# On-Orbit Radiometric Calibration of GOES-R ABI IR Bands

Zhipeng (Ben) Wang, Xiangqian (Fred) Wu, Fangfang Yu,
Hyelim Yoo, Haifeng Qian and Xi Shao
GOES-R CWG
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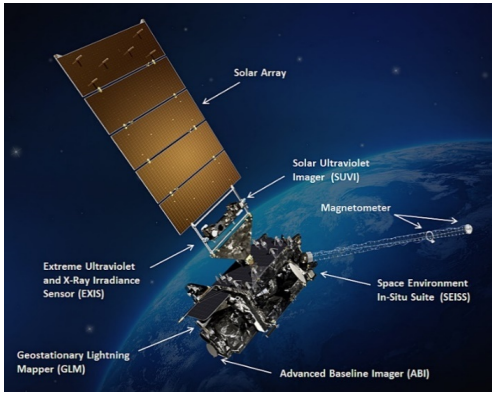
# Outline

- Overview of GOES-R ABI and its IR Calibration
- GOES-16 ABI IR Calibration
  1. IR performance assessment at PLPT
  2. major calibration anomalies investigated and resolved
- GOES-17 ABI IR Calibration
  1. LHP anomaly and its impact to IR
  2. The development of pCal algorithm to remove the calibration bias induced by drifting detector temperatures
  3. IR performance assessment
- Summary

# ABI Overview

- ABI is the main payload on-board NOAA's GOES-R series satellites: GOES-16 (Nov. 2016), GOES-17 (Mar. 2018), scheduled GOES-T (Dec. 2021) and GOES-U (2024).
- With its NS and EW scan mirrors, ABI scans the Earth in 16 spectral bands, compared to 5 on previous GOES, covering a spectral range of 0.47-13.3 µm:




| Band | Wavelength (µm) | Resolution (km) | Detector Rows | Primary Function |
|---|---|---|---|---|
| 1 | 0.47 | 1 | 676 | Aerosols |
| 2 | 0.64 | 0.5 | 1460 | Clouds |
| 3 | 0.86 | 1 | 676 | Vegetation |
| 4 | 1.38 | 2 | 372 | Cirrus |
| 5 | 1.61 | 1 | 676 | Snow/Ice discrimination, cloud phase |
| 6 | 2.25 | 2 | 372 | Cloud particle size, snow cloud phase |
| 7 | 3.90 | 2 | 332 | Fog, stratus, fire, volcanism |
| 8 | 6.18 | 2 | 332 | Atmospheric |
| 9 | 6.95 | 2 | 332 | Water vapor |
| 10 | 7.34 | 2 | 332 | Water vapor |
| 11 | 8.50 | 2 | 332 | Cloud-top phase |
| 12 | 9.61 | 2 | 332 | Total column ozone |
| 13 | 10.35 | 2 | 408 | Clouds |
| 14 | 11.20 | 2 | 408 | Clouds |
| 15 | 12.30 | 2 | 408 | Clouds |
| 16 | 13.30 | 2 | 408 | Air temperature clouds |

# ABI IR Calibration Strategy

- For IR bands 7-16, two-point calibration is conducted at detector level to calculate the gain coefficient *m*, based on the detector's responses in counts *x* when viewing an on-board ICT (blackbody) and space:

$$m = \frac{L^{eff}_{ICT} + \left(L^{eff}_{EW@ICT} + L^{eff}_{NS@ICT}\right) - \left(L^{eff}_{EW@Space} + L^{eff}_{NS@Space}\right) - Q(\overline{x}_{ICT} - \overline{x}_{space})^2}{(\overline{x}_{ICT} - \overline{x}_{space})}$$

- The radiance of each EV sample is then retrieved by

$$\frac{m \cdot (x_{sample} - \overline{x}_{space}) + Q \cdot (\overline{x}_{sample} - \overline{x}_{space})^2 - (L^{eff}_{EW@sample} - L^{eff}_{EW@space}) - (L^{eff}_{NS@sample} - L^{eff}_{NS@space})}{\rho_{EW@sample} \cdot \rho_{NS@sample}}$$

*m*: linear gain coefficient

*Q*: quadratic gain coefficient

$X_{space/ICT}$: detector counts of space/ICT

$x_{sample}$: detector counts of EV samples

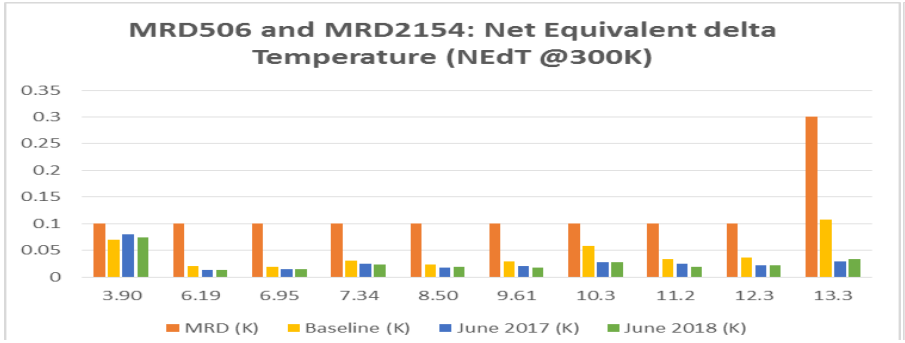
$L_{ICT}$: radiance from on-board ICT

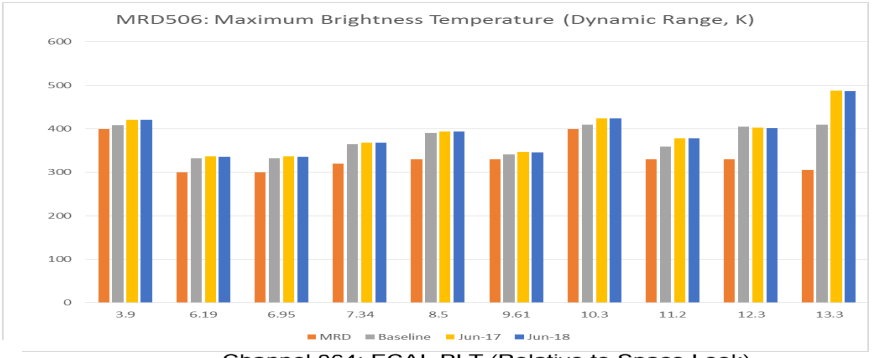
$L_{EW/NS}$: radiance from EW/NS scan mirror

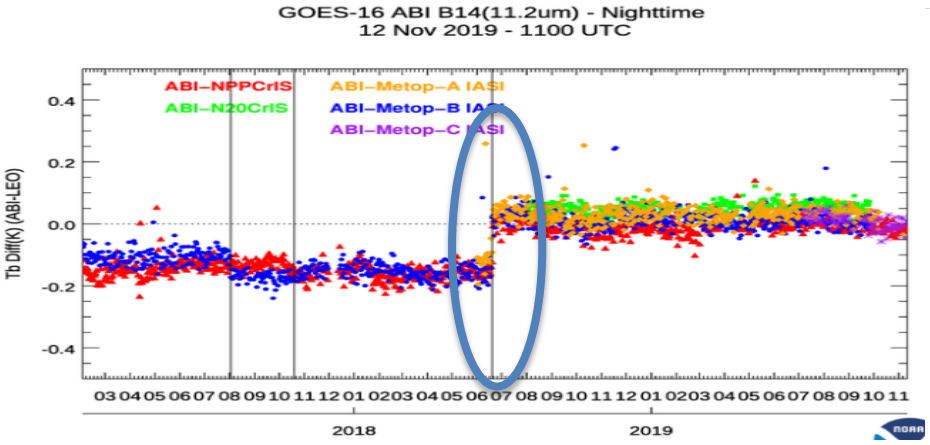
- ABI IR calibration is part of L1b generation and automatic at GS.
- Offline analysis is performed by CWG to assess calibration accuracy and investigate calibration anomalies through:
  1. Inter-sensor comparison (GEO/LEO, GEO/GEO, etc.)
  2. evaluation of instrument calibration data output by GS.

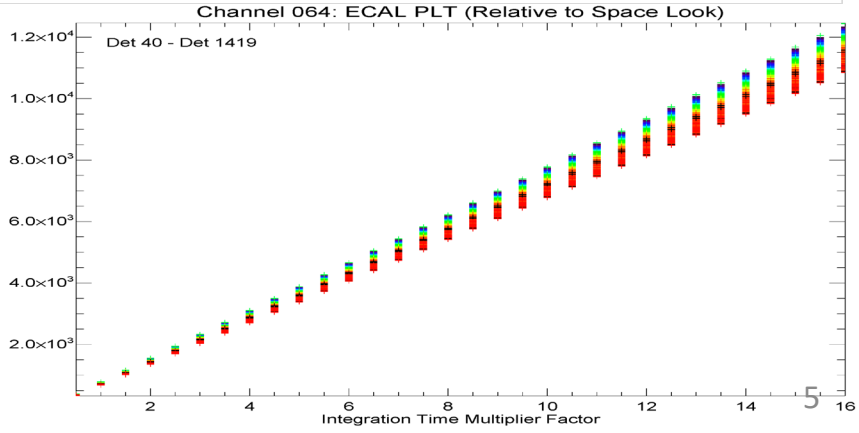
# GOES-16 ABI IR Performance

- The GOES-16 ABI IR detectors have been operating and calibrated normally at stable instrument environment: $T_{ICT} \approx 302$ K, $T_{FPM} \approx 60$ K.
- All the IR performance requirements, including the specifications of key parameters such as calibration precision, accuracy, NEdT etc. are assessed at PLPT to demonstrate L1b maturity. Full validation at 2018-06-01.



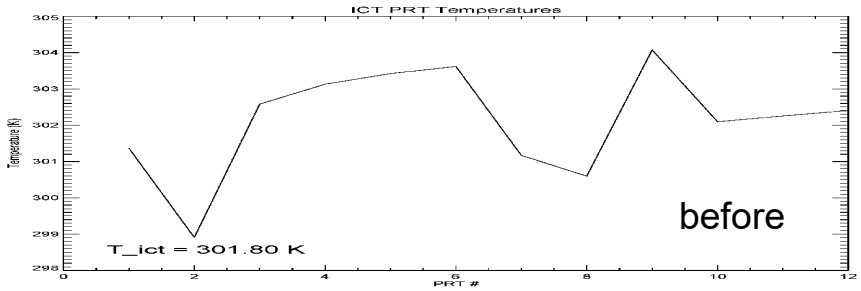



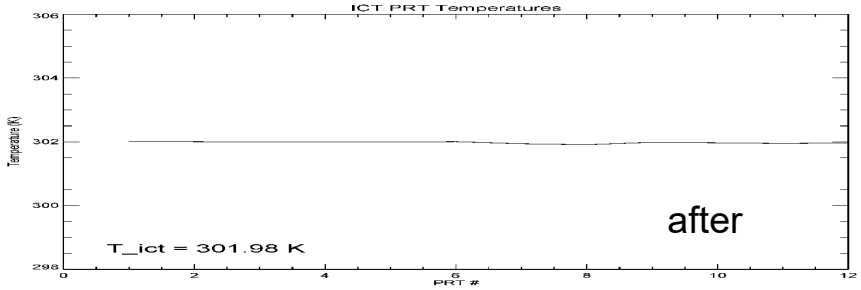



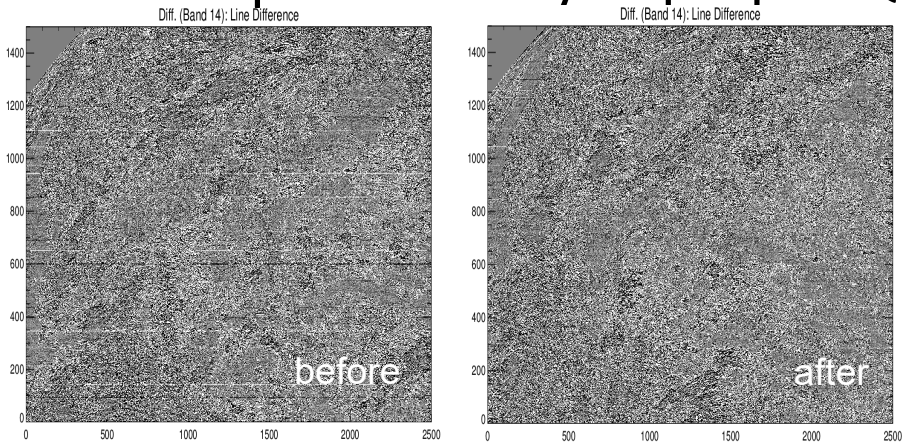
# Major IR Calibration Anomalies

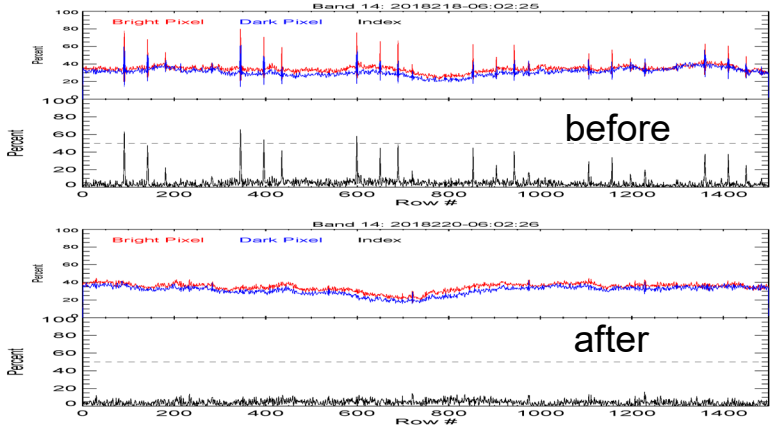
- L1b bias caused by ICT PRT temperature miscalculation.




- L1b strips caused by improper Q coefficients

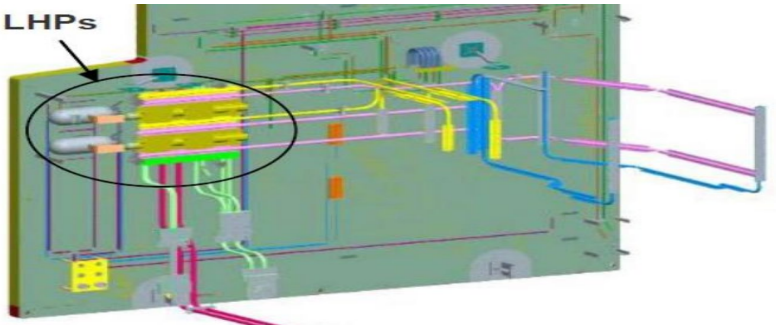


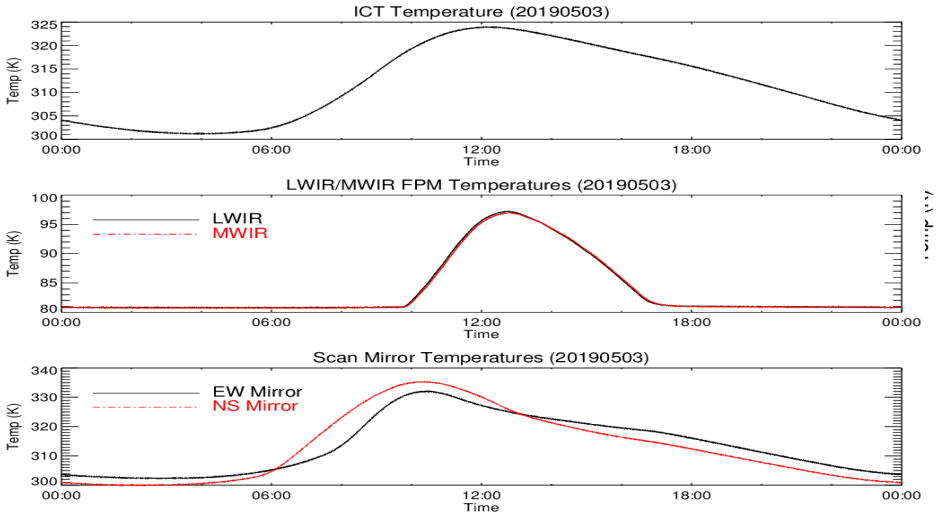

- L1b stripes caused by space look count “latch-up”
- Cold pixel around fire in band 7 imagery
- Periodic bias (PICA) due to scan mirror emissivity inaccuracy

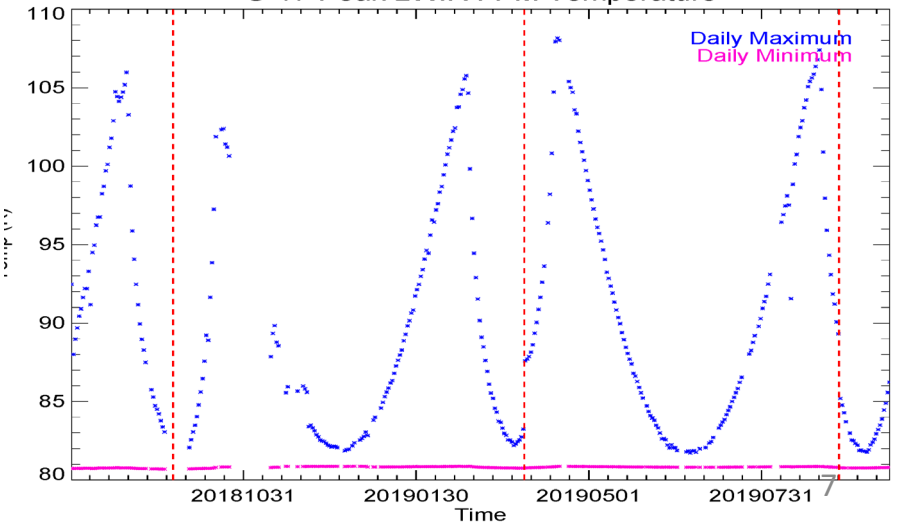
# GOES-17 ABI LHP Anomaly

- The loop heat pipe (LHP) anomaly of GOES-17 ABI prevents the detectors, assembled within the focal plane module (FPM), from operating at their intended temperature of 60 K.



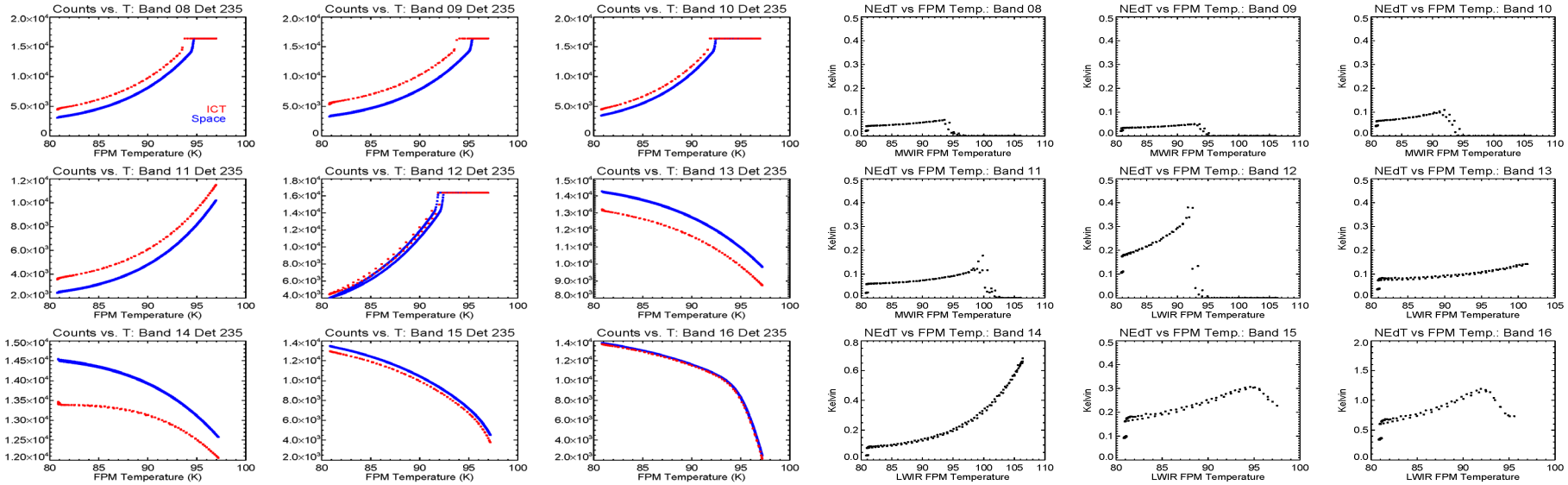

- Heat mitigation strategies:
  1. twice-a-year satellite yaw flip
  2. running both LHPs simultaneously
  3. raising limit temperatures for cryocooler reject surface
  4. raising the nominal operating temperature to 81 K



# Impact to IR Performance

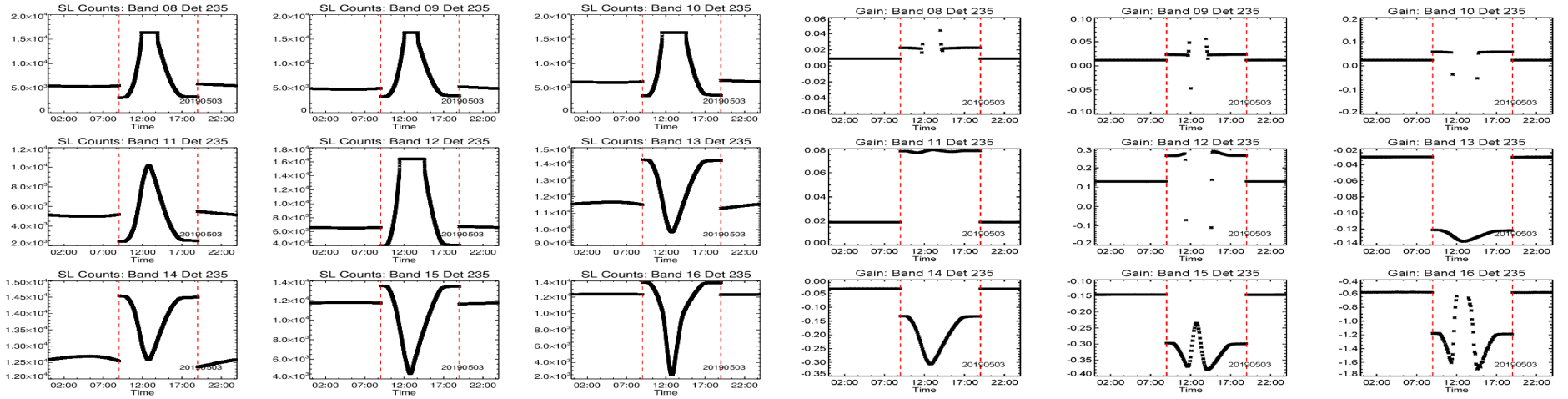
- ABI IR detectors are HgCdTe with performance tight to $T_{FPM}$ (bands 8-16).
- Higher temperature leads to low detectivity and larger thermal noise.
- Even worse, detectors saturate at higher $T_{FPM}$, yielding complete image loss.



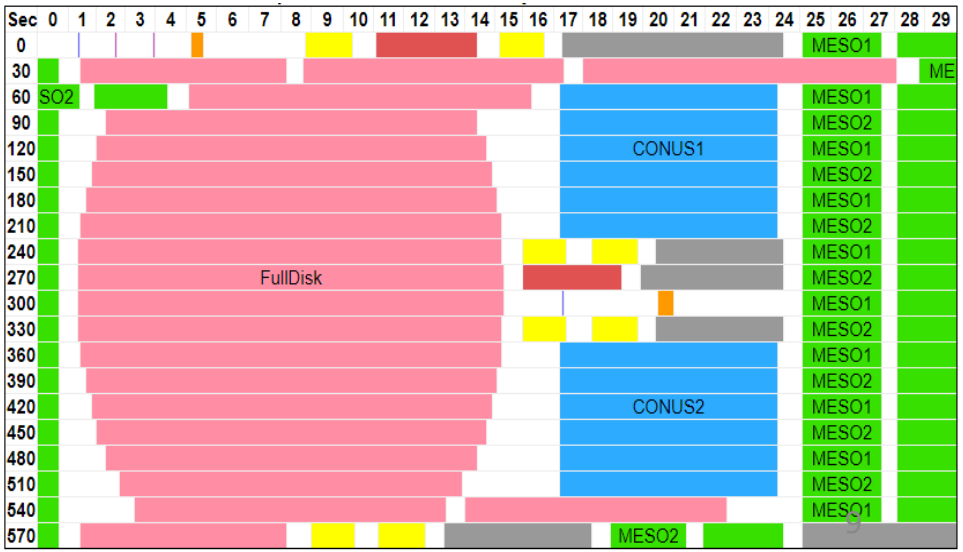

- To alleviate saturation, detectors of bands 8-16 are currently operated at two distinct gain/bias settings:
  1. gain set I maximizes detector performance at 81 K (cool period).
  2. gain set III minimizes the impact of elevated FPM temperature (hot period).
- Gain switch occurs daily when the peak $T_{FPM}$ is greater than 85 K.

# Impact to IR Calibration

- Dark counts and detector gain still vary significantly with $T_{FPM}$.

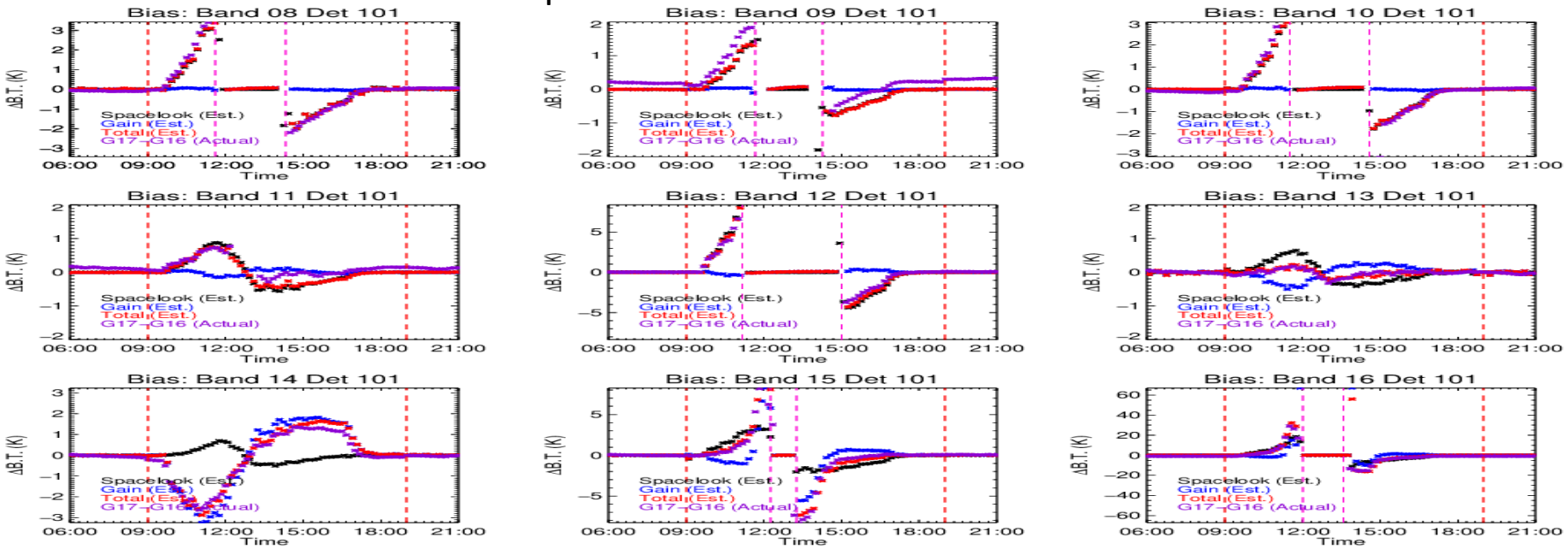



- Because they are not measured at the time of Earth image acquisition, calibration bias is introduced.
- Predictive calibration (pCal) algorithm is developed by ABI vendor to account for the bias, using the temporal extrapolation of the space look counts and gain for calibration.

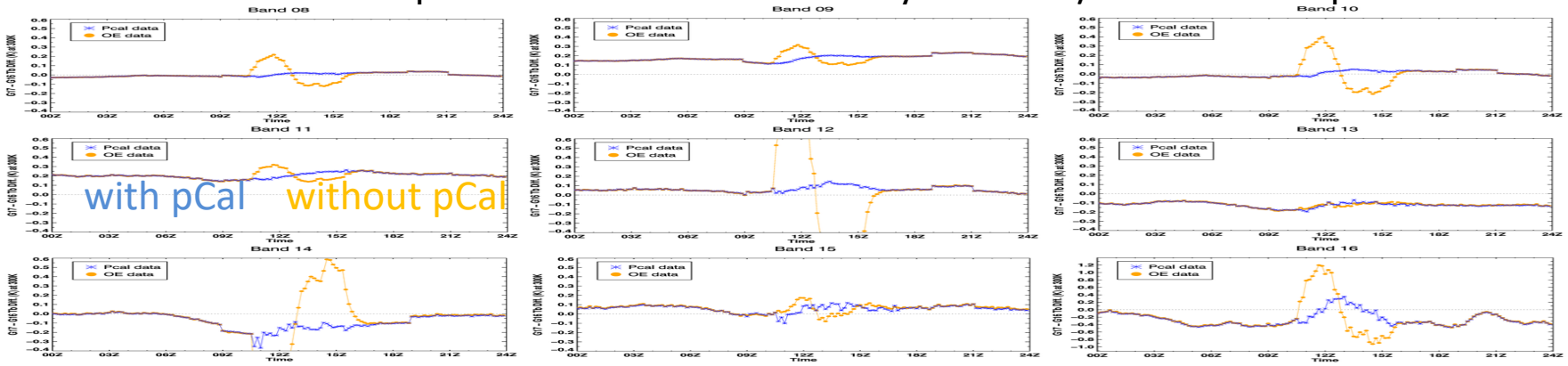


# Bias Mitigation by pCal

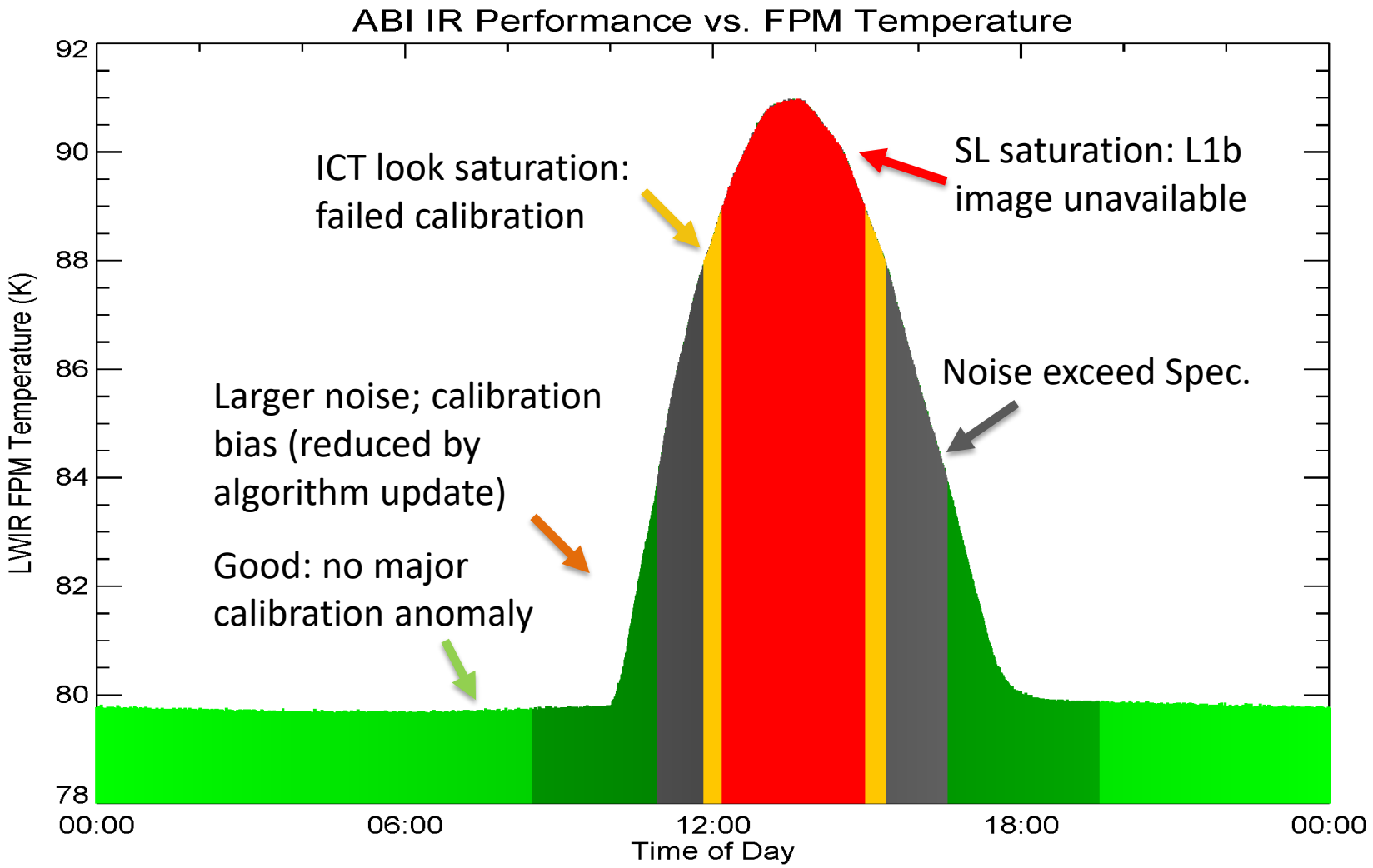
- The bias with and without pCal can both be assessed with calibration data.




- The effectiveness of pCal can also be observed by GOES-17/GOES-16 comparison.

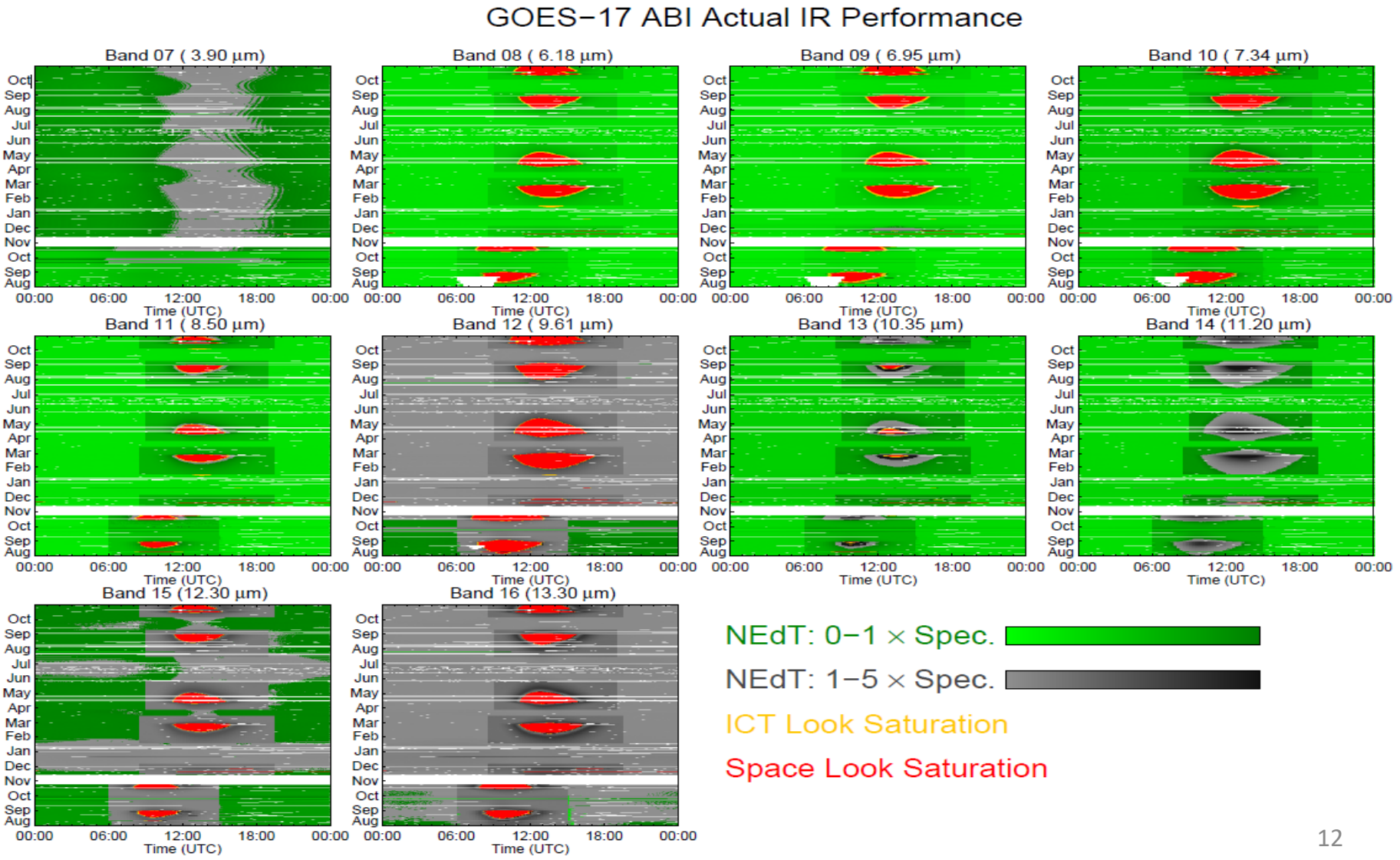


# IR Performance Assessment

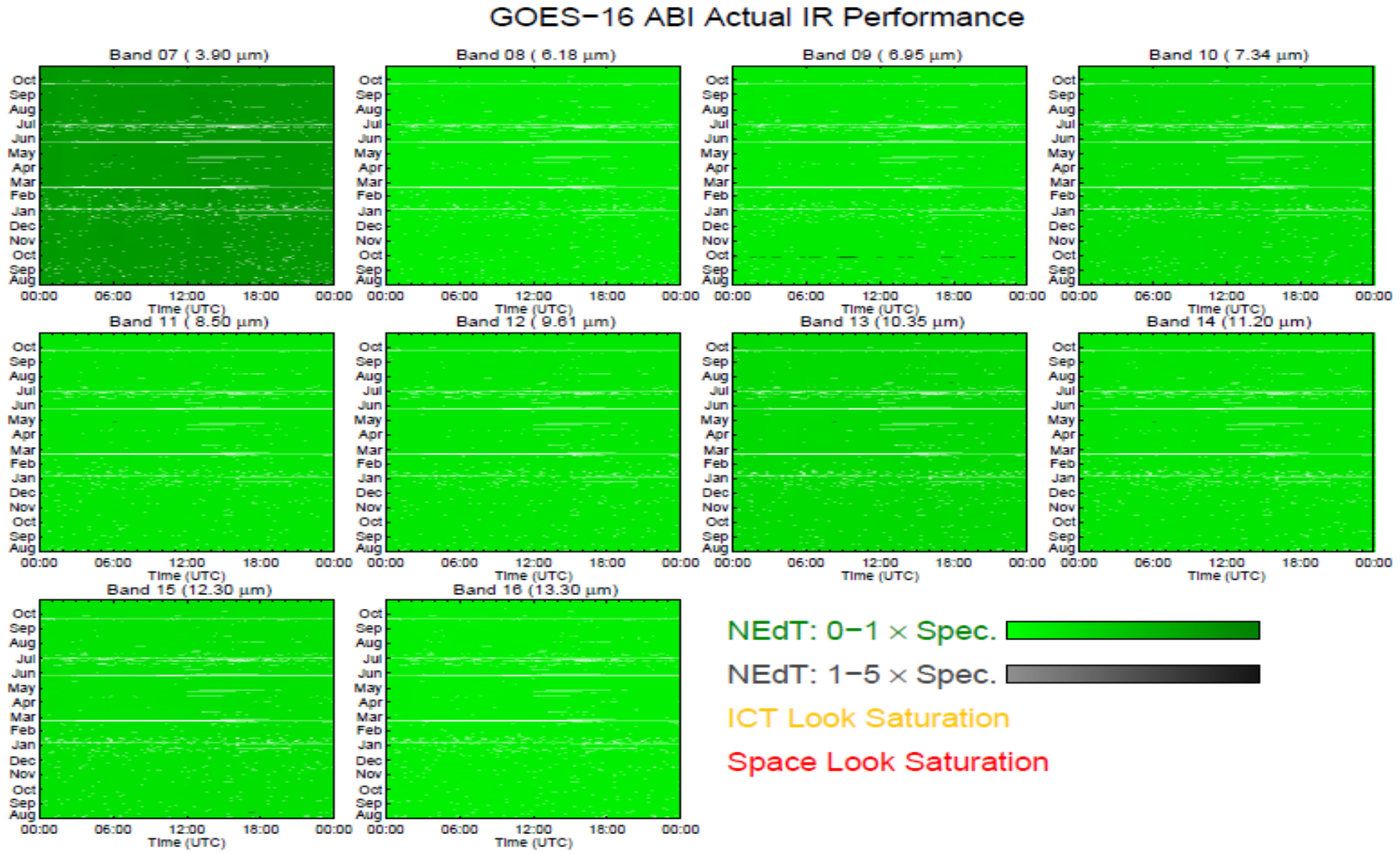



This diagram sketches how IR performance degrades with elevated $T_{FPM}$.

# G-17 IR Performance



# G-16 IR Performance



# Summary

- GOES-16 ABI IR calibration has been overall accurate and stable. Its IR performance meet requirements of specifications.
- The LHP anomaly of GOES-17 ABI seriously degrades its IR performance, even with all the improvements made since it was discovered, including the bias reduction by pCal.
- Various calibration anomalies have been addressed for both GOES-16 and GOES-17.
- CWG will continue to support the production of high quality ABI L1b products.