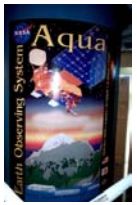
Aqua MODIS Cold FPA Performance and Operation

MODIS Characterization Support Team (MCST)

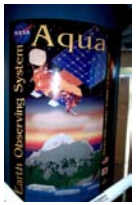
March 27, 2013

Outline



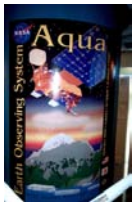
- Introduction
- On-orbit Performance
- Observed Impacts
  - Collection 6 Algorithm Improvements
- Mitigation Strategies
- Summary

Introduction



- Aqua MODIS Cold Focal Plane Temperature Control
  - Known issue with decreasing radiative cooler margin
- Prior meetings held to brief science disciplines on status, impacts and possible mitigation strategies
  - 1st meeting on May 7, 2010
  - 2nd meeting on April 25, 2012
- MCST continues to monitor instrument performance
  - Impacts observed that can affect science products
    - Orbital variation in TEB detector gain (PC bands more sensitive)
    - Increased fitting residuals from BB WUCD during a0/a2 derivation
    - Saturation in bands 33, 35-36 EV data during WUCD

Current Status



- CFPA temperature increase has continued
- CFPA orbital/seasonal oscillation grown larger – max/min difference of ~0.7 K
- Radiative cooler margin nearly lost for CFPA setpoint of 83 K
- Majority of impacts on L1B products occur during BB Warmup/Cooldown activities

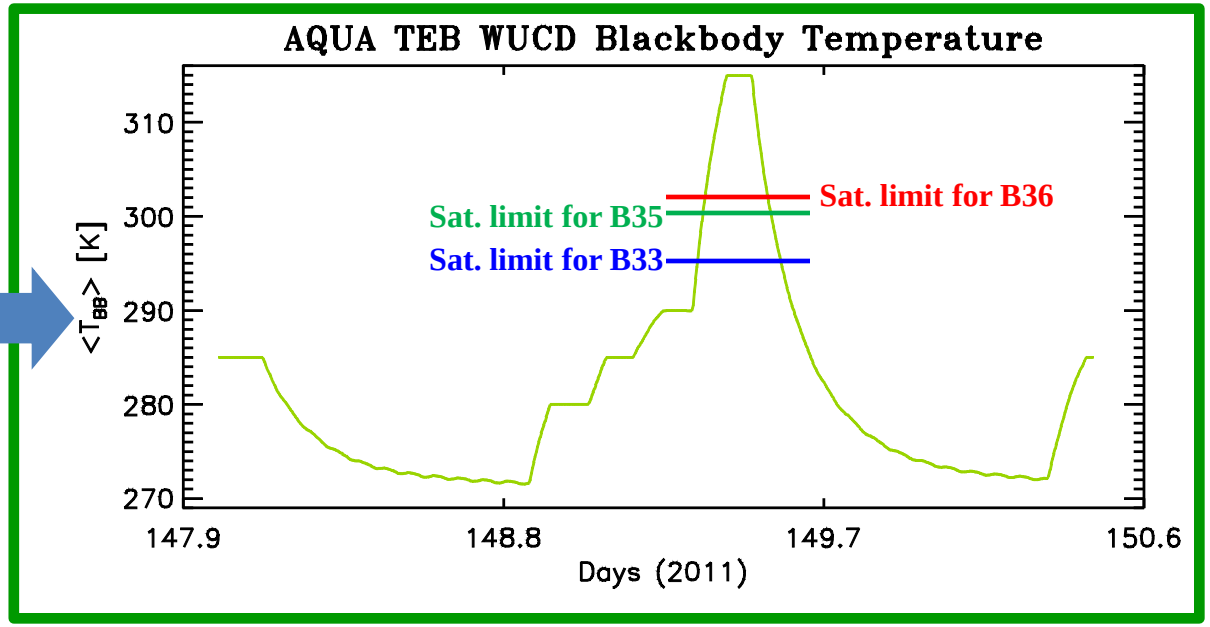
TEB Radiometric Calibration

EV Radiance:

$$L_{EV} = \frac{1}{RVS_{EV}}\left(a_0 + b_1 \cdot dn_{EV} + a_2 \cdot dn_{EV}^2 - \left(RVS_{SV} - RVS_{EV}\right) \cdot L_{SM}\right)$$

Calibration Coefficients:

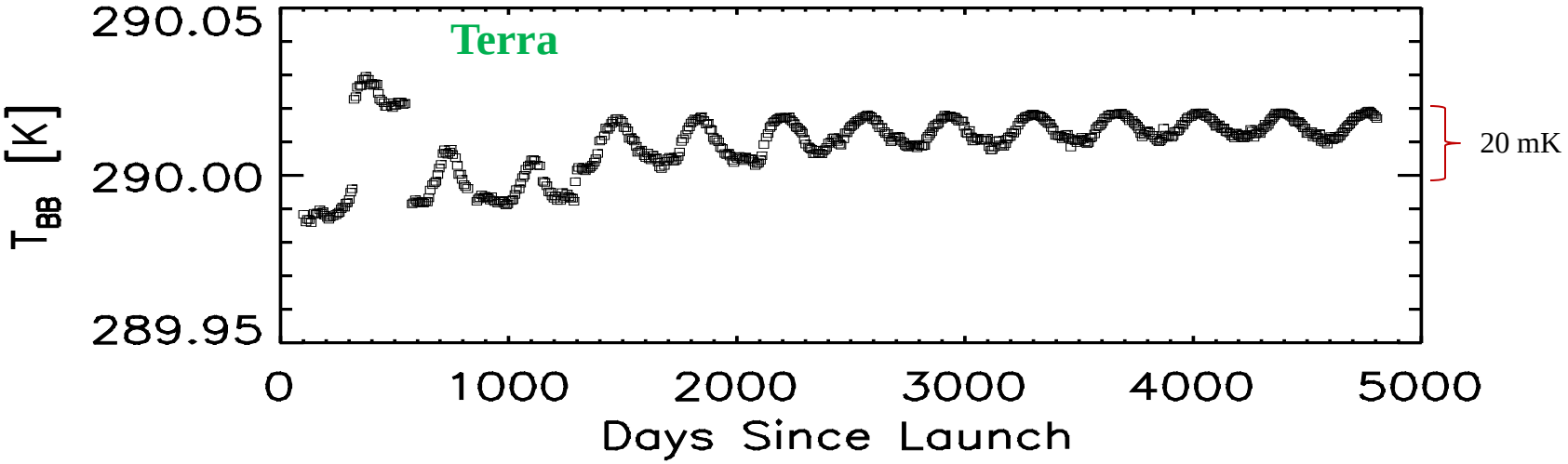
$$b_1 = \left(RVS_{BB} \cdot \varepsilon_{BB} \cdot L_{BB} + \left(RVS_{SV} - RVS_{BB}\right) \cdot L_{SM} + RVS_{BB} \cdot \left(1 - \varepsilon_{BB}\right) \cdot \varepsilon_{cav} \cdot L_{cav} - a_0 - a_2 \cdot dn_{BB}^2\right) / dn_{BB}$$

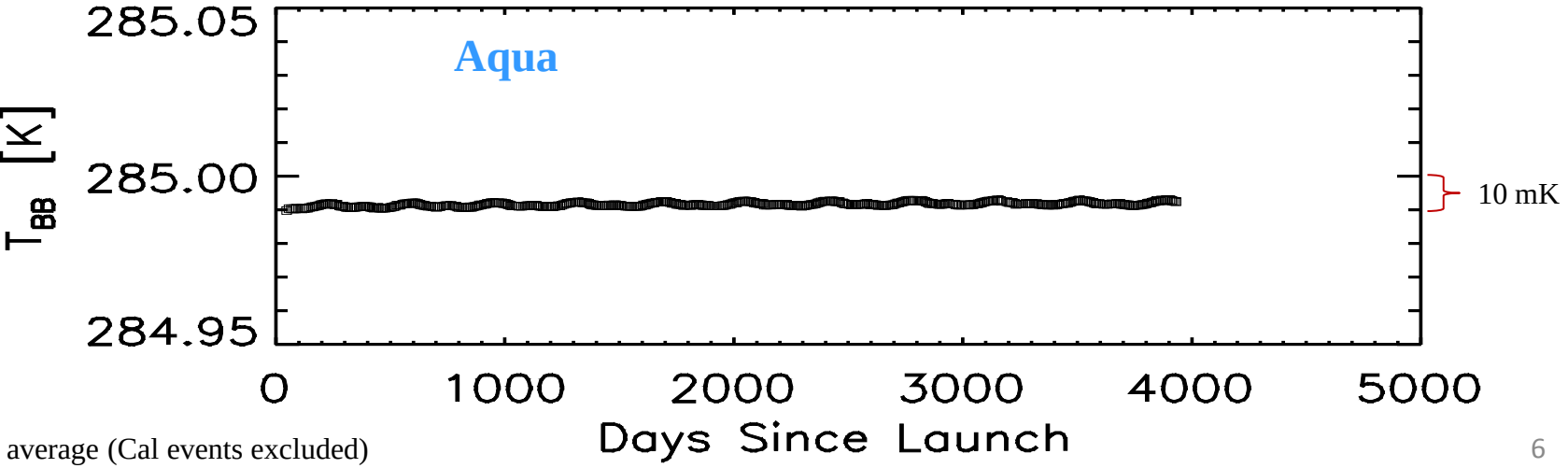


RVS: Response Versus Scan-angle
ε: Emissivity
L: Spectral band averaged radiance
dn: Digital count with background corrected
RSR: Relative Spectral Response

WUCD T_{BB}: 270 to 315K

BB Temp Trends



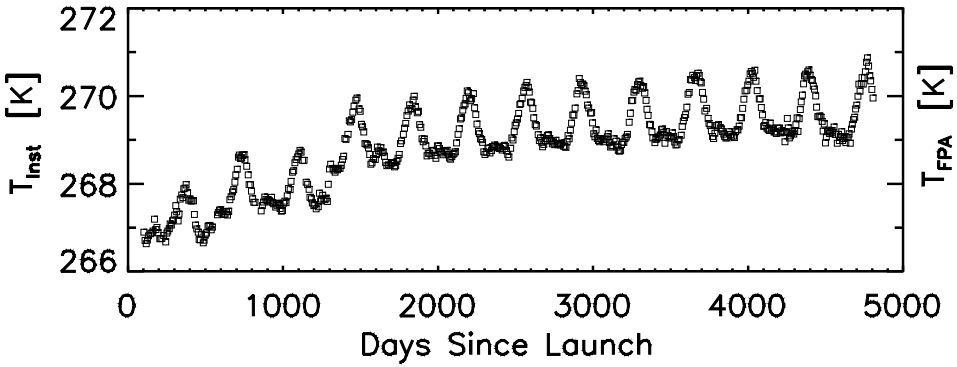


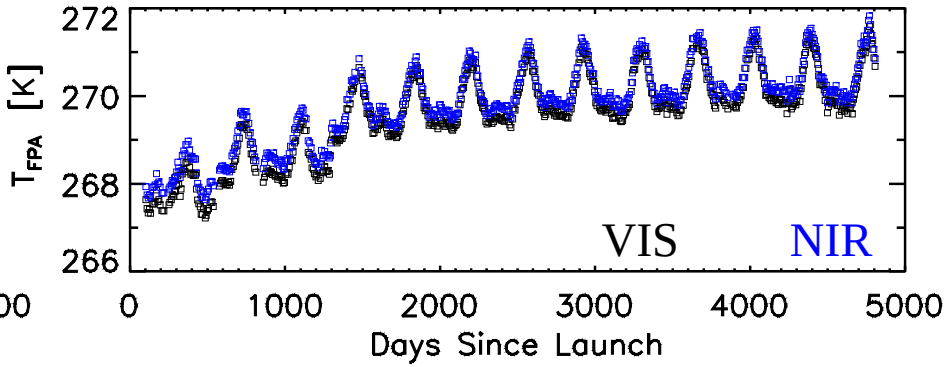
Weekly average (Cal events excluded)

Instrument & Warm FPA Temperatures

Terra

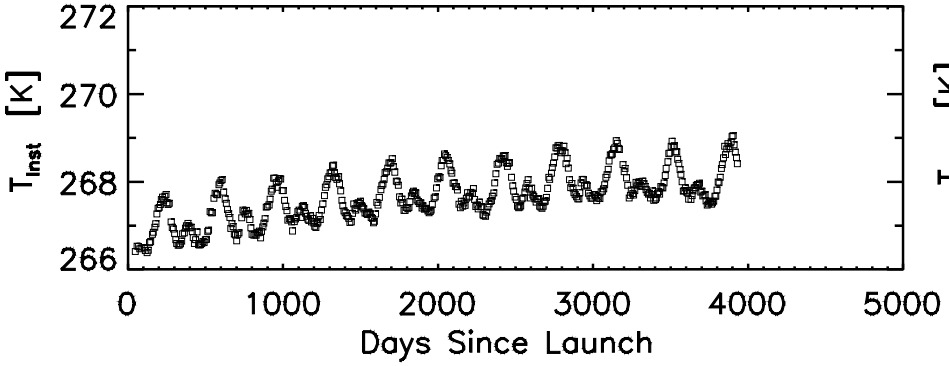
~3.5K increase over 13+ years

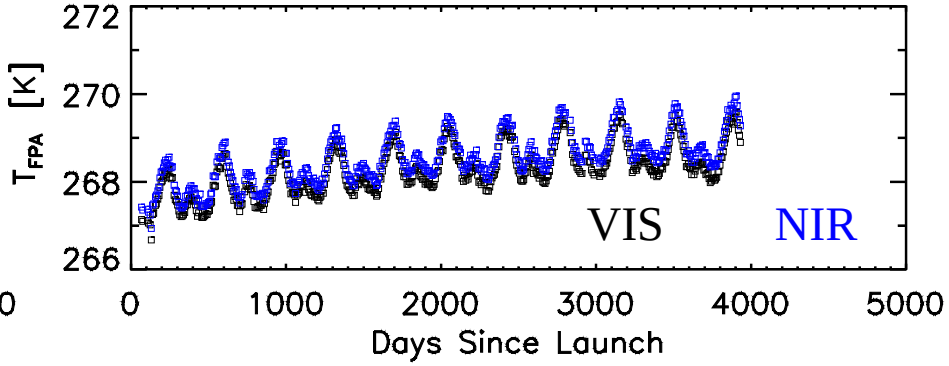




Aqua

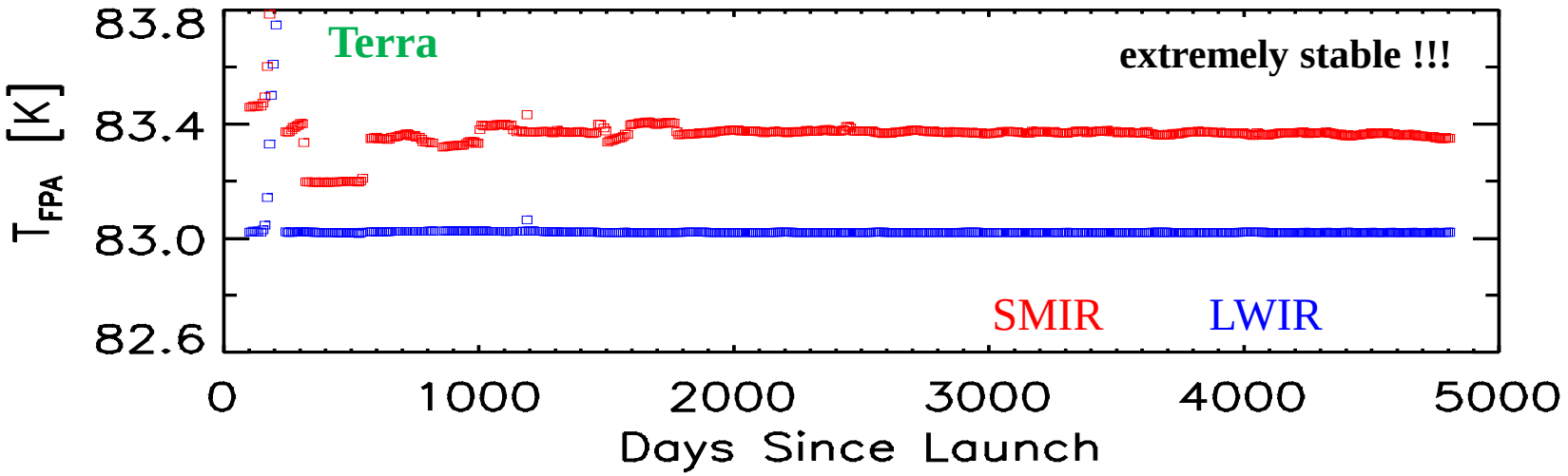
~2K increase over 11+ years

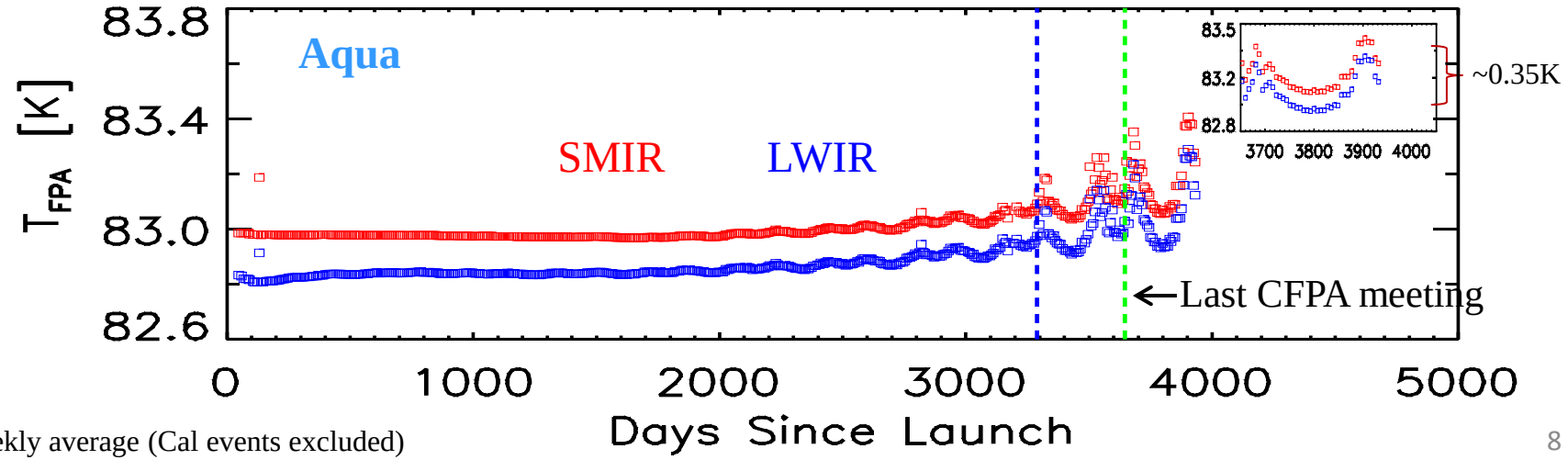




Weekly average (Cal events excluded)

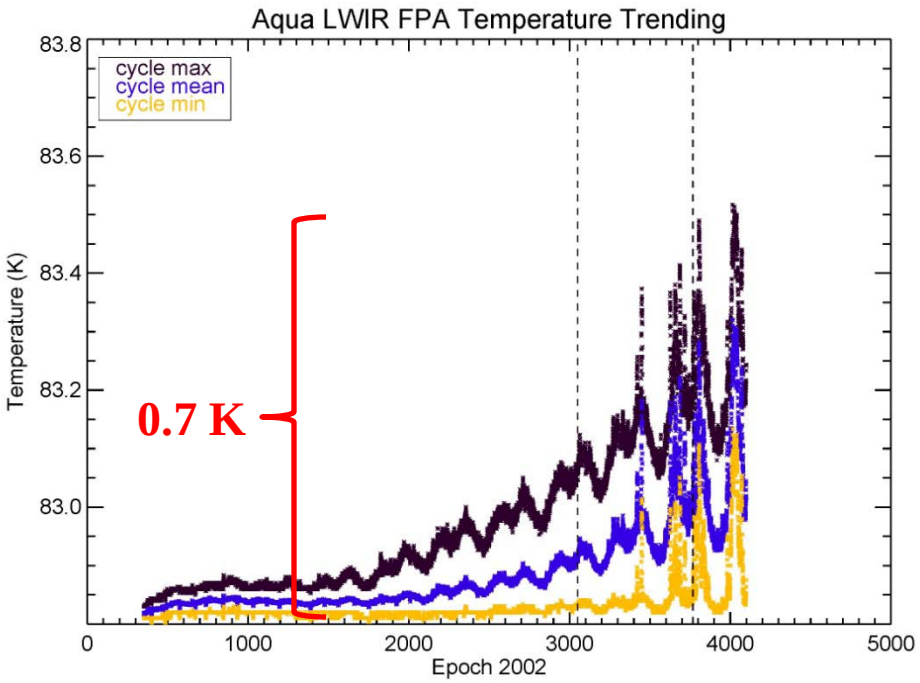
Cold FPA Temperatures

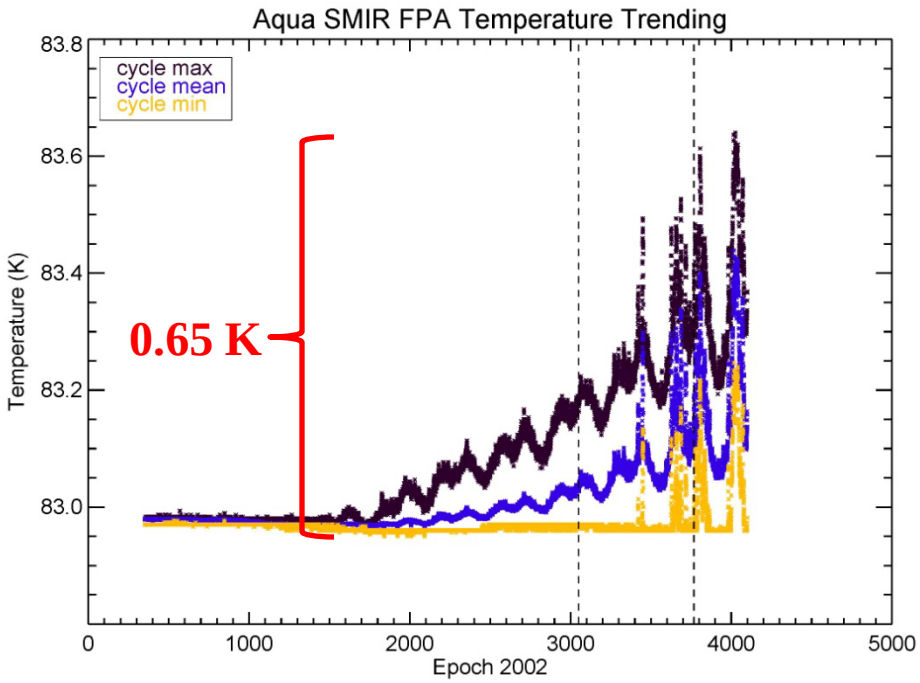




Weekly average (Cal events excluded)

Aqua CFPA Oscillations
Long-term trend

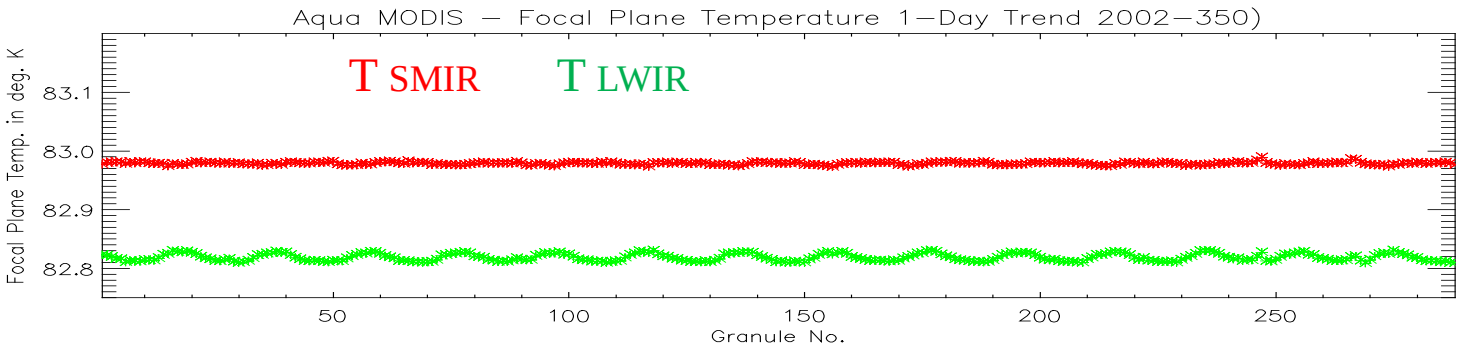


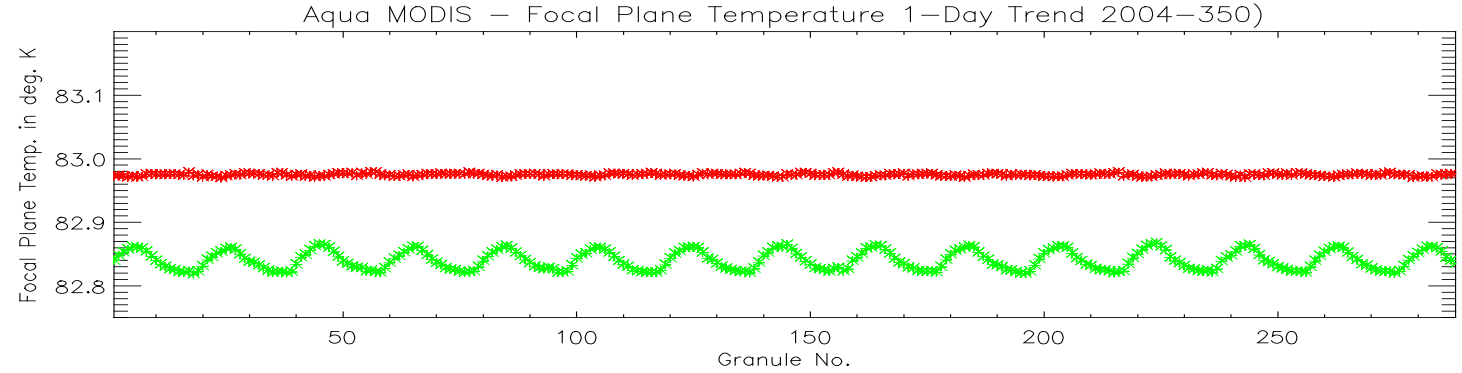


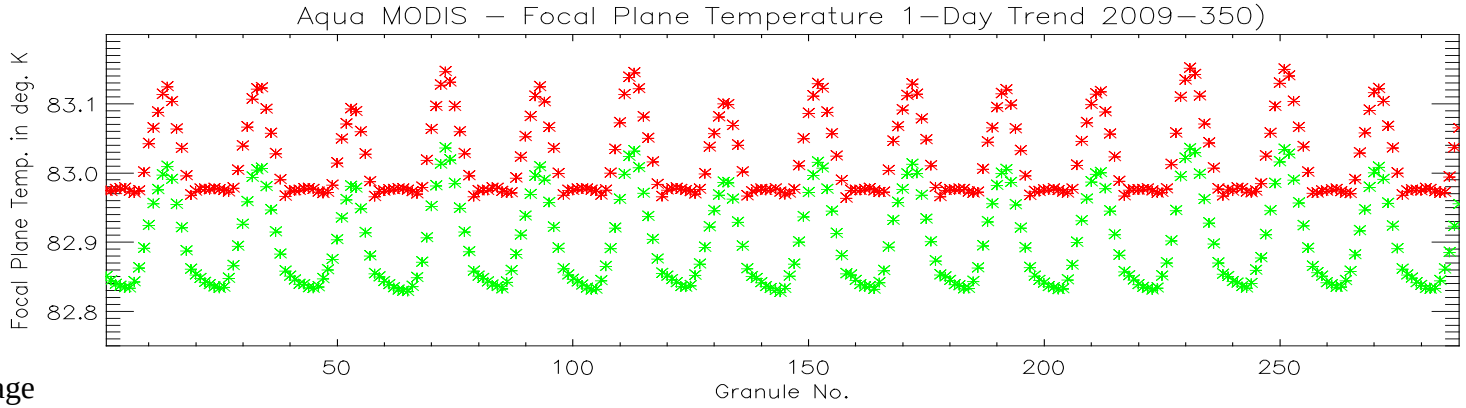
Dashed vertical lines indicate time of last two CFPA meetings.

Max/Min of 4 orbits, every 8 hours

Aqua CFPA Oscillations Short Term (1day) trend

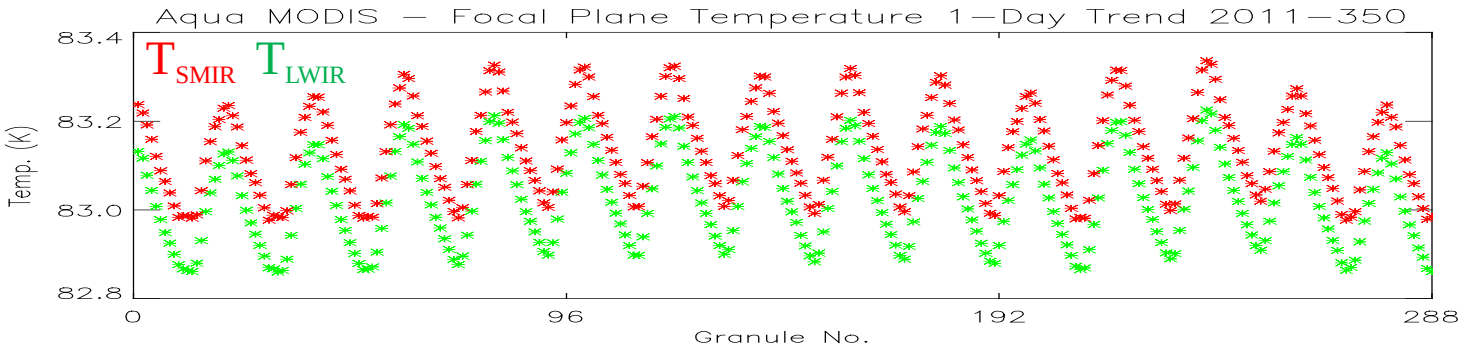


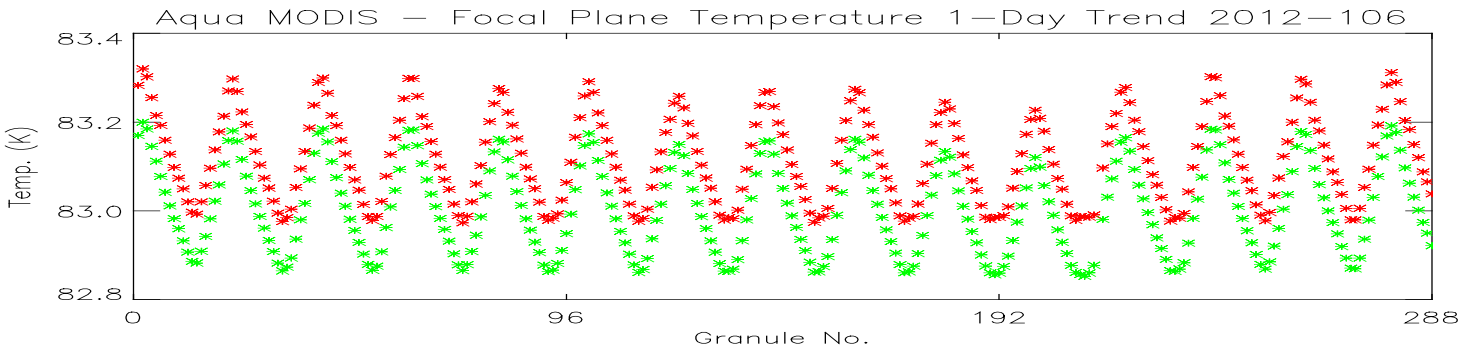


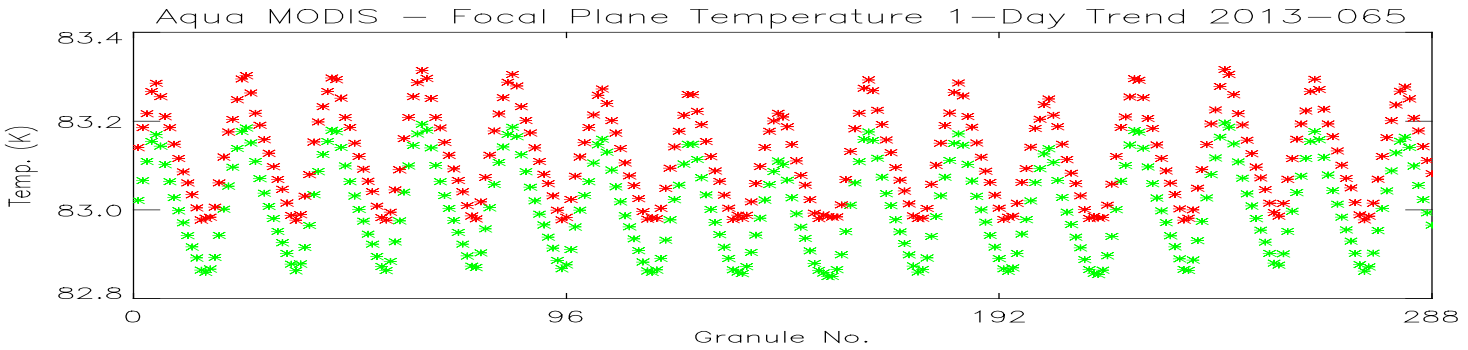


Granule average

Aqua CFPA Oscillations
Short Term (1day) trend



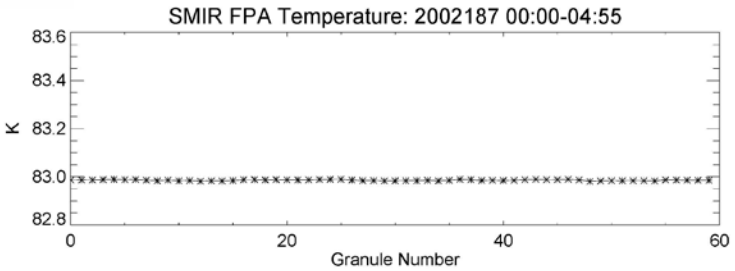


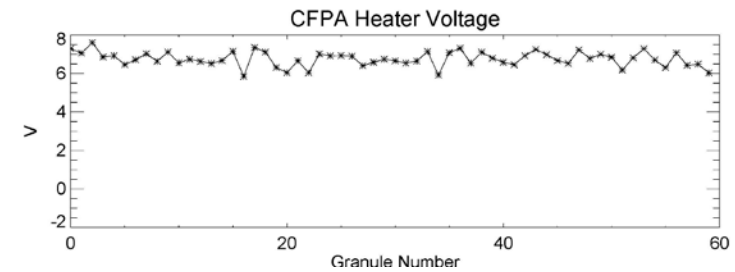


Granule average

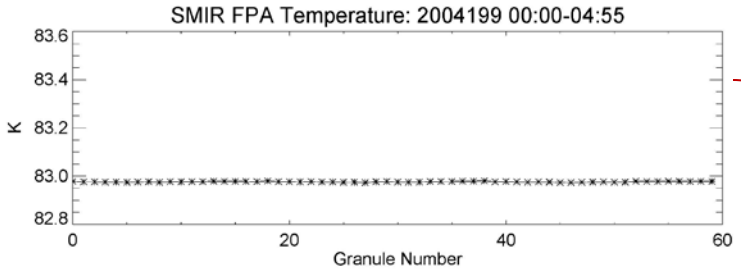
Aqua CFPA Heater Voltage

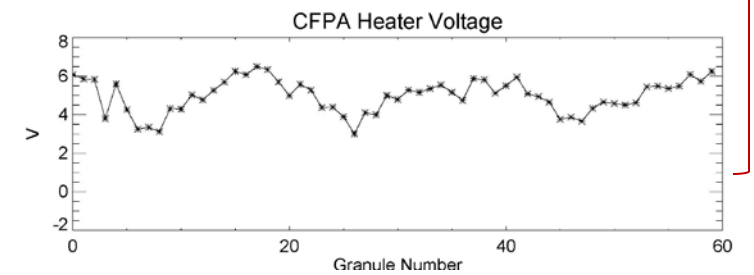
2002



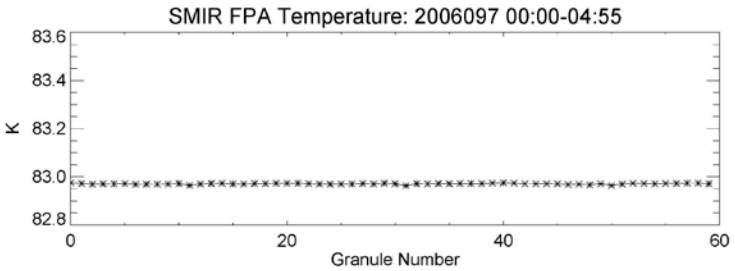


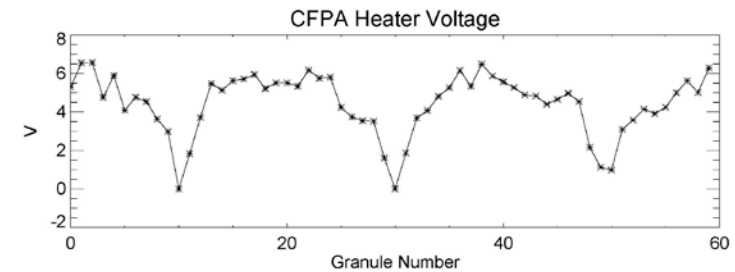
2004



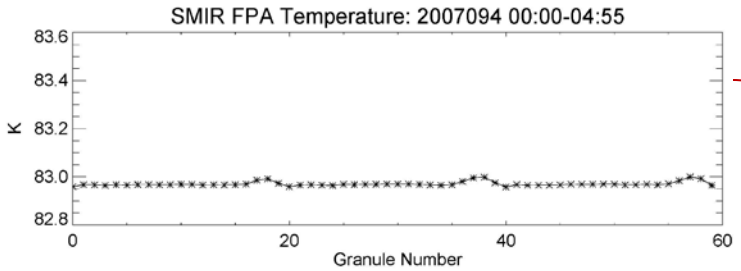


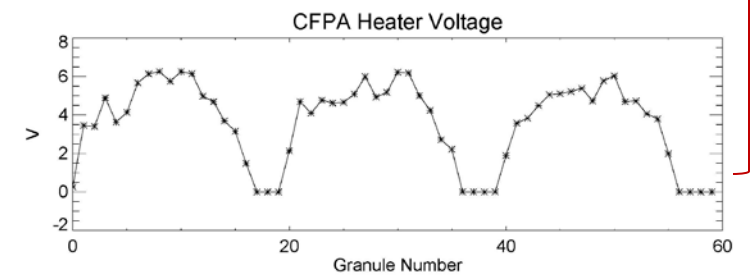
2006





2007

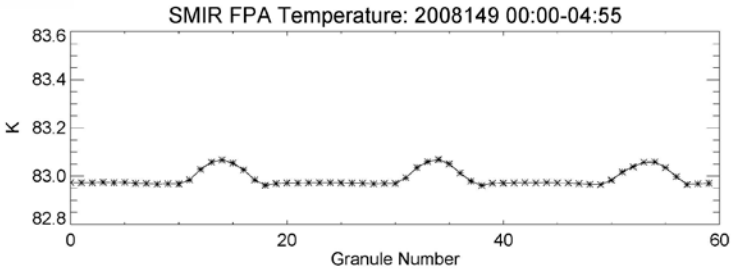


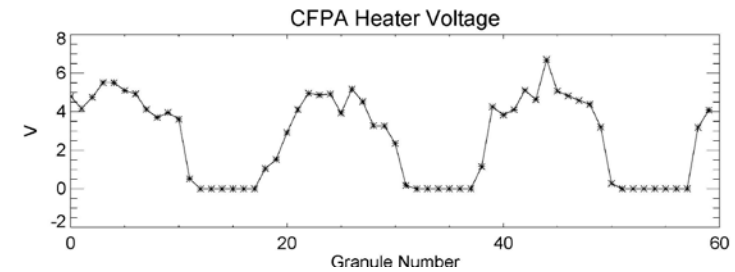


Granule average

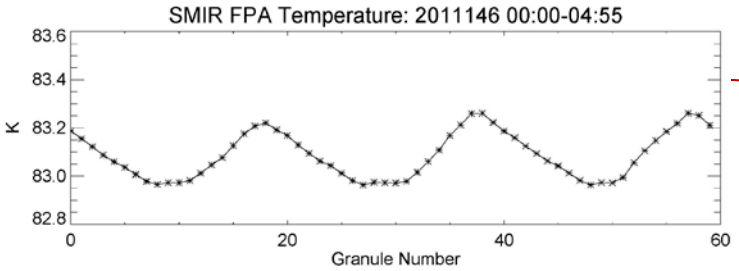
Aqua CFPA Heater Voltage

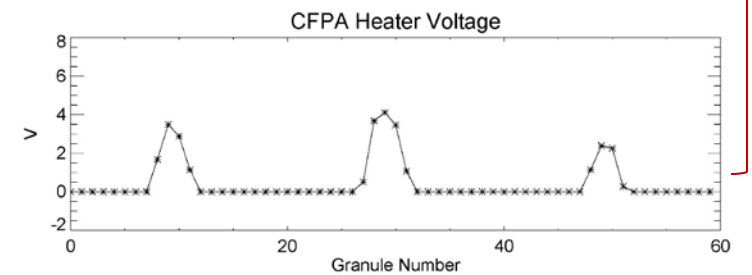
2008



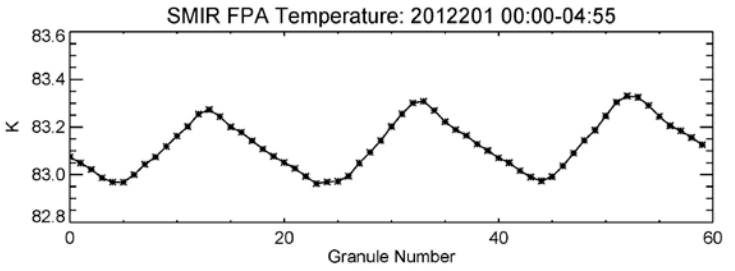


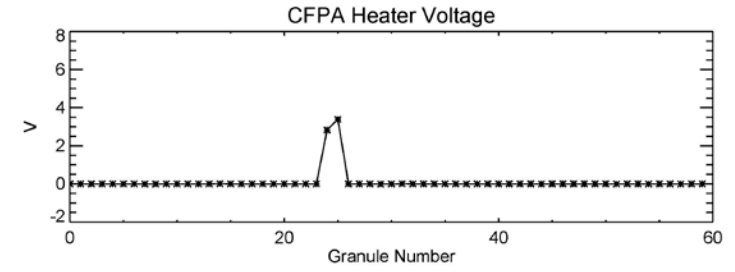
2011



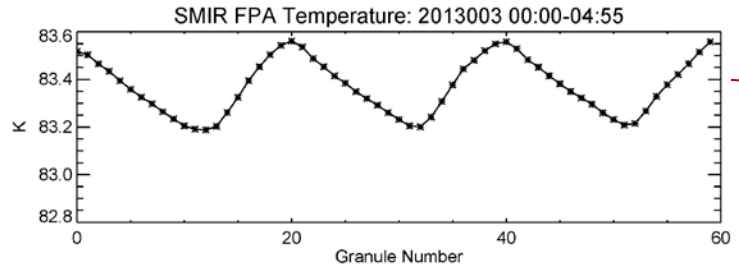


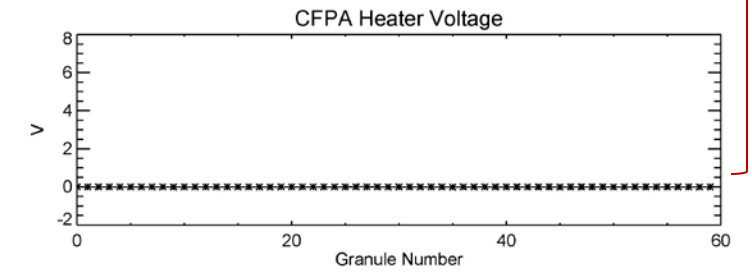
2012





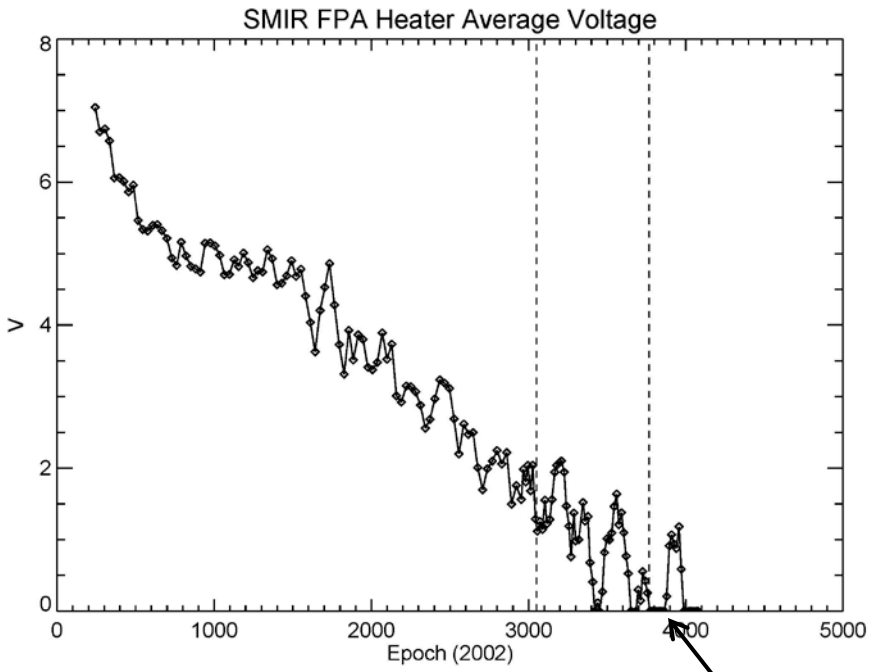
2013

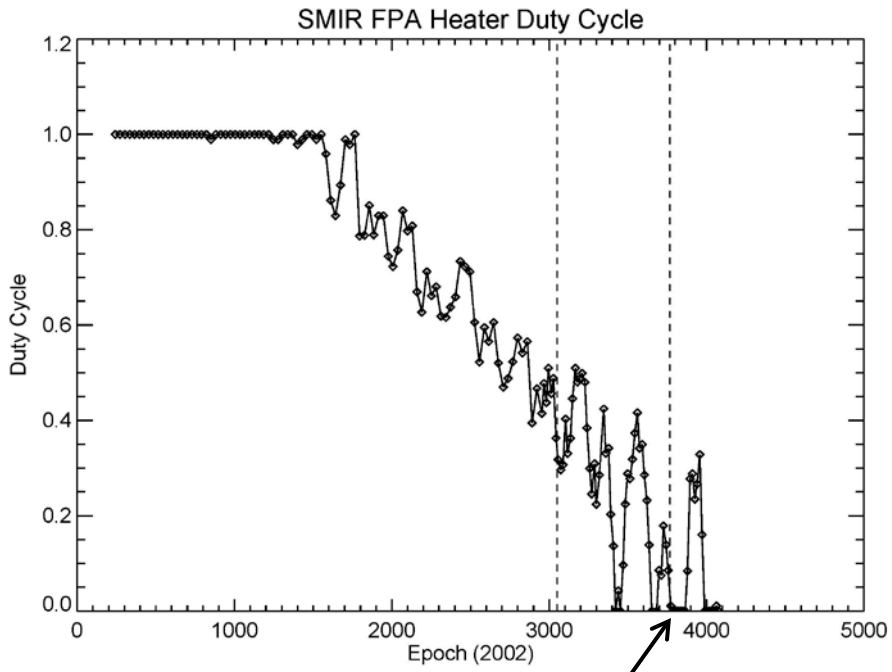




Granule average

Heater Voltage & Duty Cycle

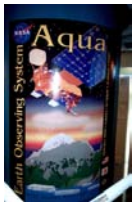




Indicates CFPA temperature not controlled

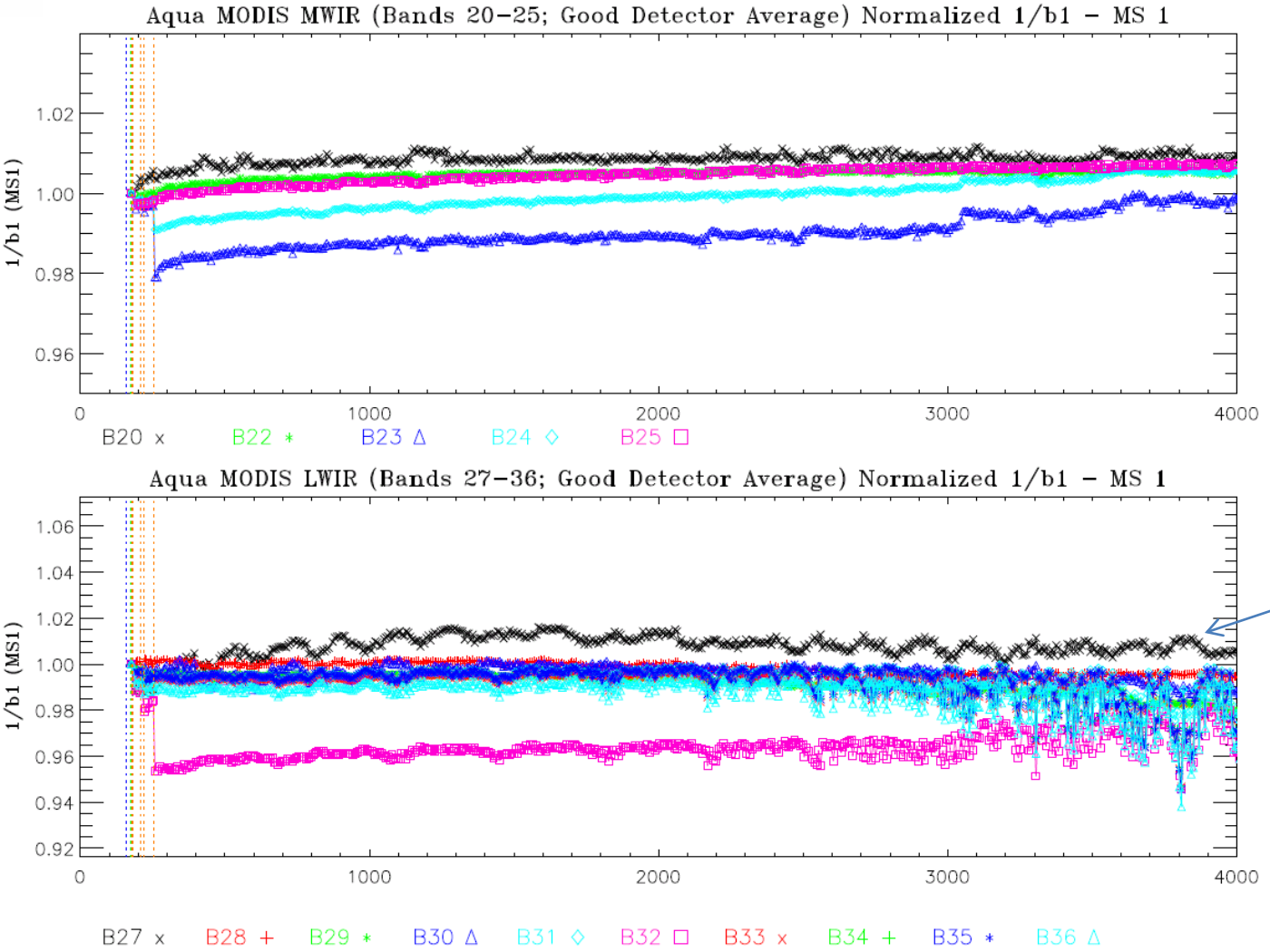
1 orbit average

Observed Impacts



- Gain variation with CFPA temperature
  - captured by scan-by-scan calibration
  - PC bands show largest effect
  - Linear relationship between gain and CFPA Temp
- BB Warmup-Cooldown Activities
  - Larger residuals for a2 derivation (a0 = 0 for PC bands)
    - Temperature correction for a0/a2 analysis implemented in C6
  - Bands 33, 35 & 36 T_{BB} Saturation
    - Increased instances of EV saturation
    - FPA temperature dependent default b1 algorithm implemented for C6
- Band 27 – Temperature dependent filter bandpass shift
  - Impact assessment under investigation

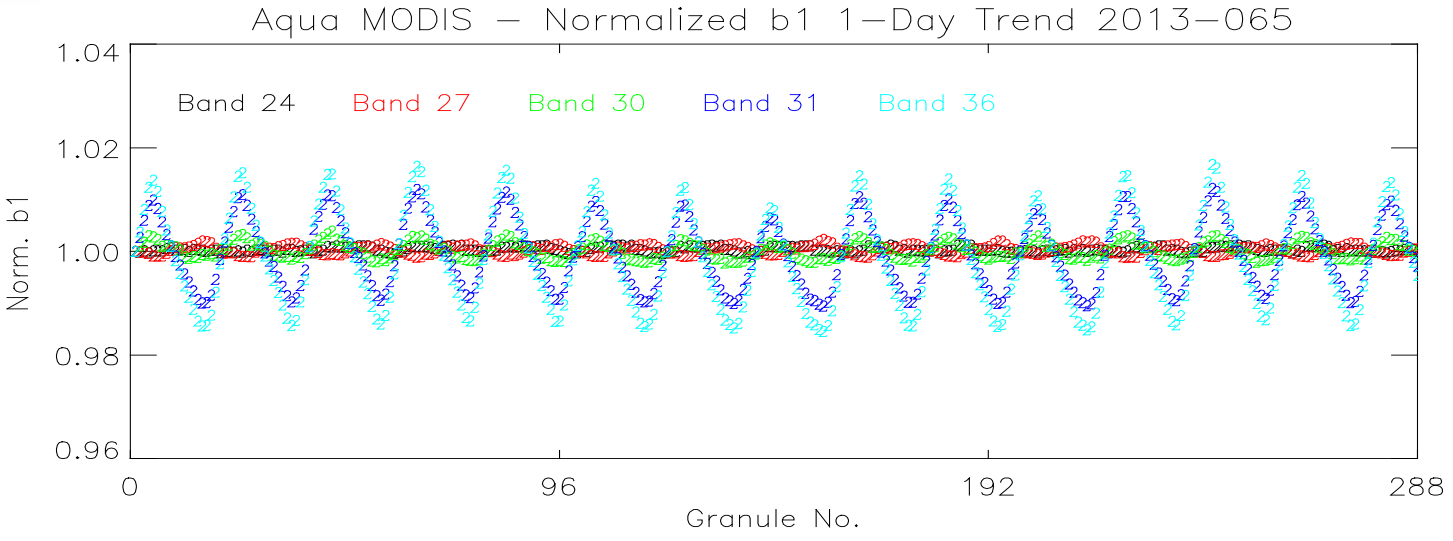
TEB Gain Response

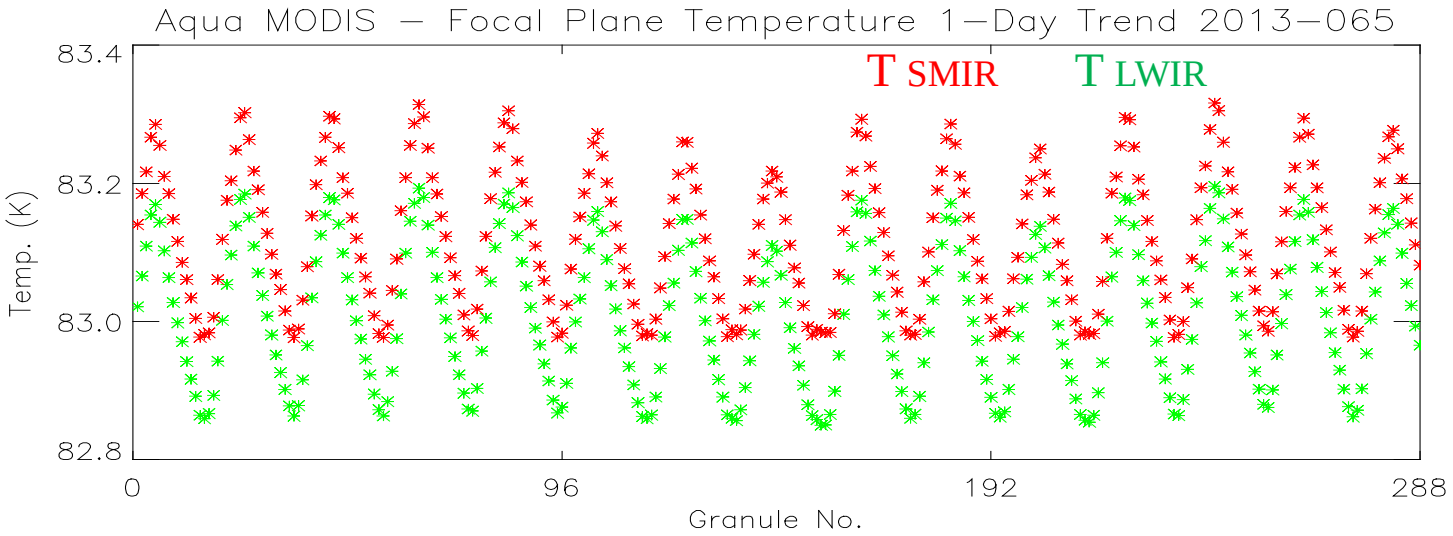


PC Bands showing increased variation in b1

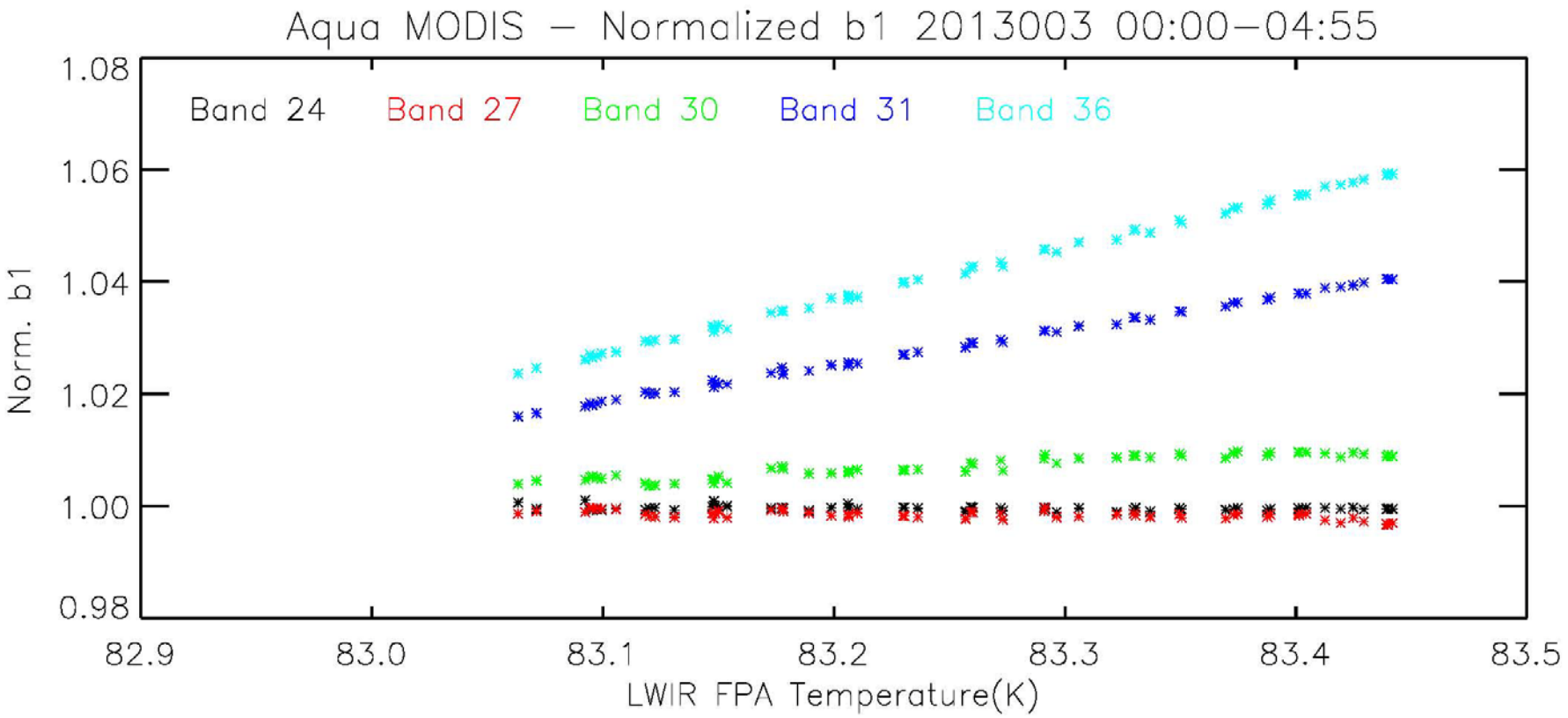
1 randomly selected granule per week (good detectors)

Gain variation with CFPA Temperature





b1 vs CFPA Temp

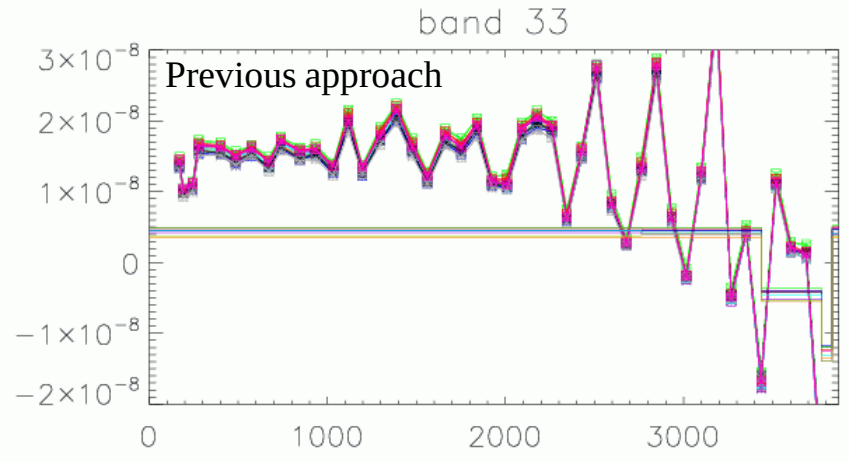


3 orbits, granule average, normalized by b1 at CFPA = 82.81 K

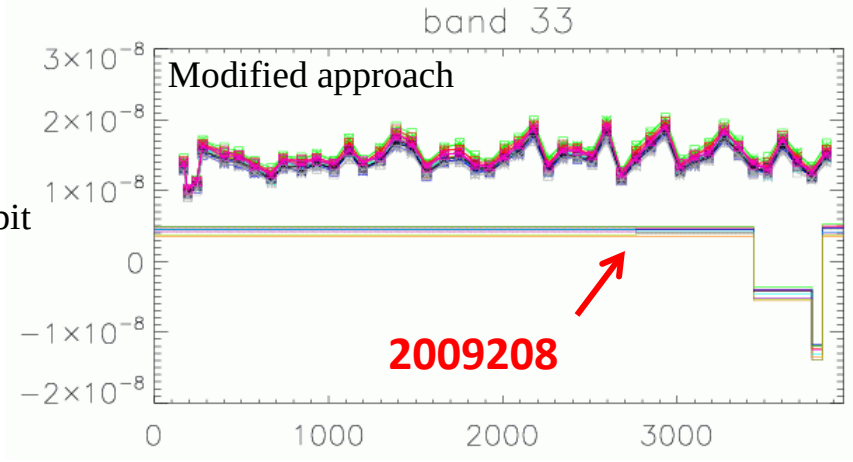
Aqua a2 modification
Reducing the fitting residuals

- In June 2012 MCST implemented a revised fitting approach for Aqua a2 to compensate for CFPA temperature fluctuations. (discussed at MsWG on 05/30/12 and 06/13/12).
  - Revised approach removes CFPA temperature effects from trending of Aqua a2
  - Largest impacts seen for PC bands (B31-36) – particularly B33
    - No impact on PV bands
  - Modified approach was applied as a forward update in C6 LUT delivered July 1, 2012 (6.1.17.1) - LUT history not modified

a2 Trending Band 33

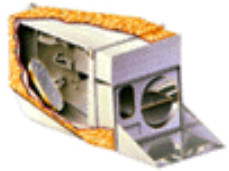


On-orbit LUT



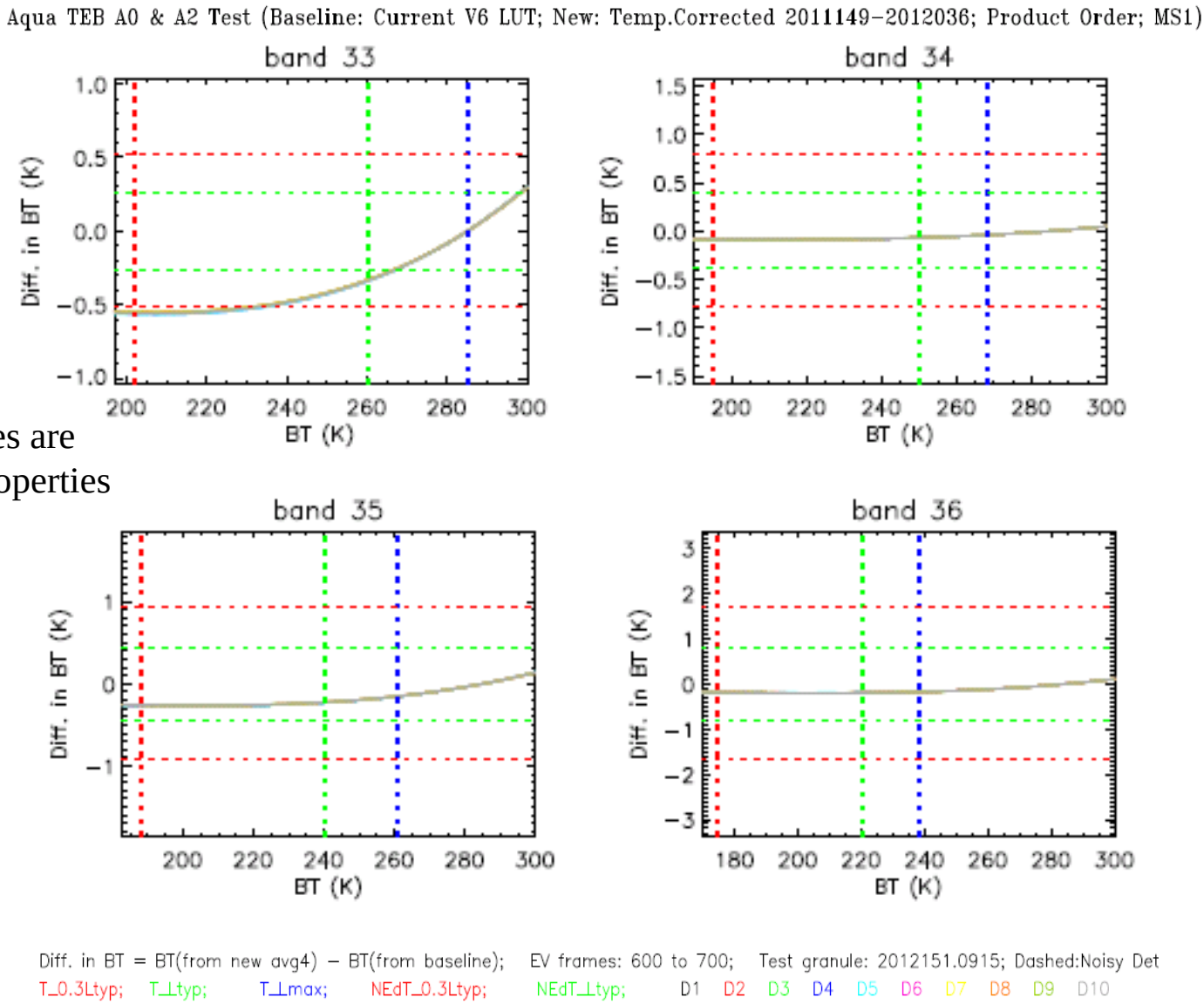
CFPA temperature impacts trends

Aqua a2 impact Assessment



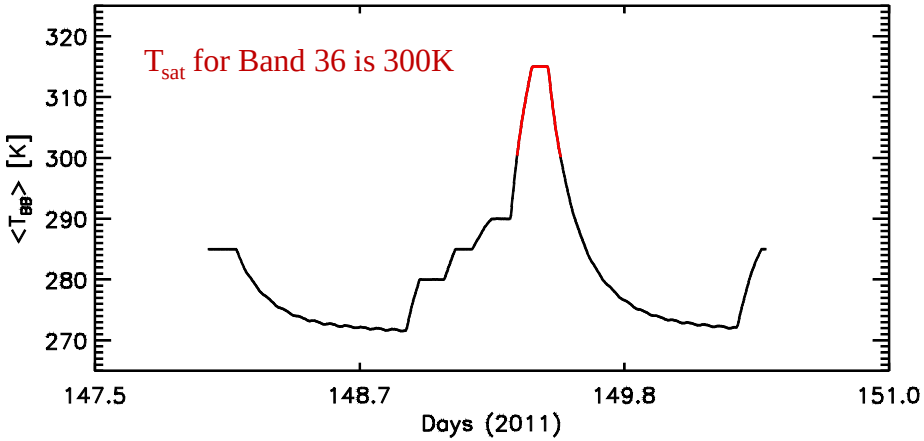
Impact

- Largest in B33
- 2nd largest in B35
- Different in each band
- Relative calibration changes are important in CO2 cloud properties algorithm

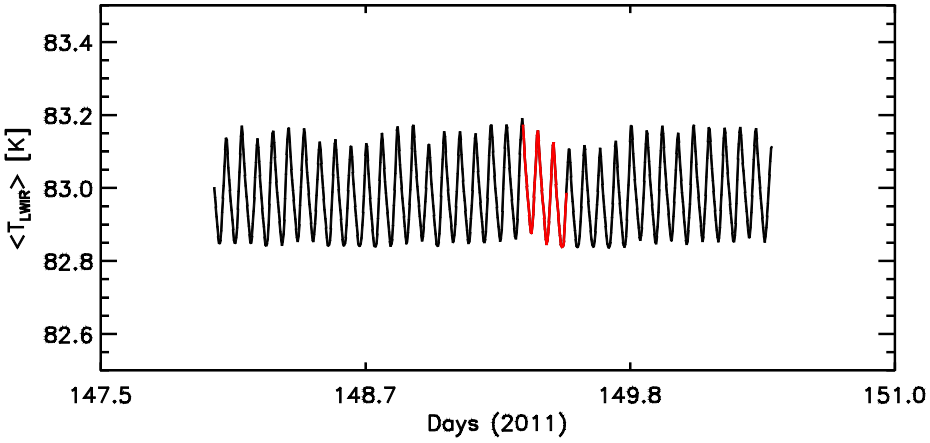


Aqua TEB: C6 default b1 example

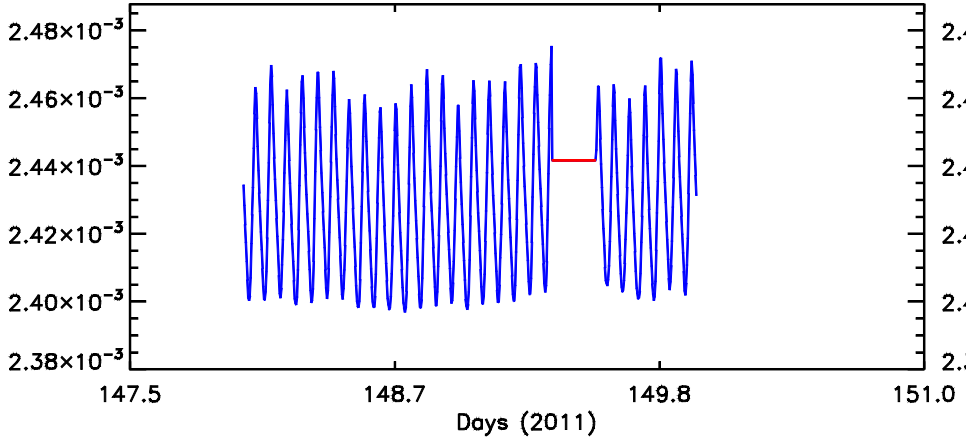
Black-Body Temperature



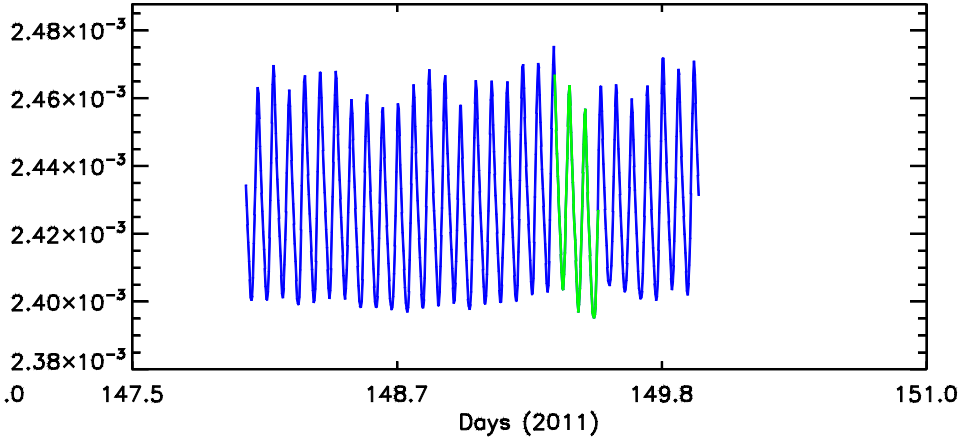
LWIR FPA Temperature



Band 36 b_1 for D1, M1; C5 L1B methodology



Band 36 b_1 for D1, M1; C6 default b1

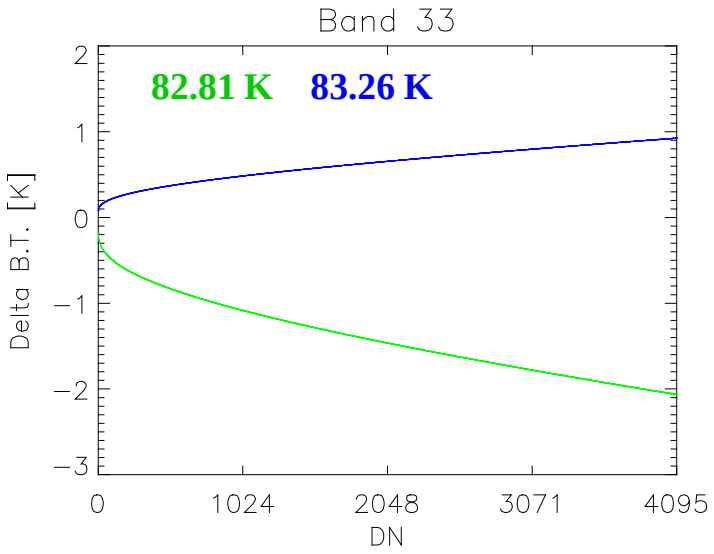


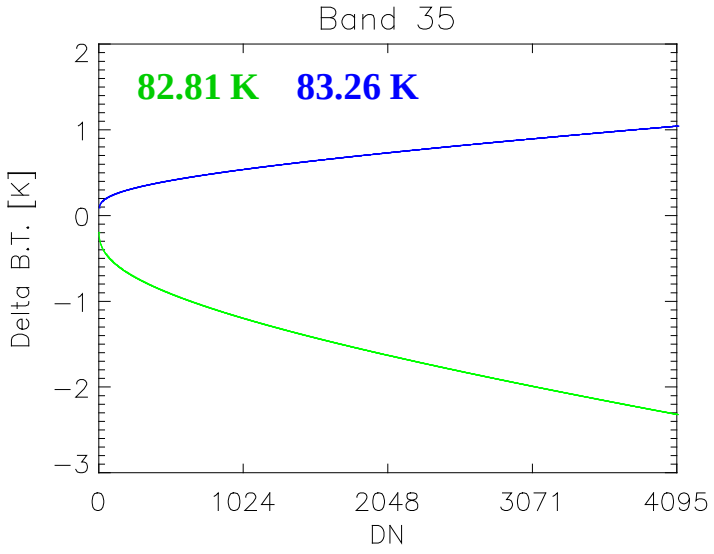
All Data shown are granule averaged

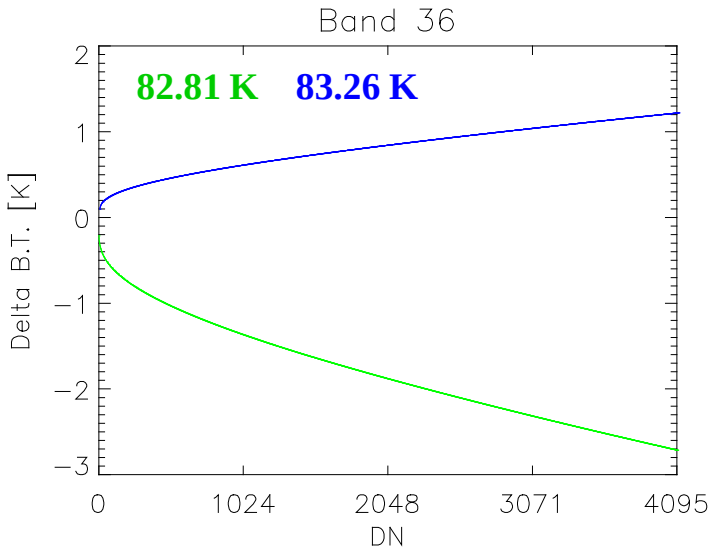
C6 default b1 impact assessment

Impact will vary depending on CFPA temperature, scene temperature and the value of the ‘current’ default b1.

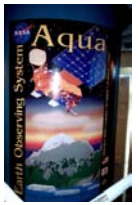
Example shown here indicates the range of difference expected for the 2011/149 WUCD activity.







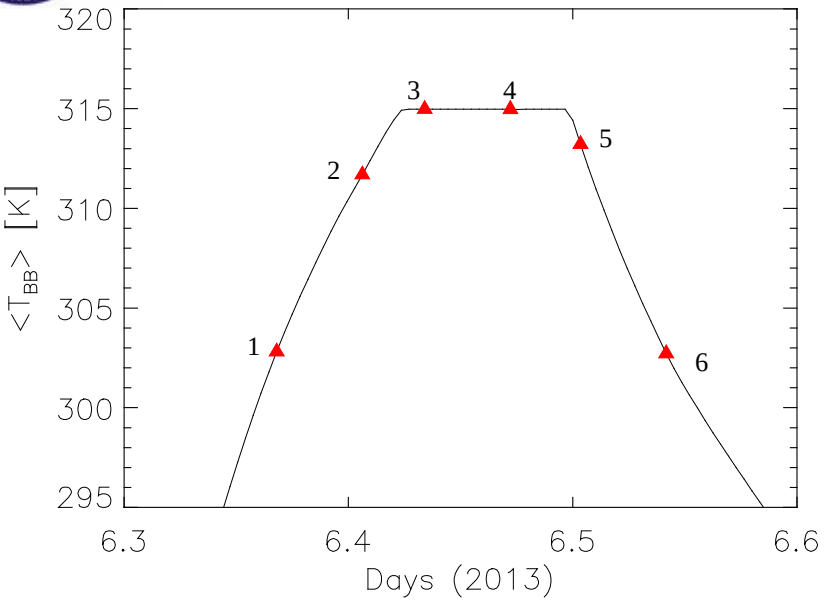
EV Saturation

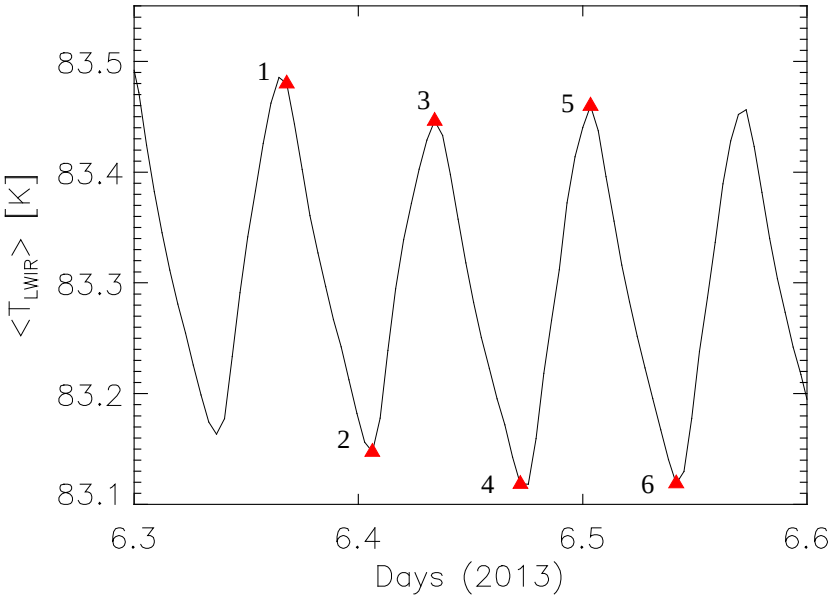


- During WUCD when the $T_{BB} > T_{sat}$ the DCR algorithm is effectively 'off' for bands 33, 35 & 36
  - $DN_{BB} = DN_{Ideal} = 4095$
- DN for all other sectors (e.g. Space View) will begin to oscillate with the CFPA temperature due to temperature dependent gain change of detectors.
  - FPA Temp ↑, Gain ↓, DN ↓ and vice versa
- EV sector will saturate periodically when DN_{SV} is high enough that the additional signal from EV saturates at 4095 during the $T_{BB} > T_{sat}$ scans
- No fix possible at L1B level and length of periods with saturated EV will continue to increase in future.
  - At most 5-6 hours of data lost every 3 months.

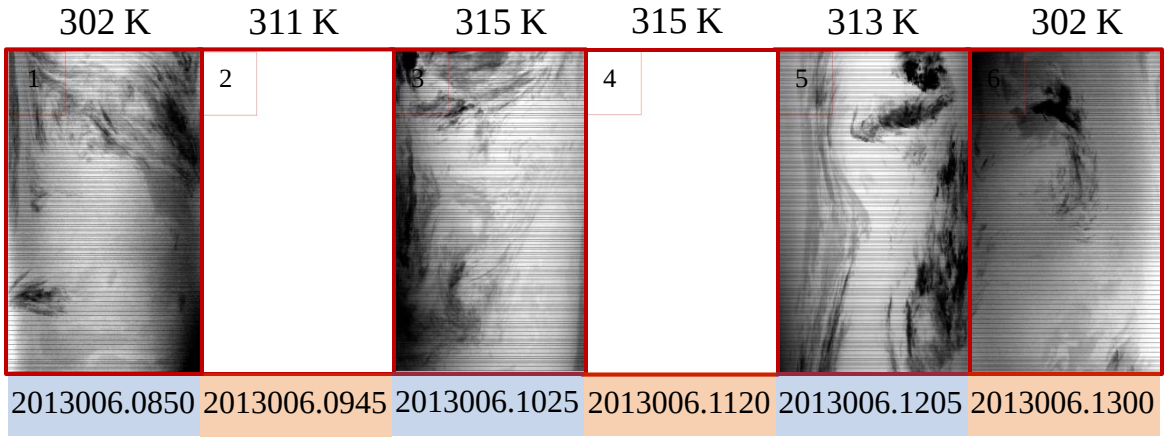
Saturation Example: Band 36

T_{sat} is conservatively determined to be 301 K





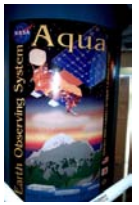
C6 L1B Imagery



LWIR Temp.

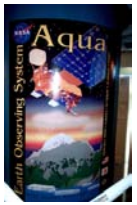
83.48 K **83.16 K** **83.45 K** **83.12 K** **83.46 K** **83.12 K**

Mitigation Strategies



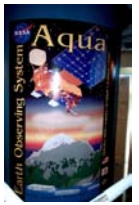
- Scan-by-scan calibration captures much of the impact of the CFPA variation.
  - CFPA temperature dependent default b1 algorithm implemented in C6
- Options under consideration to address temperature fluctuations
  1. No change – continue operations in current configuration
  2. Reduce frequency of WUCD activities
     - Optional: Flag or do not use B33, 35 & 36 data when $T_{BB} > T_{sat}$
  3. Change CFPA set point to 85K
  4. Perform Outgas
  5. Modify DCR table for bands 33, 35 & 36

IOT Procedures



- IOT is prepared & ready to implement the agreed upon solution
- For any option involving an operational change the process going forward is identical
  - Command Authorization Meeting (CAM) at the FOT, approval from at least Mission Director, Flight Systems Manager, Instruments Engineer
  - Contact request for commanding
  - Ground Ops prepared and cleared

Option 3 – Change CFPA Set Point to 85K



- S/C needs to be in “nominal mode” for this activity
- Ensure that CFPA heater B is in the ON state
- Send the following commands:

  SET_RC_CFPA_TEMP TO 1/2/3

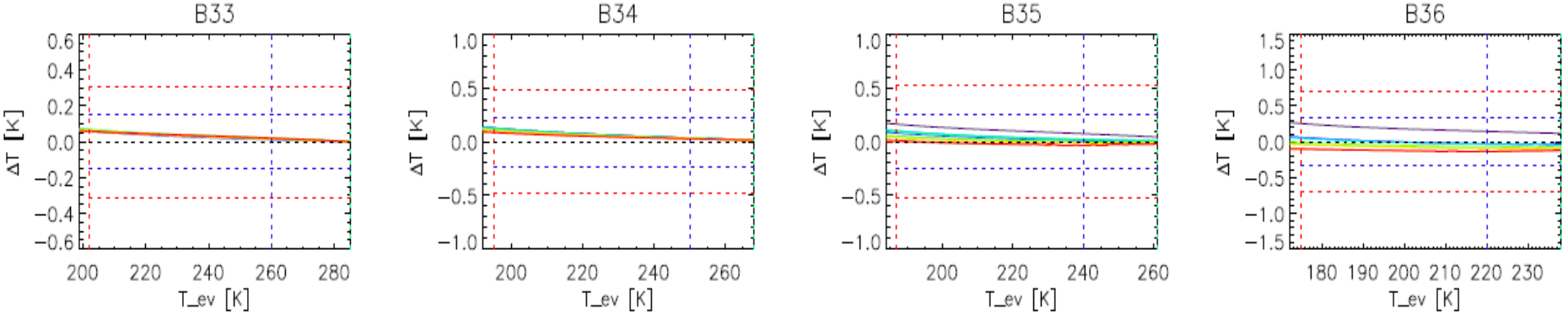
  MOD_SET_PM_RC_CFPA_TEMP(‘T2’)
- Monitor telemetry to ensure that the CFPA temperature adjusts accordingly (real time until it stabilizes)

- Concerns:
  - Majority of pre-launch LUT tables based on 83 K set point
  - DCR table for 85 K
  - Decreased radiometric resolution for TEB
  - Increased detector noise
- Advantages:
  - Gain stably controlled
  - EV saturation during WUCD removed
  - Increase in dynamic range for TEB

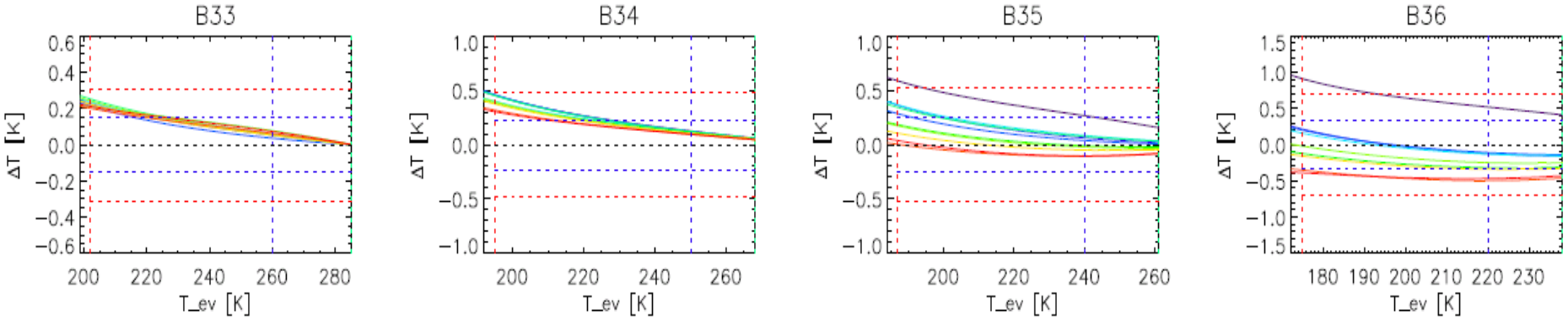
Calibration Impact Assessment

Impact due to a0, a2

Estimated B.T. difference with P. L. a0, a2 assuming the CFPA temperature of 83.6K

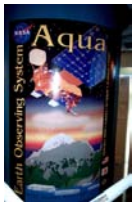


Estimated B.T. difference with P. L. a0, a2 assuming the CFPA temperature of 85 K



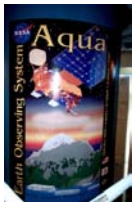
CAVEATs: 1. Estimation is based on limited P.L. data, 2. Higher error bar on P.L.

Option 4 - Outgas



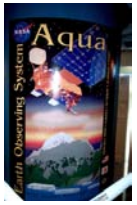
- An outgas without an anomaly requires transitioning MODIS from science mode to standby mode and then to outgas mode
  - Doors are closed, except SV door is moved to outgas position
  - This operation/action may require approval from HQ
- An outgas requires a set of commands and takes 2-3 days to complete (heaters are turned on in specific sequence)
  - CFPA will be back to ambient temperature during outgas operation
- Potential impact on SWIR (band 6 in particular) detector operability
- As a contingency for the AMSR-E recovery, IOT prepared for and has approval to perform an outgas in the event of spacecraft safe mode.

Option 5 – Modify DCR Table



- CFPA setpoint remains at 83 K
- DCR table for bands 33, 35 & 36 modified and uploaded
- Expected to reduce EV saturation during WUCD
- Can be performed by IOT as a regular table upload to MODIS.

Summary

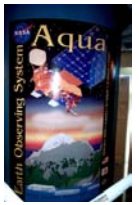


- Aqua MODIS continues to operate nominally
  - A decrease in radiative cooler margin has been observed since ~2007.
  - CFPA temperature not able to be stably controlled at set point of 83 K
    - Orbital and seasonal variations observed
  - Scan-by-scan calibration captures much of the impact of the CFPA variation
  - Collection 6 includes an improved default b1 algorithm and temperature correction to the a0/a2 analysis.

- EV saturation for bands 33, 35 & 36 during WUCD activities has increased.

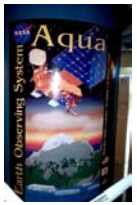
- MCST continues monitoring of CFPA performance and is prepared to implement any of the proposed mitigation strategies in the event of increasing adverse impacts on science data products

Related Documentation



- Z. Wang, S. Madhavan, X. Xiong, A. Wu, and B. N. Wenny, "Monitoring and assessment of the temperature fluctuation of Aqua MODIS cold focal plane assembly", *Proceedings of SPIE- Earth Observing Systems XVII*, vol. 8510, issue 85100K, 2012.
- B. N. Wenny, A. Wu, S. Madhavan, Z. Wang, Y. Li, N. Chen, V. Chiang, and X. Xiong, "MODIS TEB calibration approach in collection 6", *Proc. SPIE 8533, Sensors, Systems, and Next-Generation Satellites XVI, 85331M*, 2012.

Discussion



- Issues
- Actions
- Recommendations