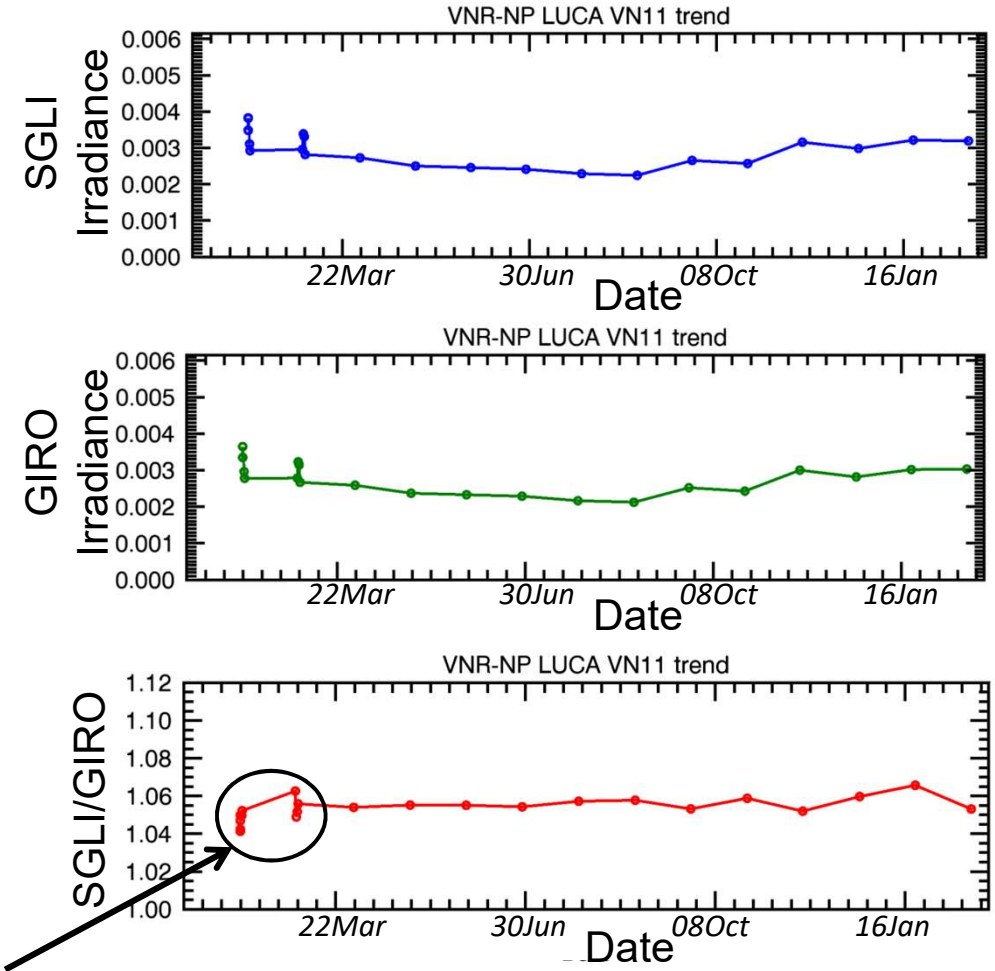
- ✓ GIRO outputs lunar irradiance $I_k{}^{GIRO}$ at each lunar observation time and satellite geometry.
- ✓ Normalized the lunar calibration time series for variations in observing geometry (Spacecraft/Moon distances, Sun/Moon distances, phase and libration angles), using GIRO output.

$$Ratio_{k,N} = I_{k,N}{}^{SGLI} / I_{k,N}{}^{GIRO}$$

Time-series Trend (VNR 1/3)

➢ Time-series trend of the ratio SGLI to GIRO [Case of VNR-NP]

VN11 (865nm)



✓ Case of Roll angle =+24/+12/-12/-24deg

- Although including the difference in phase angle, these variations indicate the deviation of inter-telescope.

Time-series Trend (VNR 2/3)

[Case of VNR-NP]

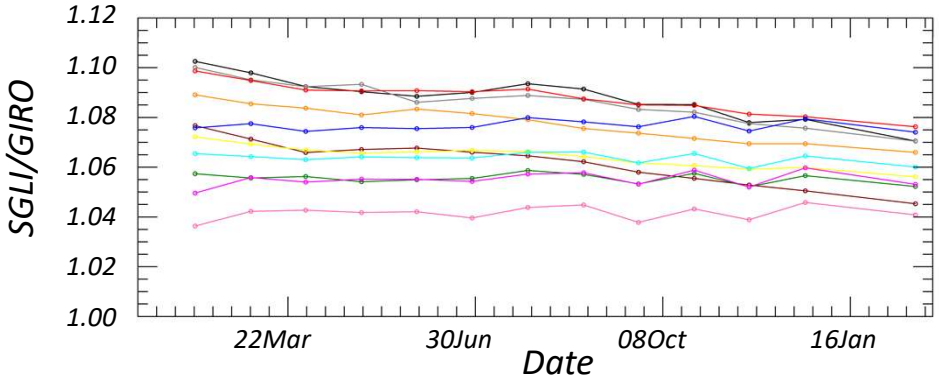
CH	VN1	VN2	VN3	VN4	VN5	VN6	VN7	VN8	VN9	VN10	VN11
WL [nm]	380	412	443	490	530	565	673.5	673.5	763	868.5	868.5

➢ Time-series trend of the ratio SGLI to GIRO

Nadir telescope

VNR-NP Nadir trend

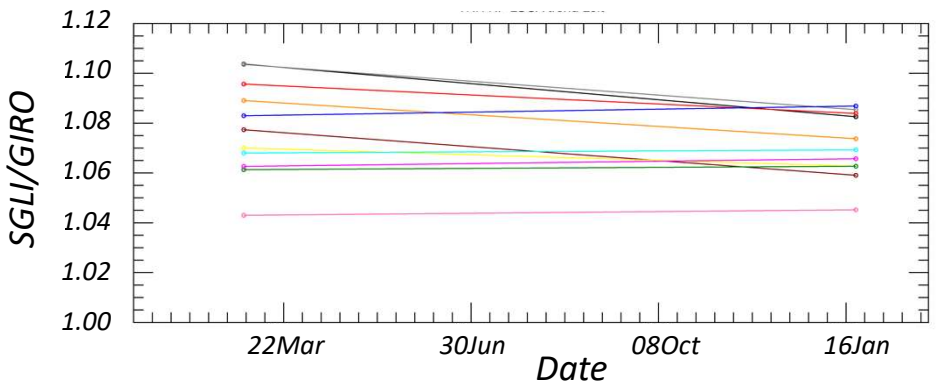
[only Roll angle =0 or +1degree]



Left telescope

VNR-NP Left trend

[only Roll angle =+24 degree]



✓ The lunar irradiance observed by SGLI are 5-10 % higher than GIRO output.

☐ These results are family with the heritage instrument (MODIS/VIIRS/PLEIADES).

Time-series Trend (VNR 3/3)

[Case of VNR-NP]

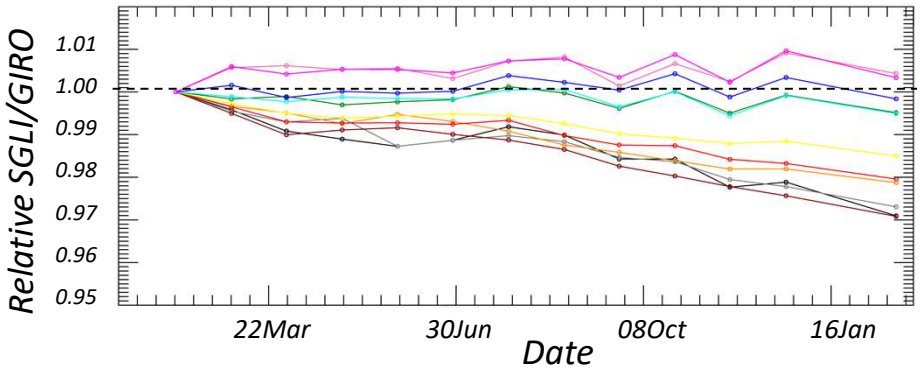
CH	VN1	VN2	VN3	VN4	VN5	VN6	VN7	VN8	VN9	VN10	VN11
WL [nm]	380	412	443	490	530	565	673.5	673.5	763	868.5	868.5

➢ Time-series trend of the ratio SGLI to GIRO【Normalized 2018/2/1】

VN01 VN02 VN03 VN04 VN05 VN06
VN07 VN08 VN09 VN10 VN11

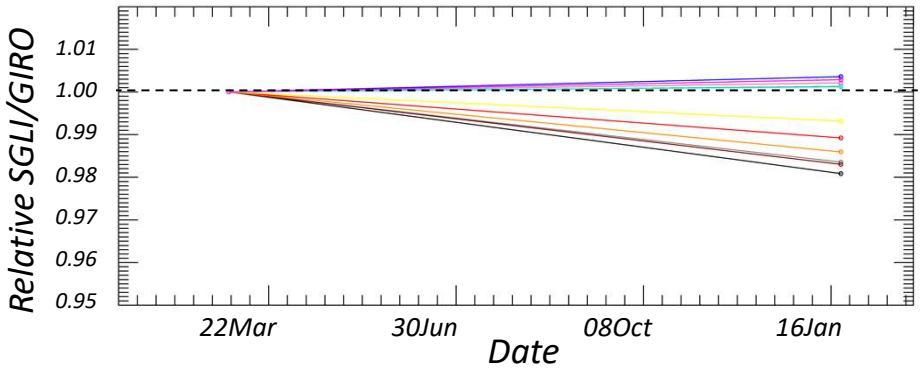
Nadir telescope

VNR-NP Nadir relative trend (Normalized 2018/2/1)
[only Roll angle =0 or +1degree]



Left telescope

VNR-NP Left relative trend (Normalized 2018/3/1)
[only Roll angle =+24degree]



✓ The short wavelength bands (VN01-06) are indicated 1-3% degradation.
✓ The trend of Red to NIR bands (VN07-11) are stable.

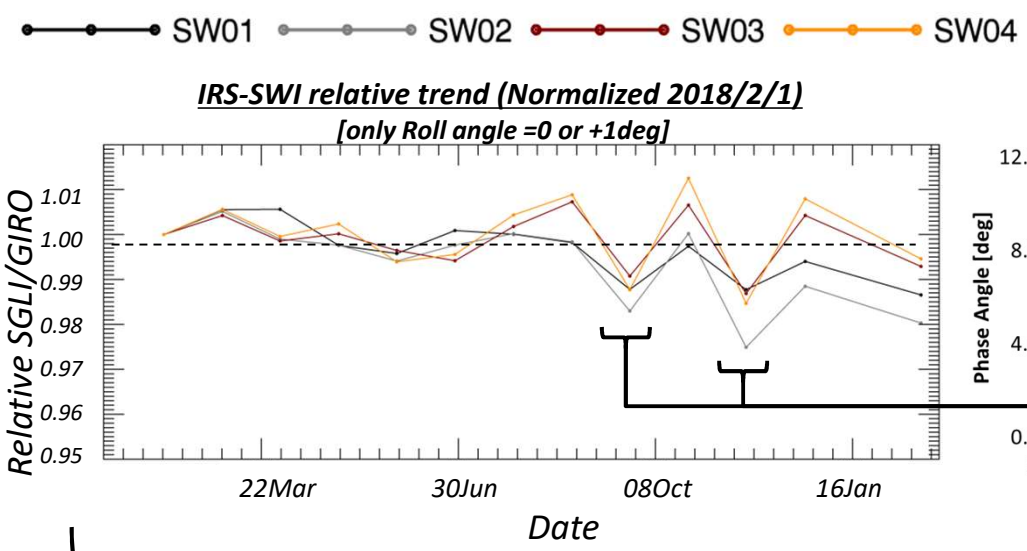
☐ These results are suggested that the short wavelength bands (VN01-06) have 1-3% degradation and that the tendency is the same between Nadir and Left telescope.

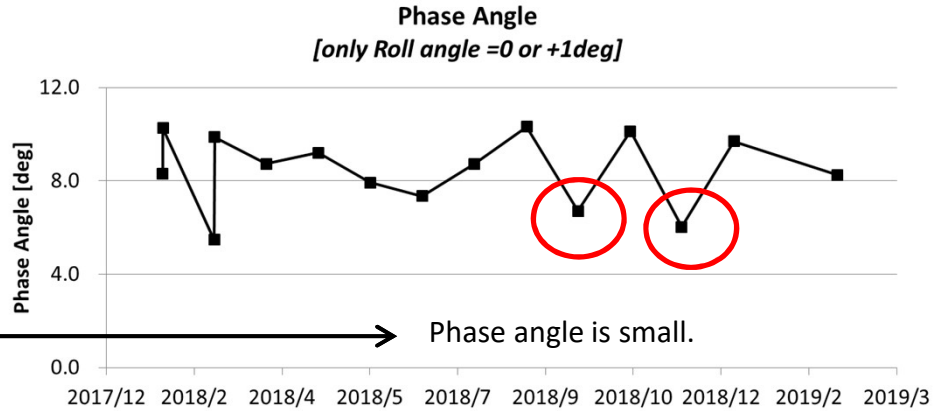
Time-series Trend (IRS 1/2)

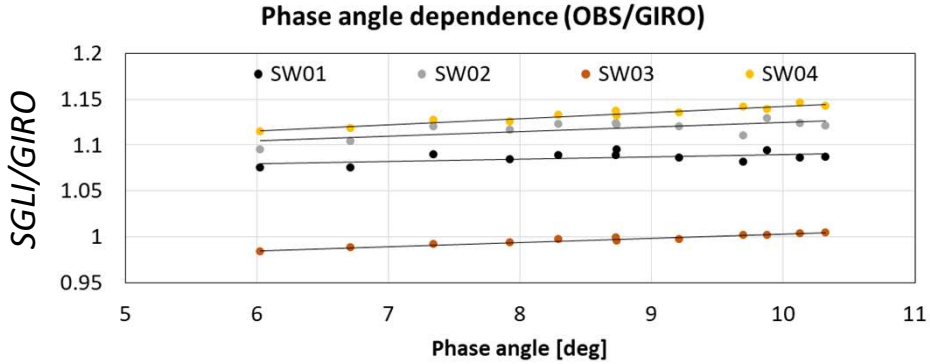
[Case of IRS-SWI]

- Time-series trend of the ratio SGLI to GIRO【Normalized 2018/2/1】

CH	SW1	SW2	SW3	SW4
WL [nm]	1050	1380	1630	2210







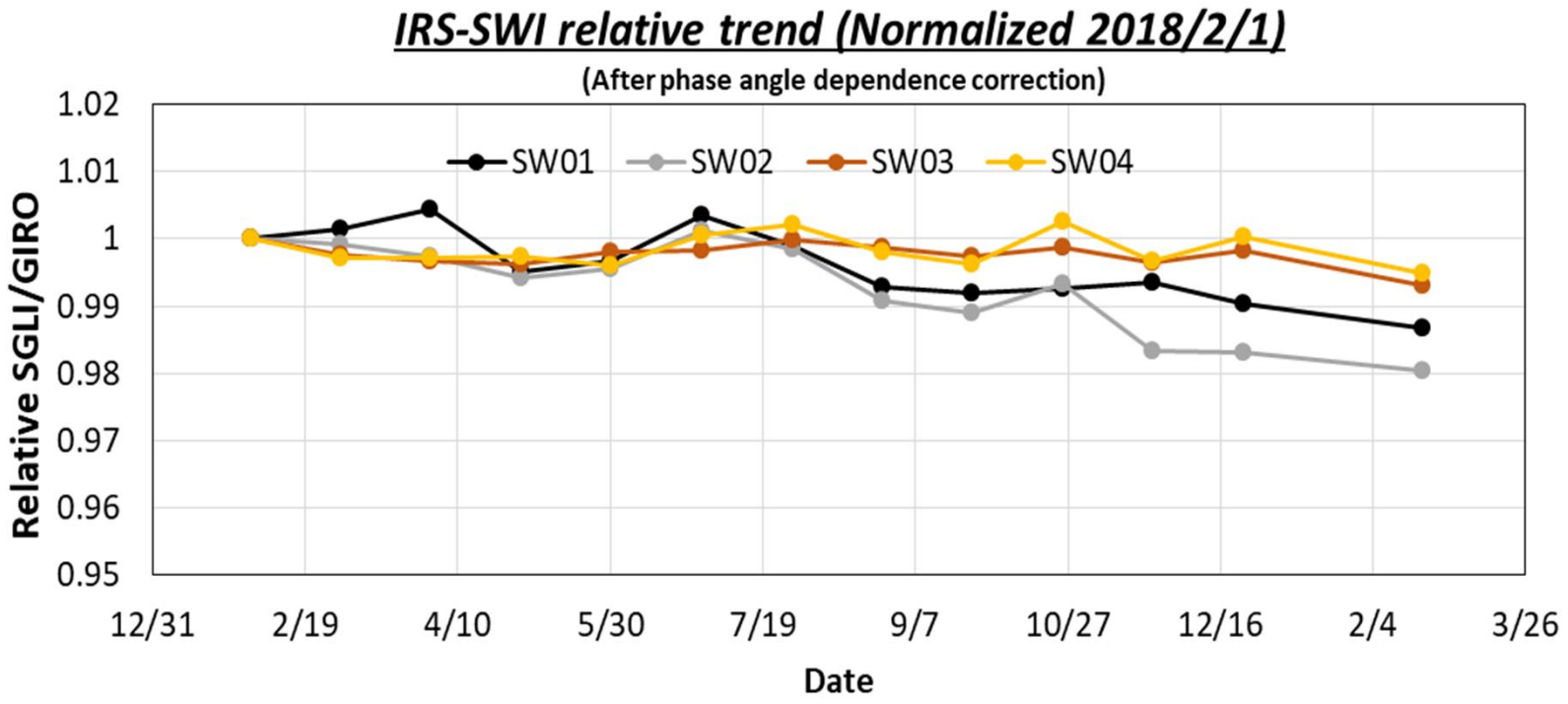
- ✓ The SGLI/GIRO ratios in short wavelength infrared band (SW01-04) have a feature of phase angle dependence.

Time-series Trend (IRS 2/2)

[Case of IRS-SWI]

➢ Time-series trend of the ratio SGLI to GIRO【Normalized 2018/2/1】

CH	SW1	SW2	SW3	SW4
WL [nm]	1050	1380	1630	2210



✓ After phase angle dependence corrections, small degradation (～1%) is observed in SW01(1050 nm) and SW02(1380 nm).

☐ These corrections need to be verified using different calibration results.

Conclusion

Conclusion

- ✓ To evaluate the different telescope and view angle for VNR, the roll angle is selectable in GCOM-C/SGLI lunar calibration.
- ✓ SGLI lunar calibration is performed as planned every 29 days and the radiometric response relative to the GIRO model are in family with those observed for the heritage instruments.
- ✓ The short wavelength bands (VN01-06) are indicated 1-3% degradation and other bands are stable.
- ✓ The ratio of SGLI / GIRO has a characteristic of the phase angle dependency at longer wavelengths(NIR~).

Future works

- ✓ Consider the case of roll angle =+24/+12/-12/-24deg.
  - inter-telescope/pixel deviation
  - phase angle dependence
- ✓ Evaluate VNR-PL (Polarization channel).
- ✓ Comparison with other on-board calibration results (solar diffuser, internal lamp) .

Acknowledgement

- ✓ The authors would like to thank GSICS lunar calibration community for GIRO usage.

- Please contact us if you have any questions.
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- GCOM-C/SGLI data access
  - ✓ https://gportal.jaxa.jp/