GOES-17 ABI Radiometric Calibration and Validation using GSICS

Fangfang Yu¹, Xiangqian Wu², Hyelim Yoo¹, Zhipeng Wang¹, Haifeng Qian³, Xi Shao¹, Vladimir Kondratovich¹, and Song Guo¹

1: University of Maryland, and 2: NOAA/NESDIS/STAR
Outline

• GOES-17 ABI
  – Loop Heat Pipe (LHP) anomaly & mitigation efforts
  – GOES-17 ABI IR performance

• What is GSICS?

• GSICS in GOES-17 ABI Cal/Val Activities
  – Radiometric calibration validation & monitoring
  – Examples of GSICS applications in ABI calibration anomaly root cause investigation & correction validation

• New G17 IR Spectral Response Functions (SRF)
  – Coming soon!

• Summary
GOES-17 Advanced Baseline Imager (ABI)

- GOES-17 is NOAA’s second new geostationary weather satellite, following GOES-16 (GOES-East)
  - Providing the weather data over the eastern Pacific Ocean
  - ABI is the primary payload
- Became operational as GOES-West at 137.2W on 12 February 2019
  - ABI Level1B data accessible to the public since after Nov. 28, 2018
  - One of the ABI-family instruments to provide weather data over Asia-Oceania to the Atlantic Ocean
    - GK-2A AMI at 128.2E
    - Himawari-8 AHI at 140.7E
    - GOES-17 ABI at 137.2W
    - GOES-16 ABI at 75.2W

https://www.nesdis.noaa.gov/content/why-does-noaa-collaborate-internationally
## GOES-R ABI Spectral Bands

<table>
<thead>
<tr>
<th>ABI Band</th>
<th>Central Wavelength (µm)</th>
<th>Type</th>
<th>Nickname</th>
<th>Best Spatial Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.47</td>
<td>Visible</td>
<td>Blue</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0.64</td>
<td>Visible</td>
<td>Red</td>
<td>0.5</td>
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<tr>
<td>3</td>
<td>0.86</td>
<td>Near-Infrared</td>
<td>Veggie</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1.37</td>
<td>Near-Infrared</td>
<td>Cirrus</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1.6</td>
<td>Near-Infrared</td>
<td>Snow/Ice</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>2.2</td>
<td>Near-Infrared</td>
<td>Cloud particle size</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>3.9</td>
<td>Infrared</td>
<td>Shortwave window</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>6.2</td>
<td>Infrared</td>
<td>Upper-level water vapor</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>6.9</td>
<td>Infrared</td>
<td>Midlevel water vapor</td>
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<tr>
<td>10</td>
<td>7.3</td>
<td>Infrared</td>
<td>Lower-level water vapor</td>
<td>2</td>
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<tr>
<td>11</td>
<td>8.4</td>
<td>Infrared</td>
<td>Cloud-top phase</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>9.6</td>
<td>Infrared</td>
<td>Ozone</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>10.3</td>
<td>Infrared</td>
<td>&quot;Clean&quot; longwave window</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>11.2</td>
<td>Infrared</td>
<td>Longwave window</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>12.3</td>
<td>Infrared</td>
<td>&quot;Dirtly&quot; longwave window</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>13.3</td>
<td>Infrared</td>
<td>CO₂ longwave</td>
<td>2</td>
</tr>
</tbody>
</table>

How to Characterize the Level 1B Data?

• How useful - Resolutions:
  – Spectral/Spatial/Temporal/Radiometric resolutions
  – Instrument design
  – Compared to Imager, ABI has 3 x more spectral resolution, 4 x spatial resolution, 5 x faster coverage

• How accurate – Calibrations
  – Spectral/geometric/radiometric calibrations
  – Instrument performance
Advanced Baseline Imager (ABI)

- **Spectral Calibration:**
  - Well calibrated in the prelaunch program at the designed instrument operational temperatures

- **Radiometric Calibration: On-orbit calibration for all the bands:**
  - On-orbit solar diffuser (SD) for VNIR bands
  - Blackbody for IR bands

- **Geometric Calibration:**
  - GPS for orbital position, spacecraft attitude determined from gyroscopes and star trackers, ABI line of sight and channel co-registration are found from star observations with help of the Kalman filter processing
  - New “take image first and navigate it later” approach. Very fast, stable and accurate
LHP Anomaly & Mitigation Efforts

• Loop heat pipe (LHP) anomaly detected in late April 2018 causes the malfunction of the cooling system
  – Degraded data quality at all IR channels
  – Geometric calibration of good images is not appreciably affected by the anomaly. The INR performance meets the requirements.

• Great progress made to optimize the instrument performances. Main mitigations include:
  – Different operational focal plane module (FPM) temperature from the designed ones
  – Different gain-set configurations applicable at different time in a day for some IR bands
  – Predictive Calibration algorithm (pCal) to improve IR radiometric calibration accuracy during the satellite nighttime
  – Updates of many calibration look-up-tables (LUTs)
  – New IR SRFs at 81K to be operationally implemented soon
  – FPM temperature dependent solar calibration scheme for the VNIR bands (ongoing effort)
NOAA/STAR GOES Calibration Website
https://www.star.nesdis.noaa.gov/GOESCal/
G17 ABI IR Performance

GOES-17 ABI Actual IR Performance

- Light to dark green: adequately to barely meet the original requirement
- Gray: failed the original requirement
- Orange: ICT counts were saturated but most earth view count not.
- Red: data not usable

Daily maximum FPM temperature

NEdT: 0–1 × Spec.
NEdT: 1–5 × Spec.
ICT Look Saturation
Space Look Saturation

Time in a day
Month in a year

00 03 06 09 12 15 18 21 24 UTC
07/01/2018 09/20/2018 12/11/2018 03/03/2019 05/24/2019 08/14/2019
What is GSICS?

- Global Space-based Inter-Calibration System (GSICS) is an international collaborative effort initiated in 2005 by WMO and CGMS to monitor, improve and harmonize the quality of observations from operational weather and environmental satellite of the Global Observing System (GOS)
- GSICS develops common methodologies and implements operational procedures to ensure quality and comparability of satellite measurements taken at different times and locations, by different instruments, operated by various satellite agencies.
  - Best or common practiced algorithms/tools - deliverables
  - Products
- Current 18 entities are contributing to GSICS coordination, including CMA, CNES, ESA, EUMETSAT, IMD, ISRO, JAXA, JMA, KMA, NASA, NIST, NOAA, ROSCOSMOS, ROSHYDROMET, USGS, and WMO
GSICS in G17 ABI Cal/Val Activities

• **Absolute Radiometric Calibration Accuracy**
  – **GSICS GEO-LEO inter-calibrations as the primary tools**
    • Two reference instruments for VNIR bands: SNPP VIIRS and NOAA20 VIIRS
      o Lunar calibration, DCC and Desert Monitoring also applied
    • Five reference instruments for IR bands: SNPP CrIS, NOAA20 CrIS, Metop-A/B/C IASI
    • All the monitoring are available at: [https://www.star.nesdis.noaa.gov/GOESCal/index.php](https://www.star.nesdis.noaa.gov/GOESCal/index.php)

• **Relative Radiometric Calibration Variations**
  – **Spatial Variation: Response versus Scan angle (RVS) within the Field of Regard (FOR)**
    • Lunar calibration with a series of special lunar image collections
  – **Temporal Variation:**
    • GEO-GEO inter-comparison using GOES-16 ABI as reference

• **Anomaly Investigations and Correction Validations**
  – Some examples
Calibration Accuracy at Stable FPM Time

G17ABI (Gain Set=1)/G16ABI vs. CrIS/IASI, Night Time

- Tb bias to collocated hyperspectral LEO Instrument measurements is less than 0.15K, except for B16(13.3um) at ~+0.45K
- Comparable to G16 with mean difference less than 0.1K, except for B09 (0.22K) and B16 (0.57K)
No apparent strong scene radiance dependent Tb bias to collocated LEO hyperspectral measurements.
Long-term Monitoring at Stable FPM Time

More detailed daily and long-term monitoring available at: [https://www.star.nesdis.noaa.gov/GOESCal/](https://www.star.nesdis.noaa.gov/GOESCal/)
pCal Performance Validation

pCal was operationally implemented on 07/25/2019 to improve the radiometric calibration accuracy when the IR FPM temperature is unstable and images are available.

Temporally and geo-spatially paired pixels with similar viewing geometry

OE: without pCal algorithm
ITE: with pCal algorithm turn-on
FPM temperature

The pCal algorithm greatly reduces diurnal variation.
The pCal algorithm significantly improves the G17 IR radiometric calibration accuracy at the unstable FPM time.
New G17 IR SRF Is Coming!

• The current operational G17 IR SRFs were measured with FPM at 60K, the designed operational temperature.
• Yet the operational IR FMP temperature is controlled at ~81K when applicable
  – IR SRF should be changed
  – Impact on the radiometric calibration accuracy is the most apparent at B16 (13.3um) with the largest uncertainty at ~0.45K
• Vendor delivered the new SRFs at 81K
• GSICS GEO-LEO played the critical role in simulating and validating the performance
  – Current status: already tested at the ITE server and the converged agreement made by the users
• This new set of G17 IR SRF will be implemented soon
  – New SRF available at: https://ncc.nesdis.noaa.gov/GOESR/ABI.php
Impact of the Coming New SRF Change

Big change at B16 (13.3um)

- Will reduce the mean Tb bias to IASI within 0.1K for all IR bands except for B12 (9.61um) at ~0.2K.
- Will reduce the mean calibration difference to G16 within 0.1K for all the IR bands
Rad. Calibration Accuracy for VNIR Bands

G17 ABI vs. NPP VIIRS

- Difference to SNPP/VIIRS were within 5% for B01, B03 and B06, brighter than SNPP/VIIRS by ~8% at B02, and ~5.5% at B05 in the early time (PLT/PLPT)
- Differences to SNPP/VIIRS are within 5% for all the six VNIR bands, after a series of updates in the solar calibration LUTs and the operational calibration algorithm in April-May 2019,
  - Update of the operational calibration algorithm in early April 2019
  - Update of the B02 solar diffuser BRDF look-up table in late April 2019
  - Update of the lunar intrusion LUTs in early May 2019
Scene Dependent Reflectance Ratio to SNPP/VIIRS

- Scene reflectance (radiance) dependent reflectance ratio to SNPP/VIIRS is most likely attributed to the variation in the radiometric calibration accuracy caused by the floating FPM temperature.
- Effort is undergoing to mitigate the FPM temperature dependent calibration accuracy.
Spatial Uniformity Validations

- GSICS Implementation of the ROLO model (GIRO) was used to simulate the lunar irradiance
- All the G16/G17 ABI VNIR bands meet the RVS requirements
- G17 RVS is comparable with GOES-16 and well within the specification, with slightly more random noise than G16.
Summary

• Despite the LHP anomaly, greatly improvements in the IR radiance quality have been made for GOES-17 ABI to join GOES-16 to provide the visible and infrared imagery with high spatial, temporal and spectral, radiometric and geometric quality.

• GSICS tools play the critical role in validating and monitoring the radiometric calibration accuracy and detecting calibration anomalies
  – The overall calibration accuracy for the VNIR bands are within 5%, after the recent updates in April - May 2019
  – IR radiance is stable and well calibrated when the IR FPM temperature is controlled
  – The predictive calibration algorithm greatly improves the radiometric calibration accuracy at the unstable FPM temperature time in a day
  – New IR SRF will be implemented very soon to improve the radiometric calibration accuracy at the controlled FPM temperature time
  – EW spatial uniformity is well within the requirement for the VNIR bands

• Efforts are still ongoing to further improve the G17 ABI radiance quality
Acknowledgements

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