Visible Channel Calibration of JMA's Geostationary Satellites using the Moon Images

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GSICS Global Space-based Inter-Calibration System
http://gsics.wmo.int

Abstract

The Moon is one of the invariant calibration targets without atmosphere and has been captured by historical geostationary meteorological satellites such as GMS-5 and MTSAT-2 by chance. A new generation geostationary meteorological satellite, Himawari-8 can observe the Moon as much as possible using super rapid-scanning mode performed every 30 seconds.

Radiometric calibration system using lunar observation is based on the GSICS Implementation of the ROLO model (GIRO), which provides reference lunar irradiances. These lunar observation data are very useful for estimating long term instrument degradation due to its small uncertainty.

A total of 62 and 2979 lunar images derived from MTSAT-2/Imager and Himawari-8/AHI observation are used in this study. A 2.71% annual drift of MTSAT-2/Imager visible channel with a 0.15% uncertainty shows good agreements with other post-launch calibration using deep convective clouds and radiative transfer simulation. Frequent lunar observations by AHI are expected be of help not only to enhance its calibration capability but also to improve the reference model such as lunar phase angle dependence.

Global Space-based Inter-Calibration System (GSICS)

GSICS: established by WMO and CGMS in 2005 to foster collaboration among satellite operators on best practices for accurate & consistent calibration throughout the global constellation

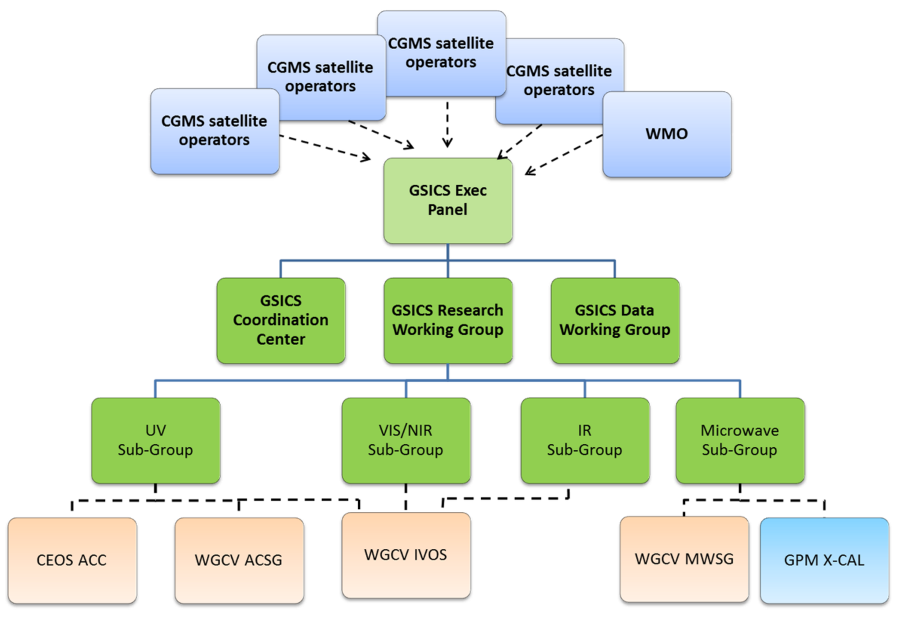
Outcomes: integrated inter-calibration system enabling:
- Better consistency between instrument data
- Lower bias in derived products
- Traceability of measurements
- Re-calibration of archive data
- Better specification of future instruments

with similar methods and common references to be reliable and interoperable for applications

Target users:
- Satellite users interested in accurate/consistent calibration
  - Stable Level 2 product generation, Level 3 multi-satellite products
  - Climate Data Record generation (e.g. "SCOPE-CM", WCRP/ISCCP)
  - Reanalysis
  - Assimilation in NWP models: bias characterization of radiances
- Satellite operators sharing developments, best practices, and tools
  - Prelaunch instrument characterization
  - In-orbit commissioning and Cal/Val plans
  - Instrument monitoring, detection/analysis of anomalies
  - Improved calibration
- Partner programmes: CEOS WGCV, GPM X-cal, GHRSST, GRUAN, etc...

EUMETSAT, CNES, JMA, USGS, NIST, JAXA, NOAA, CMA, KMA, ROSHYDROMET, IMD, ISRO, NASA, WMO, ROSCOSMOS, CNSA, ESA

15 satellite operators (3 observers) + NIST and WMO



Lafeuille (2015), 2015 GSICS User's Workshop

Lunar Calibration Method

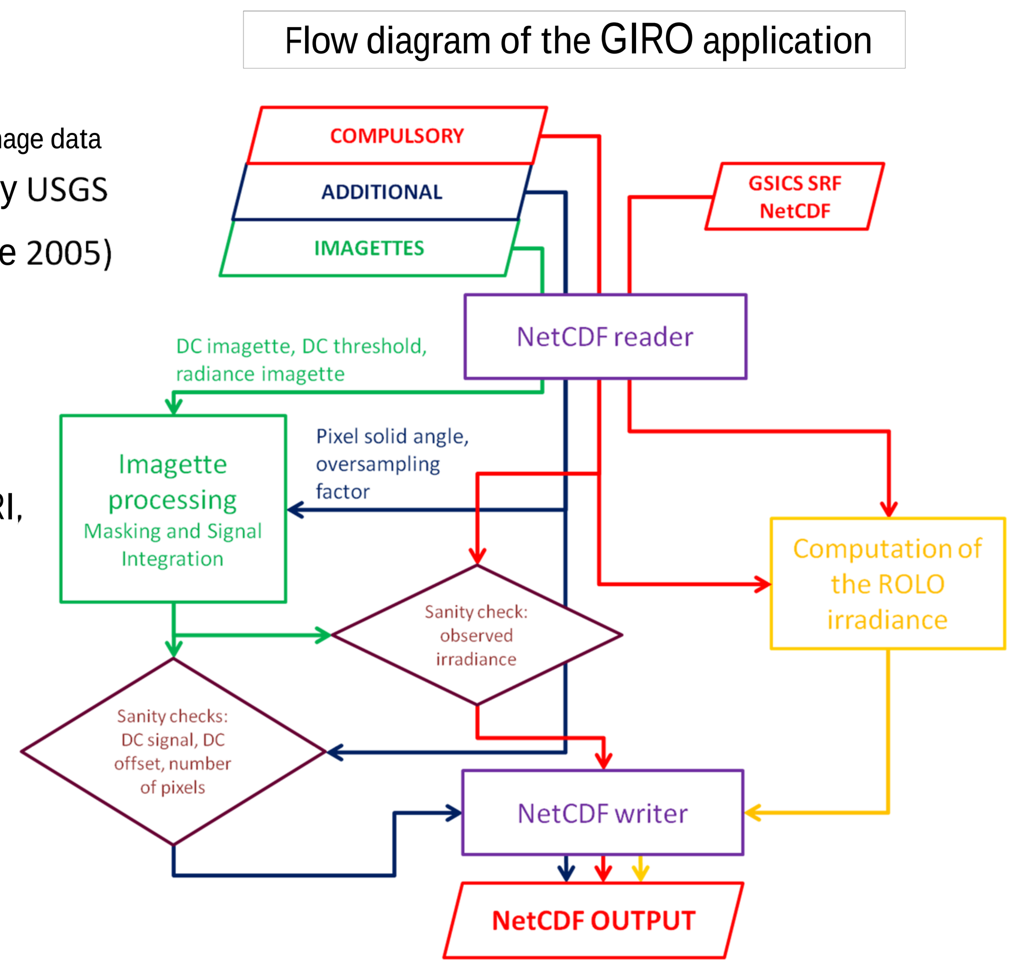
- Comparison of observed/predicted disk-integrated lunar irradiance

$$Irr_{OBS} = \sum_{pixel \in Mask} \frac{\Omega_{PIX}}{F_{PIX}} \cdot Imgt_{Rad}$$

Irr_{OBS} : observed irradiance, Ω_{PIX} : pixel solid angle, F_{PIX} : oversampling factor, $Imgt_{Rad}$: radiance image data

- Robotic Lunar Observatory (ROLO) model: calibration reference developed by USGS
  - Empirical model to derive disk-integrated lunar irradiance (Kieffer and Stone 2005)
  - Based on more than 8 years of the MOON observations at Flagstaff, AZ
  - Applicable spectral range: 0.35-2.5 µm
  - Applicable lunar phase angle range: 2-92 deg.
  - Has been used for many satellite instruments: SeaWiFS, MODIS, MSG/SEVIRI, GOES/Imager, ...
  - Accuracy of the reference irradiance
    - ✓ 5 – 10 % uncertainty in absolute irradiance scale
    - ✓ ~ 1 % relative accuracy
    - -> Very useful for validating long term instrument drift
- GSICS Implementation of the ROLO model (GIRO)
  - Implemented in 2014
  - Lead by core agencies (USGS, EUMETSAT, NASA, CNES)
  - Standard reference model for the lunar calibration community

Flow diagram of the GIRO application



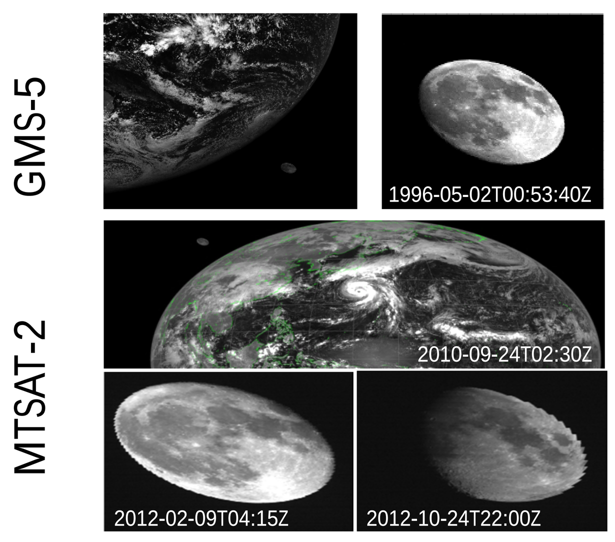
Viticchie (2014), Lunar Calibration Workshop
https://gsics.nesdis.noaa.gov/wiki/Development/LunarCalibrationWorkshop

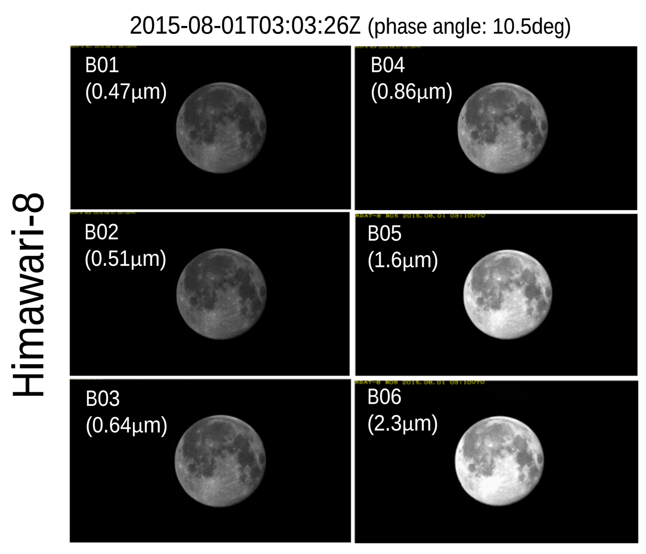
Lunar Calibration at JMA

Lunar observations of JMA GEO satellites

Satellite	SSP Lon	H. Reso at SSP	# of bands	Operation	Period used in this study	# of Obs. (for GIRO/total)
Himawari-8	140.7E	0.5/1/2km	VNIR: 6 IR: 10	2015-	Mar. 2015 – Aug. 2015	2979/4956
MTSAT-2	145 E	1km	VIS:1 IR:4	2010 – 2015	2010 – 2013	62/98
MTSAT-1R	140 E	1km	VIS:1 IR:4	2005-2014 (Incl. back-up operation)	N/A due to its scanning pattern	
GMS-5	140 E	1.25km	VIS:1 IR:3	1995 – 2003	1995 – 2003	48/50

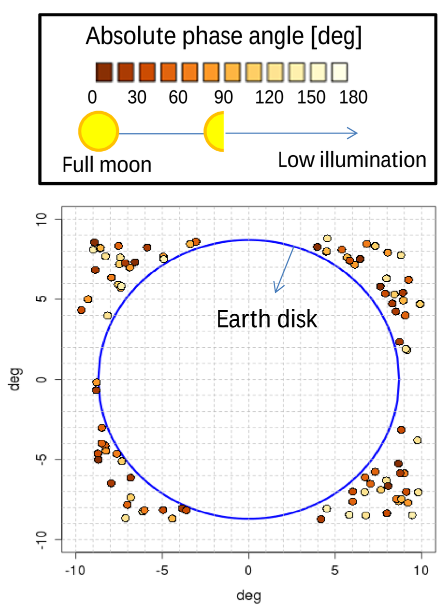
# of lunar observations will increase in future (re-) processing
Lunar observations of GMS-4, -3, ... will also be extracted in future





MTSAT-2/Imager

- Manual extraction of lunar observations:
  1) Predict the Moon position using JPL DE405
  2) IR (10.8µm) image is used to find the Moon
- Lunar calibration results
  - Good agreements with RT simulation approach and Deep Convective Clouds method
  - the smallest uncertainty of a regression line

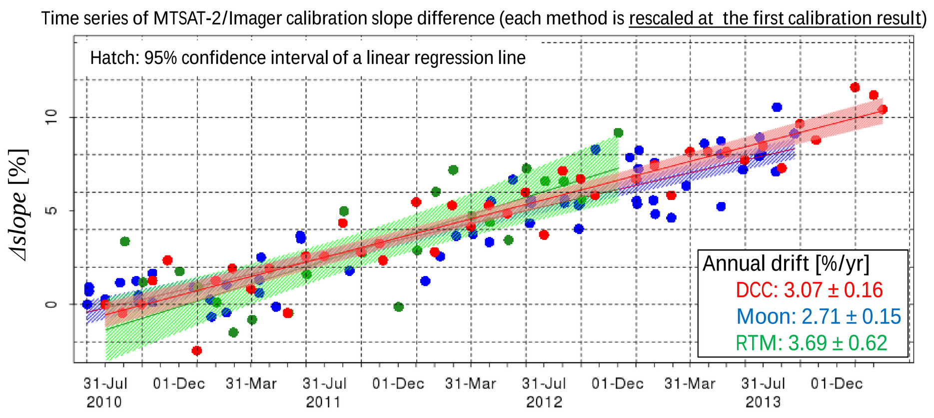


Positions of the Moon wrt. the centre of the Earth for MTSAT-2/Imager (Jul.2010 – Dec.2013)

$$Slope_{ROLO} = \frac{F_{PIX} \cdot Irr_{ROLO}}{\Omega_{PIX} \cdot \left(\sum_{i=1}^{N_{PIX}} (DCi) - N_{PIX} \cdot Off_{DC}\right)} \quad [\mathrm{W\,m^{-2}\,\mu m^{-1}\,DC^{-1}}]$$

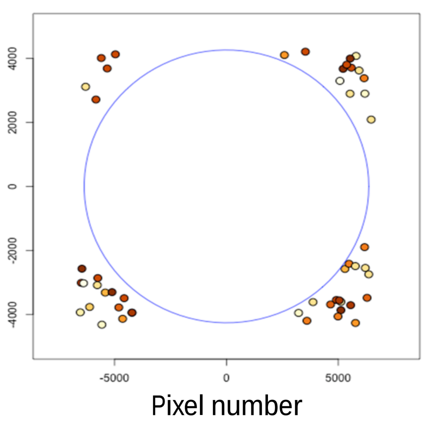
F_{PIX} : Oversampling factor, Ω_{PIX} : Pixel solid angle [sr^{-1}], DC_i : Digital count of the Moon pixel, Off_{DC} : Averaged deep space DC, N_{PIX} : Number of the Moon pixels

Time series of MTSAT-2/Imager calibration slope difference (each method is rescaled at the first calibration result)

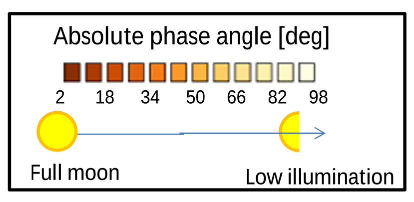


GMS-5/VISSR

- VISSR VIS channel
  - ✓ 4 detectors
  - ✓ Destriping is required (under-processing)
- Analyses in time series will be performed in future

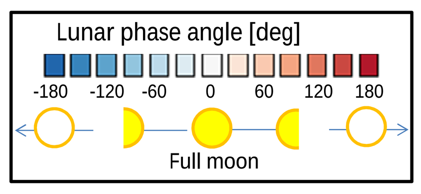


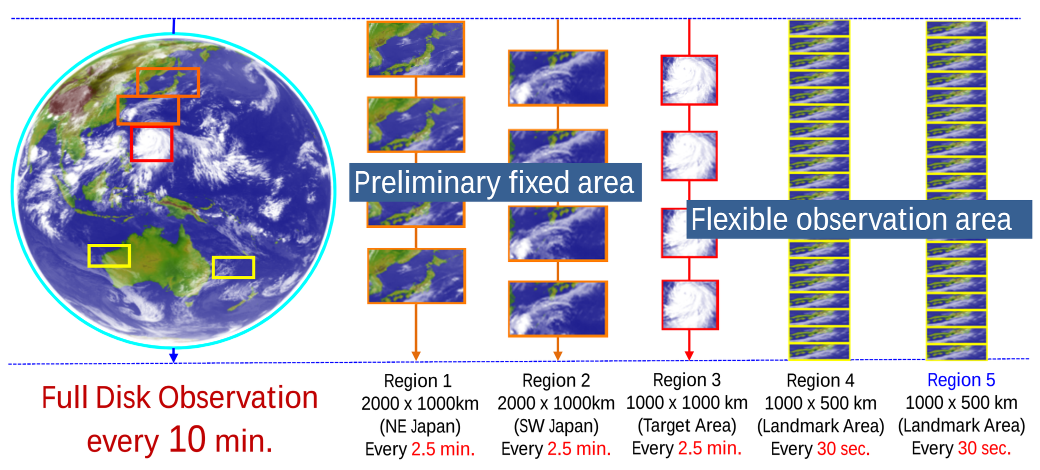
Positions of the Moon wrt. the centre of the Earth for GMS-5/VISSR (Jul. 1995-Feb.2003)

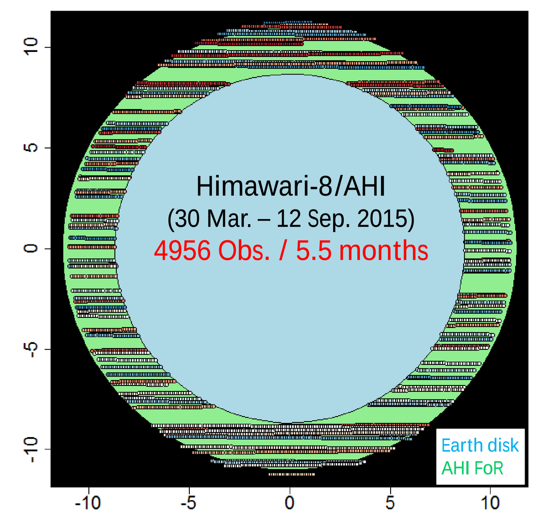


Himawari-8/AHI

- Region 4, 5 (1000 x 500 km for the earth scene, flexible observation):
  - mainly used for landmark observation
  - but region 5 is also used for lunar observation based on its position prediction
- Just one scan to observe the Moon
- 1 observation / 30 seconds -> lots of observation

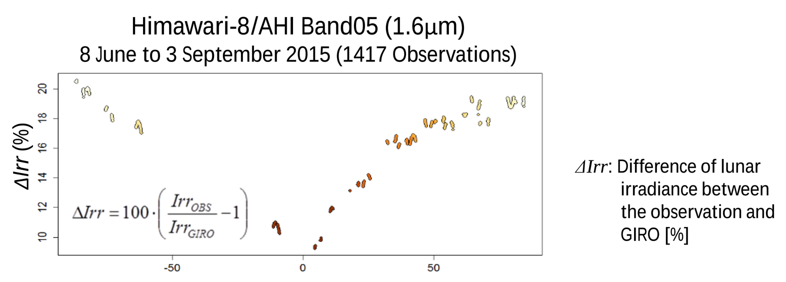


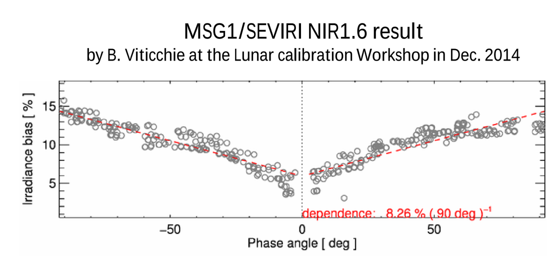




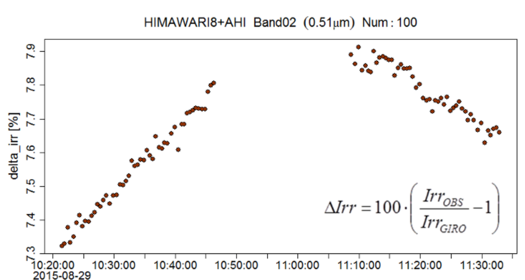
Expected outcome using multi-bands, huge-amount lunar observation data

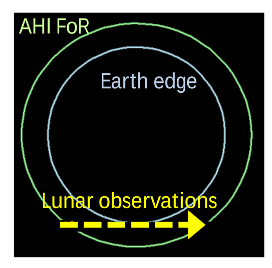
Case 1: Detection of possible phase angle dependence
- Similar results with other instruments (e.g. MSG/SEVIRI NIR1.6)
- Will be investigated further in collaboration with GSICS





Case 2: Validation of the image processing using lots of lunar observations within a short range
- 29 August 2015
  - The Moon passed at the south of the earth edge
  - Phase angle: from -11.5 to -9.0 [deg]
  - 100 observation / ~90 minutes
- ~0.6 % variation in ΔIrr
  - Could be related to incorrect image processing (e.g. consideration of deep space counts)
  - Root cause is under-investigation





Summary and Future Plan

- Lunar calibration: applicable to all imagers on geostationary satellite (in principle)
  - Combination of multiple calibration methods (DCC, desert, ...) ensures calibration reliability
- GMS-5: Need for the further investigation (phase angle dependence, detector equalization, usage of detector signals instead of digital counts, etc.)
- MTSAT-2: Calibration trend (annual drift) : consistent with other calibration method in terms of the uncertainty
- Himawari-8: Multi-bands, huge amount of lunar observation: potential to improve lunar calibration method
  - Usage of the lunar calibration to monitor/validate on-board solar diffuser calibration by blending other calibration methods