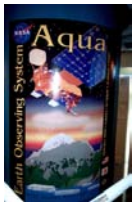
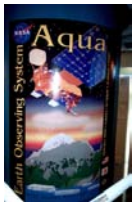


Aqua MODIS Cold FPA Performance and Operation

MODIS Characterization Support Team (MCST)

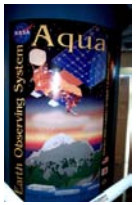
April 25, 2012

Outline



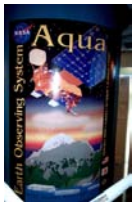
- Prior Meeting Summary
- TEB Introduction
- Updates on Aqua MODIS performance
  - Key instrument telemetry
  - TEB performance
- Observed impacts
- Mitigation Strategies

Prior Meeting Summary



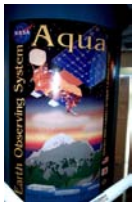
- MCST held previous workshop in May 7, 2010
  - Meeting was held to review the Aqua MODIS CFPA on-orbit performance, provide its possible implications on the L1B product, and give scenarios to stabilize the CFPA operating point.
- Aqua MODIS slow loss of cooler margin causing an increase and periodic variations (orbital & seasonal) of CFPA temperatures (up to 0.2K)
- Impacts observed
  - Orbital variation in TEB detector gain
    - Captured predominantly by the scan-by-scan calibration
    - Linear relationship between CFPA Temp and TEB detector gain
    - PC bands more sensitive to CFPA temperatures
  - Increased fitting residuals from BB WUCD during a0/a2 derivation

Current Status



- MCST has continued to monitor telemetry and TEB performance
  - CFPA temperature continues to increase
  - CFPA orbital/seasonal oscillation grown larger – max/min difference of ~0.5 K
  - Radiative cooler margin almost entirely lost.
- Majority of impacts on L1B products occur during BB Warmup/Cooldown activities

TEB Calibration Requirements



Band	CW	Ttyp	NEdT	UC (%)	UC (K)
20	3.75	300	0.05	0.75	0.18
21	3.96	335	0.20	1	0.31
22	3.96	300	0.07	1	0.25
23	4.05	300	0.07	1	0.25
24	4.47	250	0.25	1	0.19
25	4.52	275	0.25	1	0.24
27	6.72	240	0.25	1	0.27
28	7.33	250	0.25	1	0.32
29	8.55	300	0.05	1	0.53
30	9.73	250	0.25	1	0.42
31	11.03	300	0.05	0.5	0.34
32	12.02	300	0.05	0.5	0.37
33	13.34	260	0.25	1	0.62
34	13.64	250	0.25	1	0.59
35	13.94	240	0.25	1	0.55
36	14.24	220	0.35	1	0.47

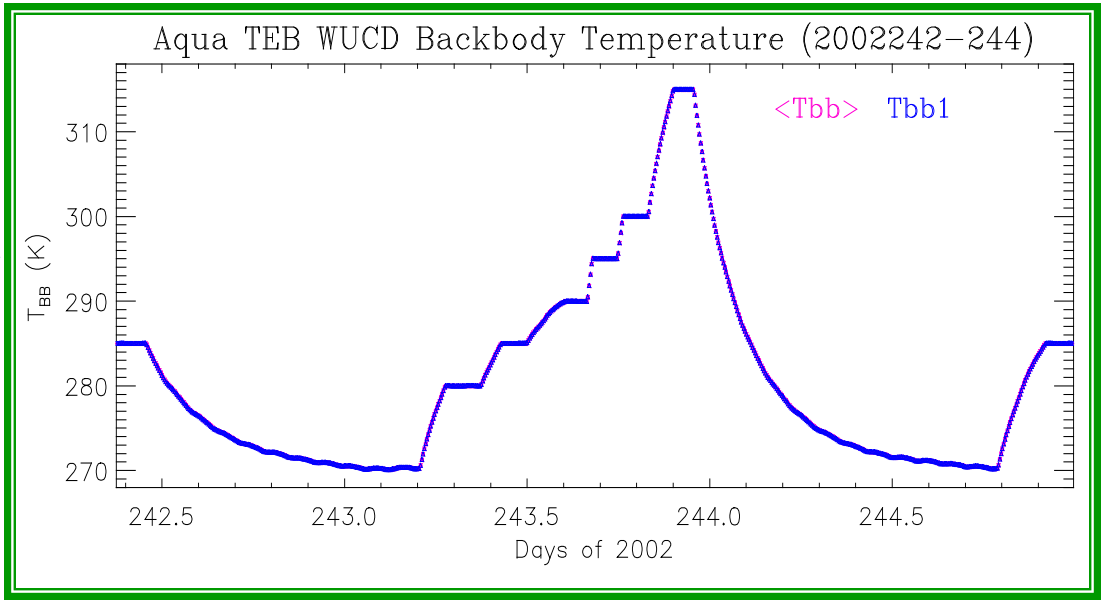
CW: center wavelength in μm;
Ttyp: typical scene temperature in K;
NEdT: noise equivalent temperature difference in K;
UC: uncertainty in percentage (radiance) and in K

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:

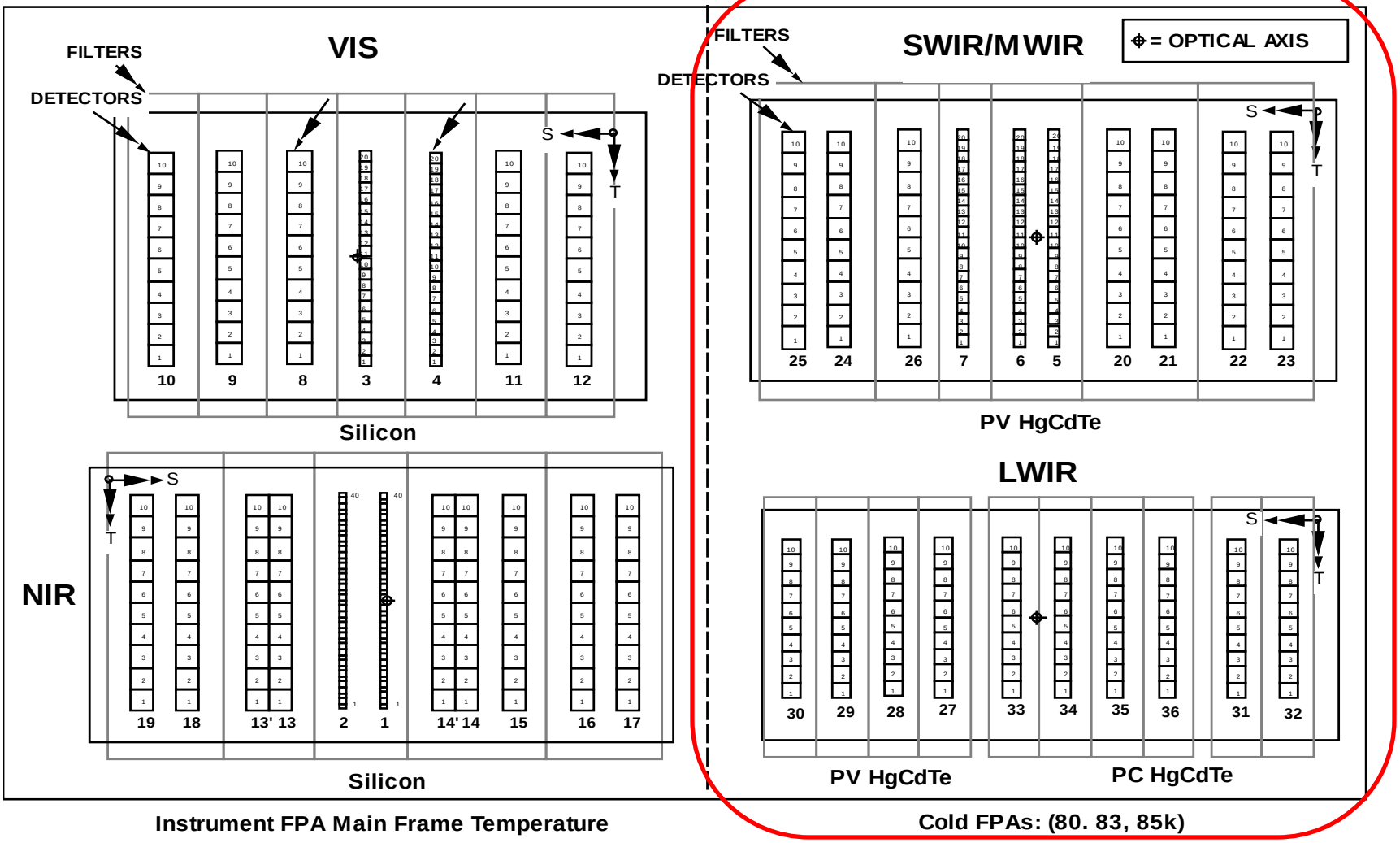
$$b_1 = \left(RVS_{BB} \cdot \varepsilon_{BB} \cdot L_{BB} + \left(RVS_{SV} - RVS_{BB}\right) \cdot L_{SM} + RVS_{BB} \cdot \left(1 - \varepsilon_{BB}\right) \cdot \varepsilon_{cav} \cdot L_{cav} - a_0 - a_2 \cdot dn_{BB}^2\right) / dn_{BB}$$



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

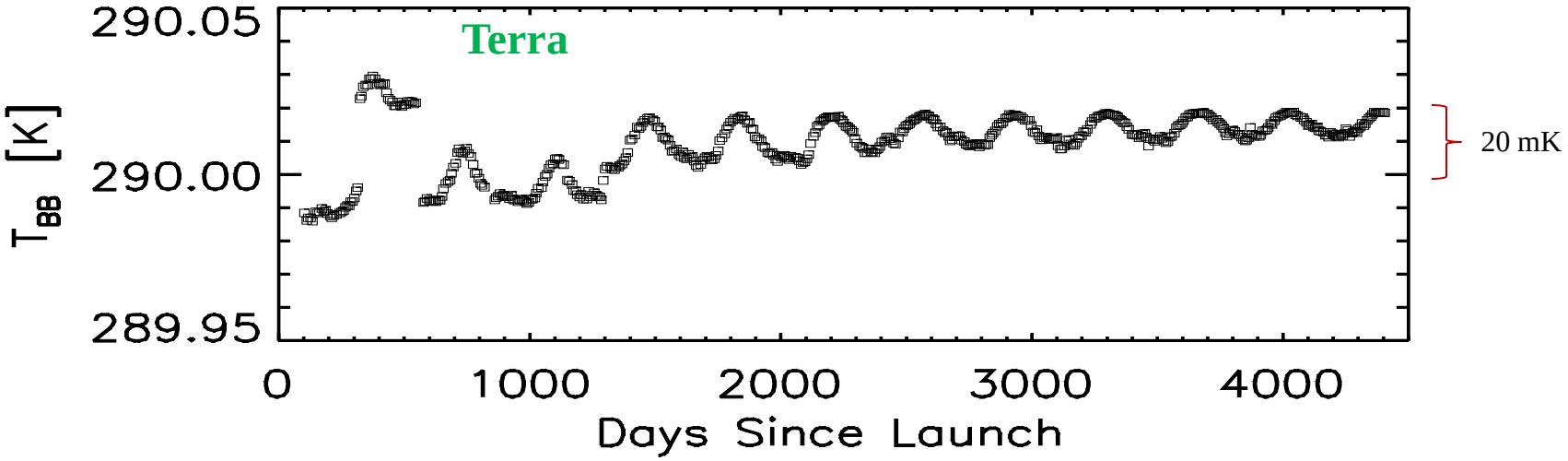
MODIS Focal Plane Assemblies (FPA)

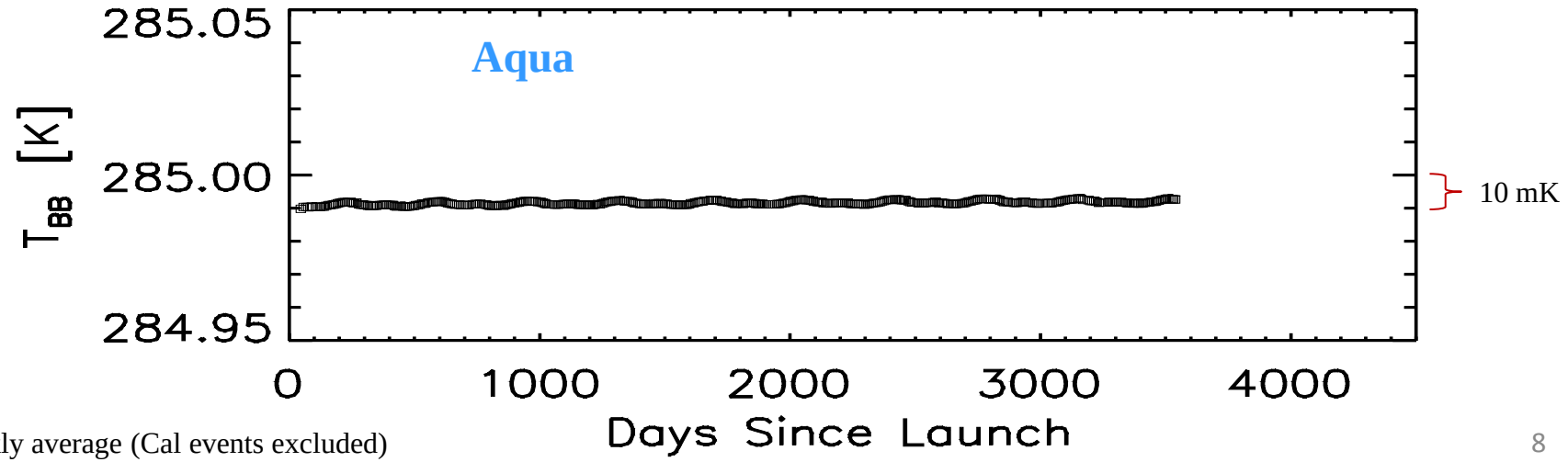


Warm FPA: VIS and NIR;

Cold FPA: SMIR and LWIR

BB Temp Trends



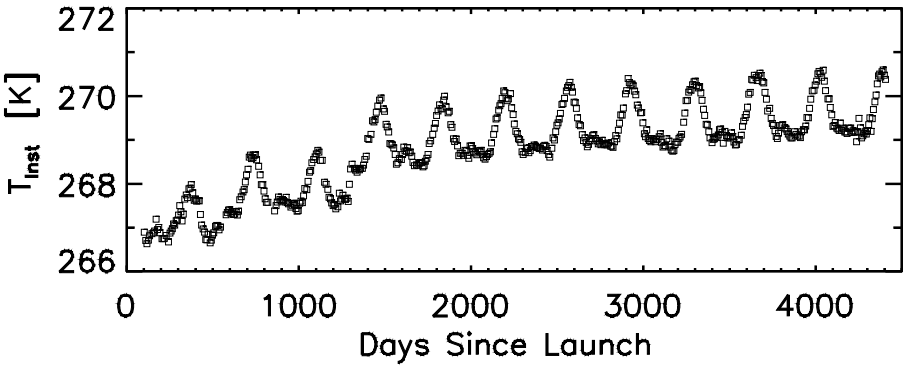


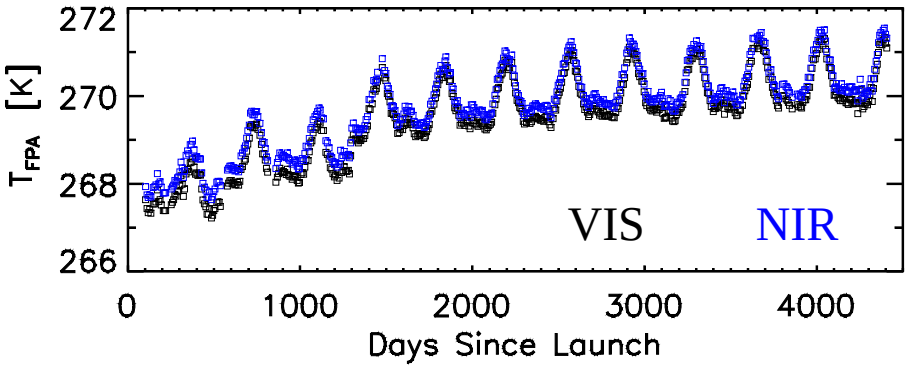
Weekly average (Cal events excluded)

Instrument & Warm FPA Temperatures

Terra

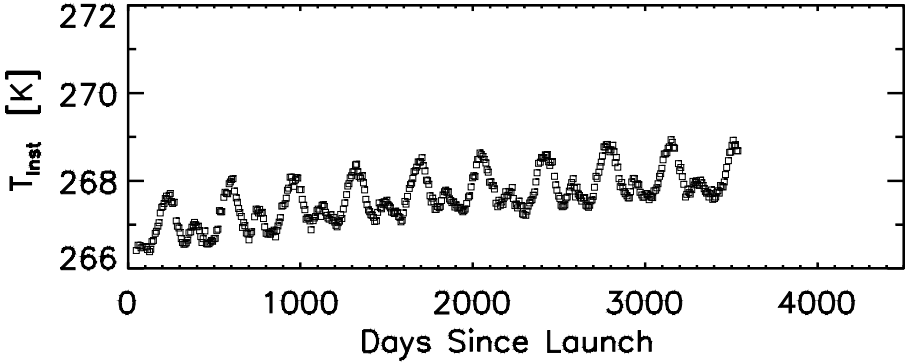
~3.5K increase over 11+ years

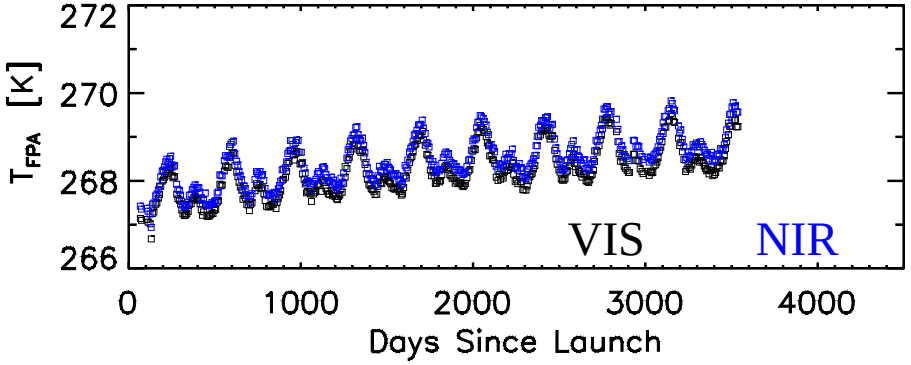




Aqua

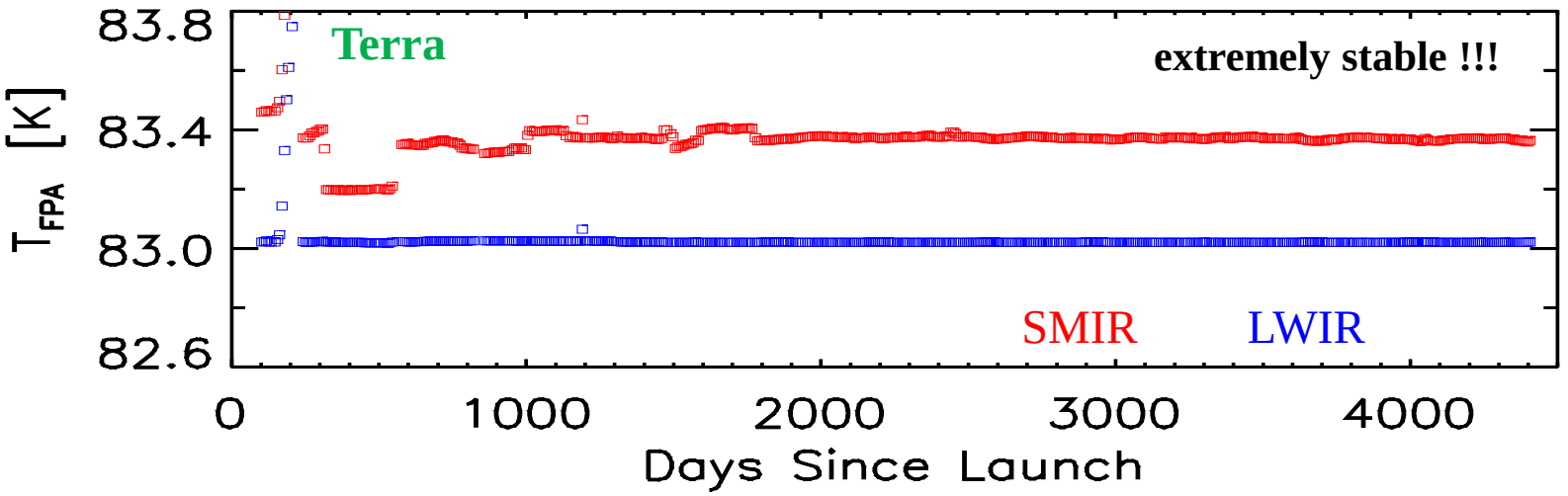
~2K increase over 9+ years

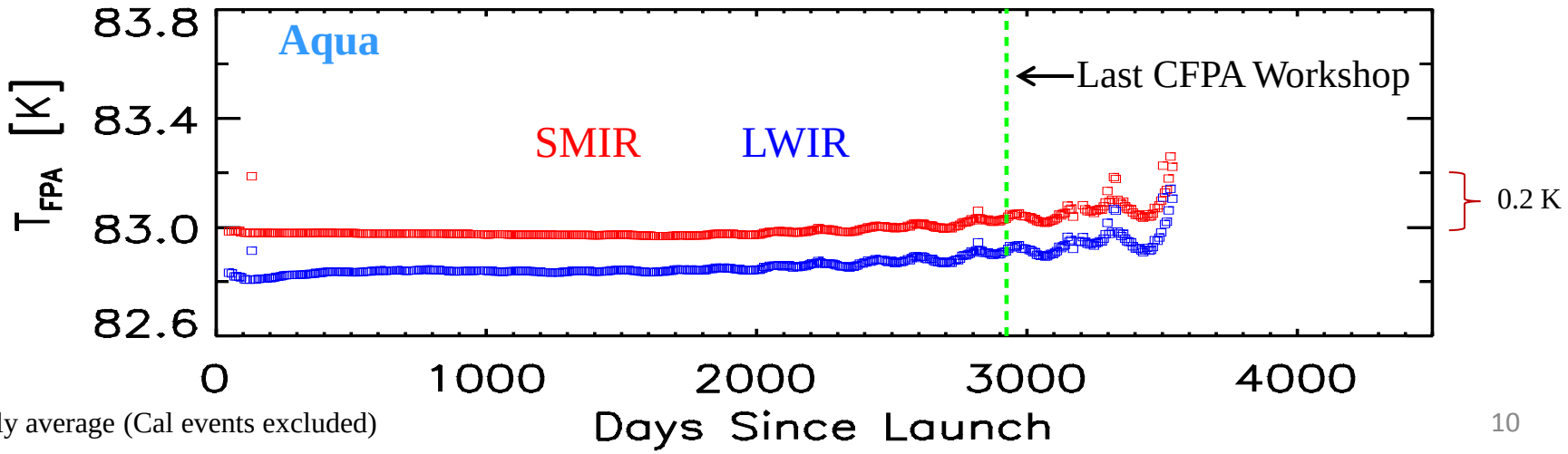




Weekly average (Cal events excluded)

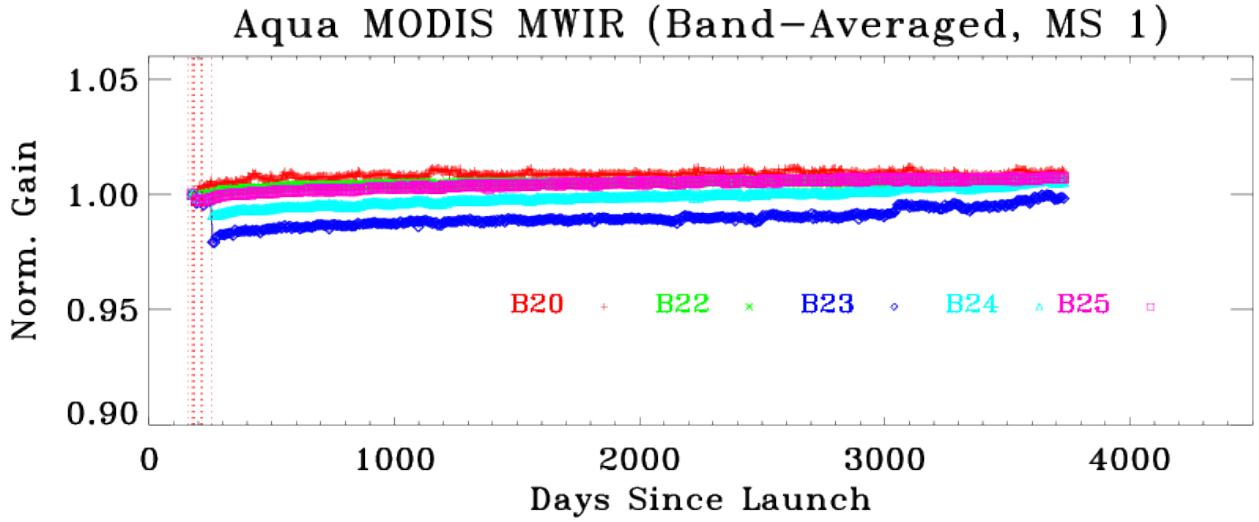
Cold FPA Temperatures

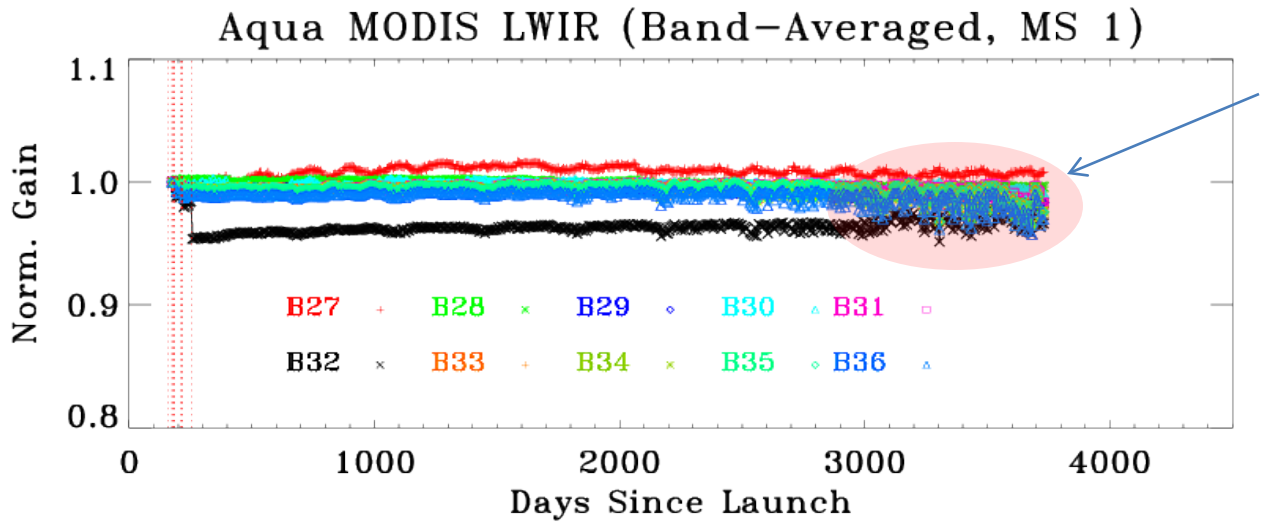




Weekly average (Cal events excluded)

TEB Gain Response



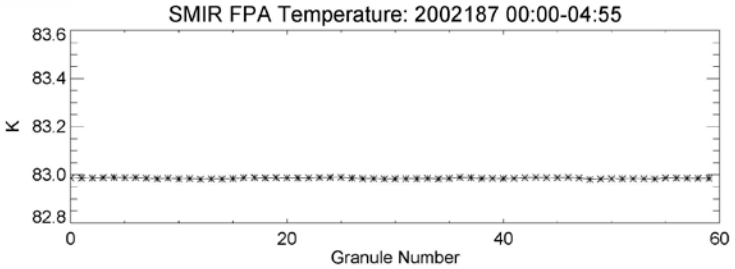


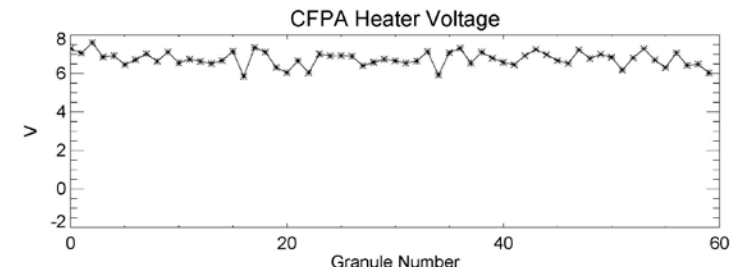
PC Bands showing increased variation in b1

1 randomly selected granule per week (good detectors)

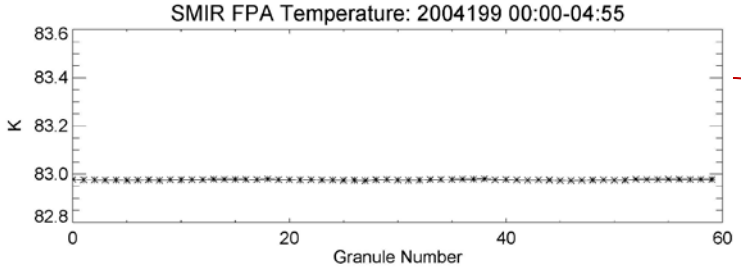
Aqua CFPA Heater Voltage

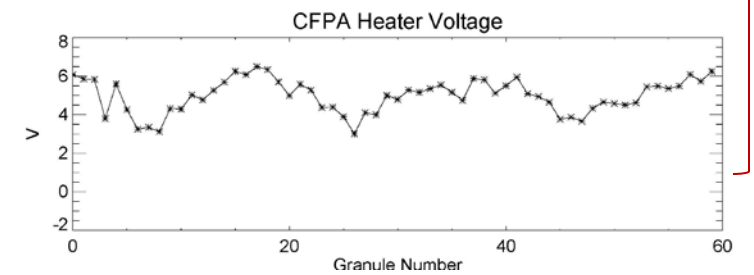
2002



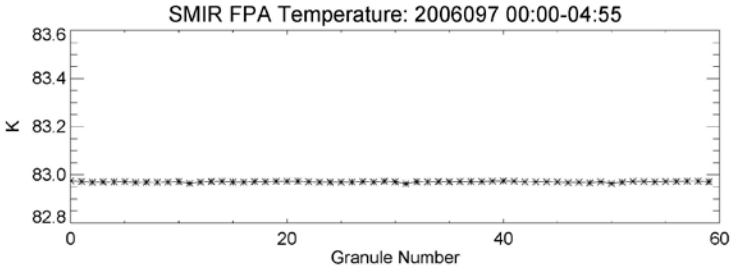


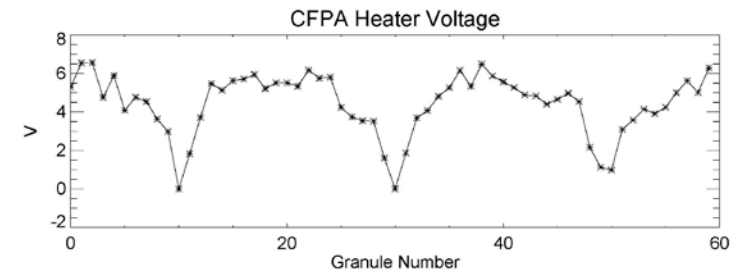
2004



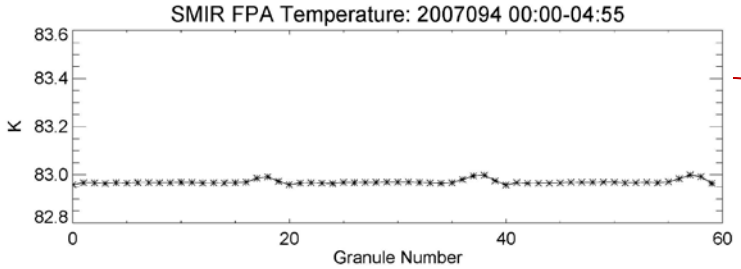


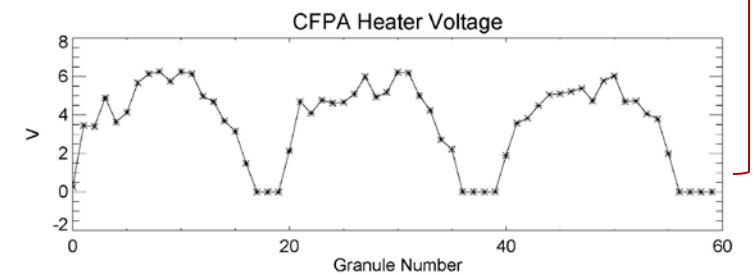
2006





2007

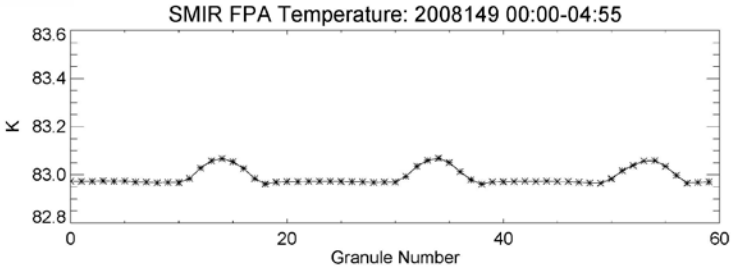


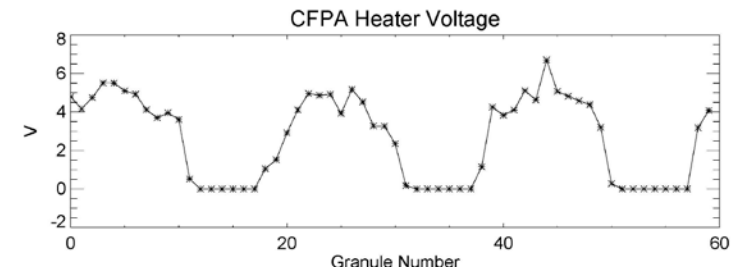


Granule average

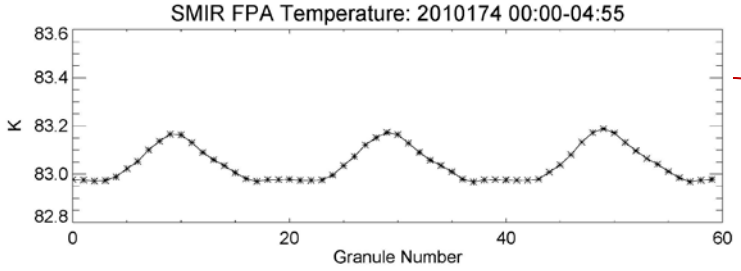
Aqua CFPA Heater Voltage

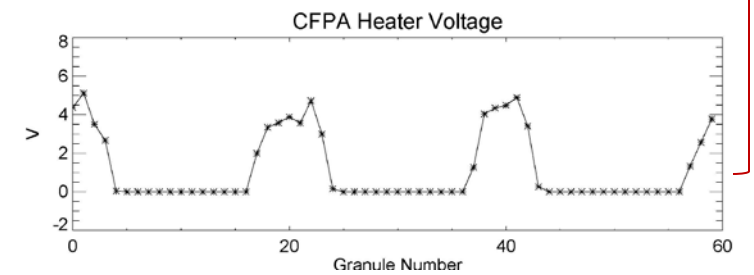
2008



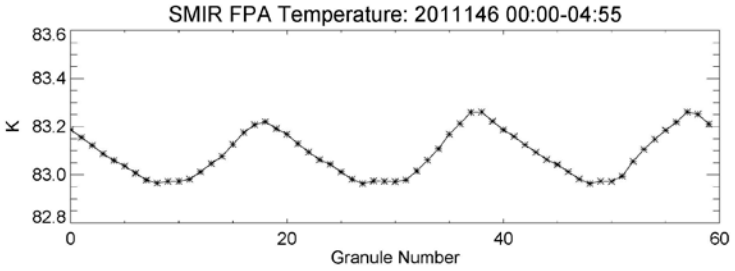


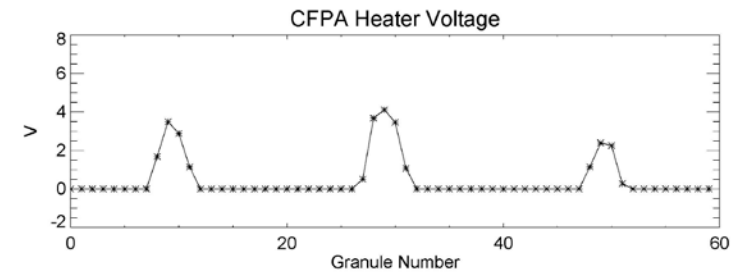
2010



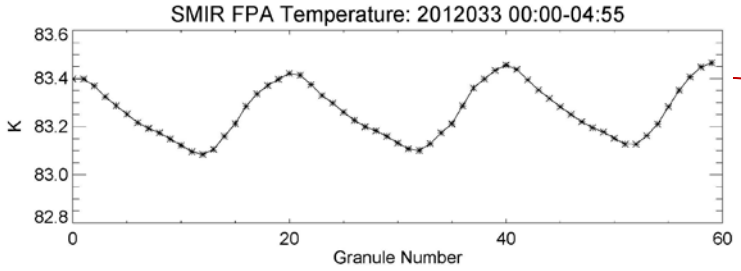


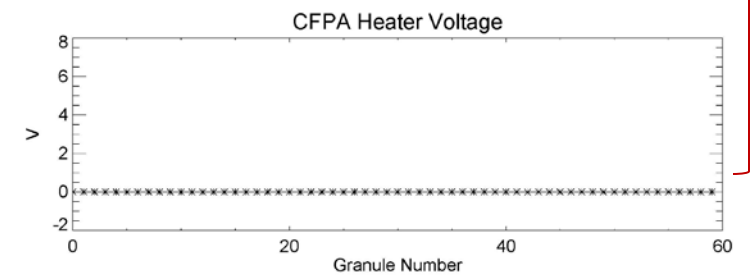
2011





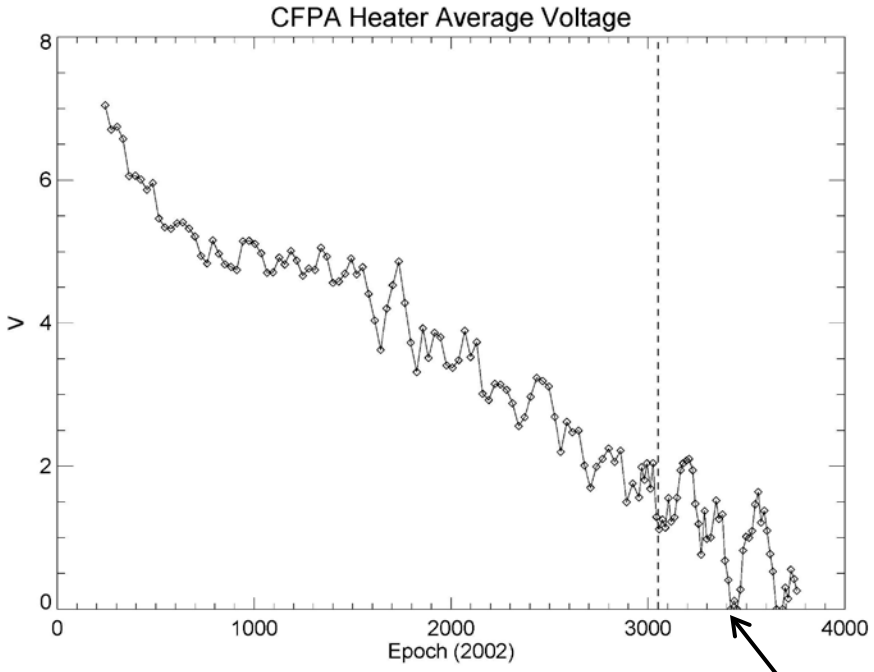
2012

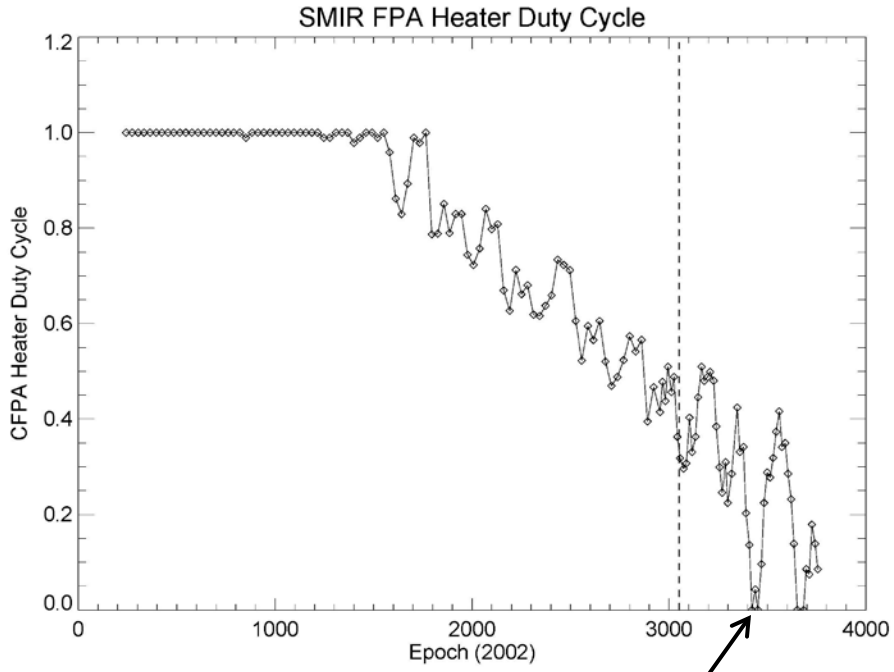




Granule average

Heater Voltage & Duty Cycle

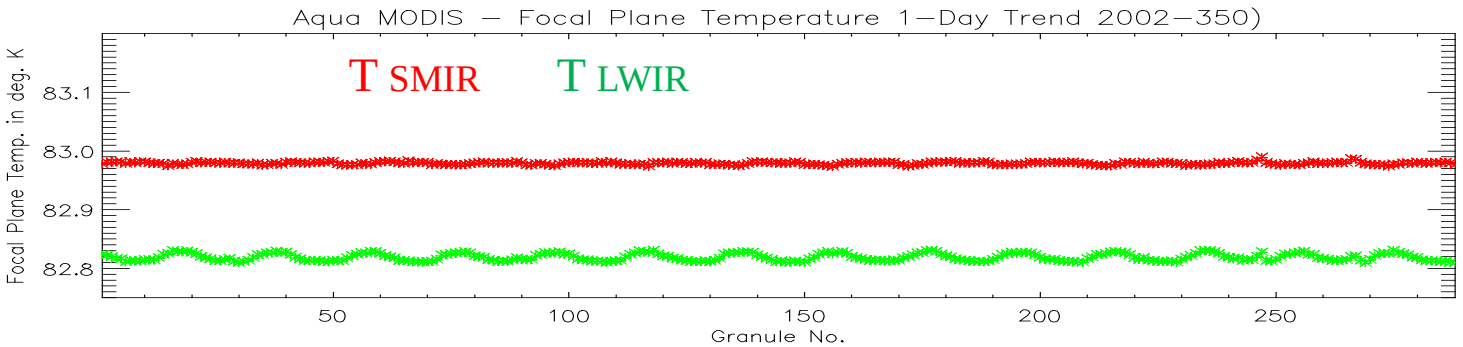


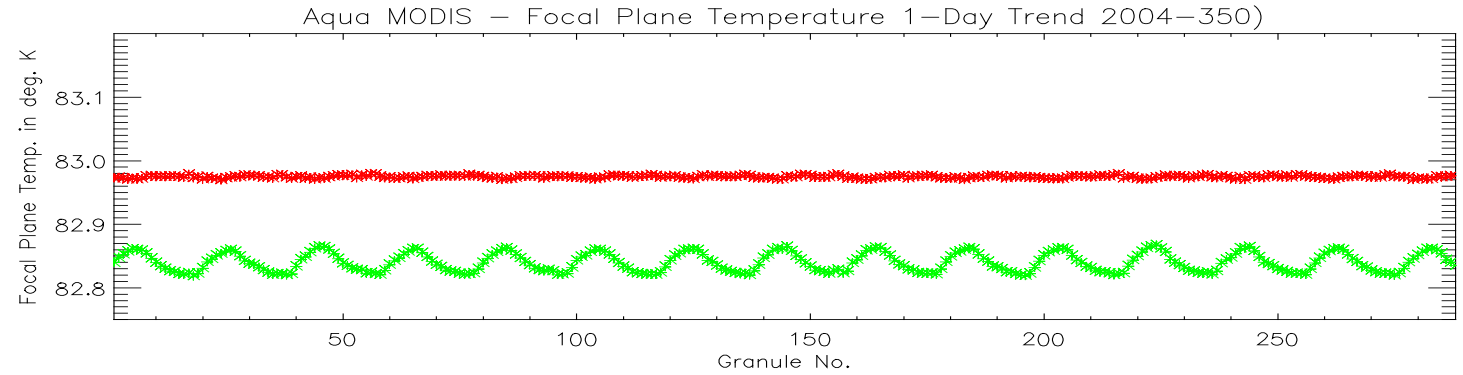


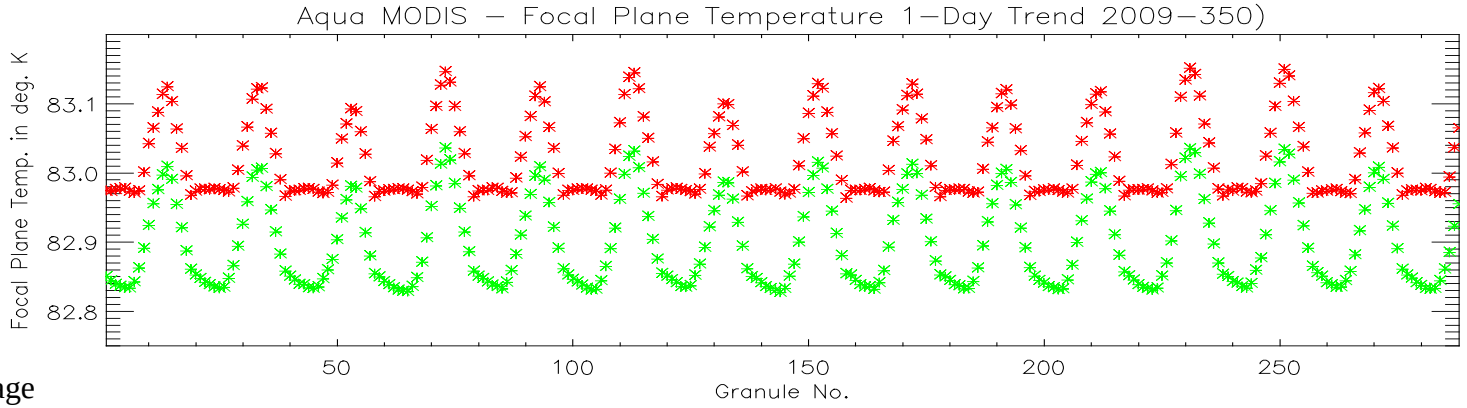
Indicates complete loss in control

1 orbit average

Aqua CFPA Oscillations
Short Term (1day) trend

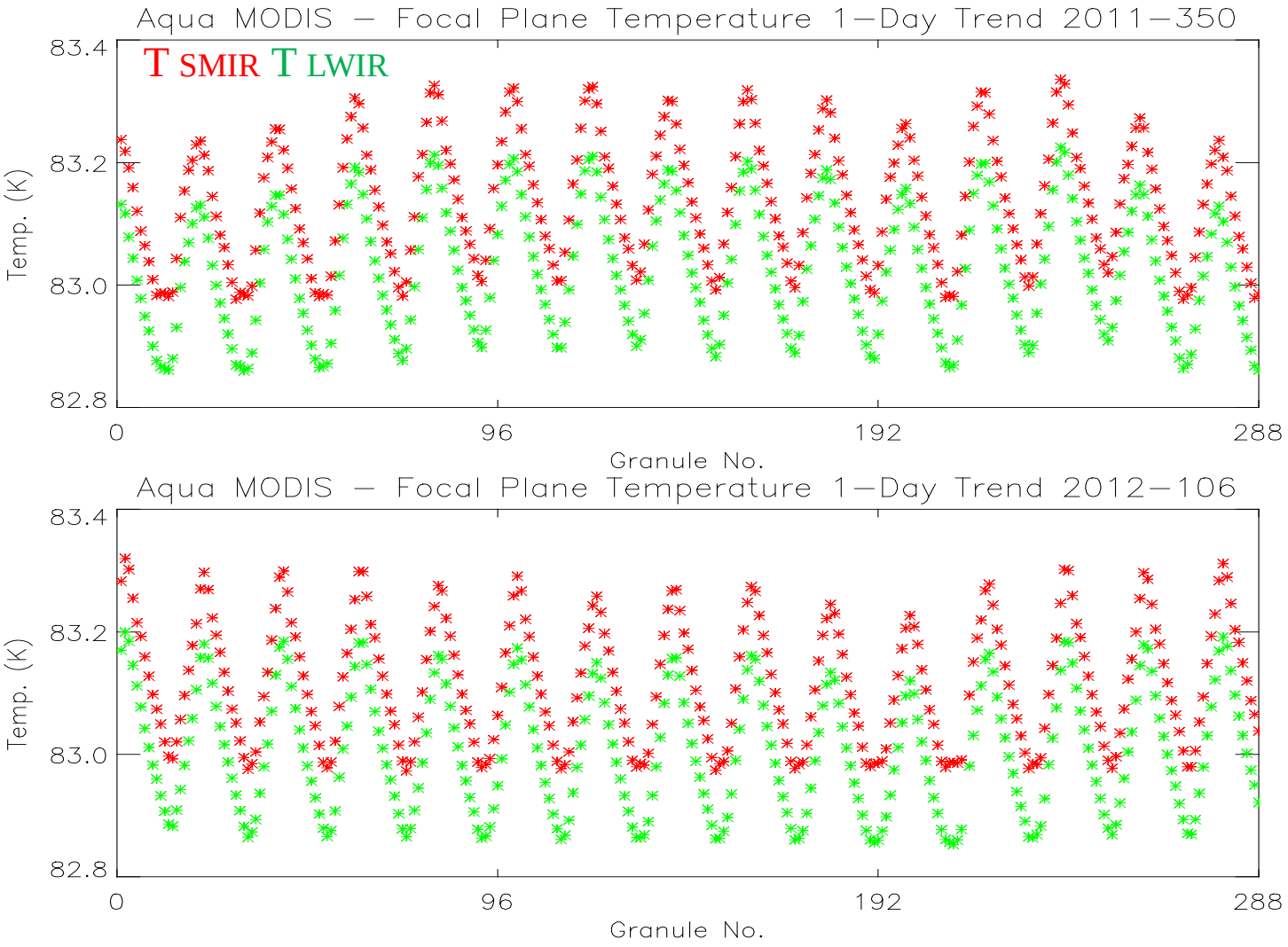






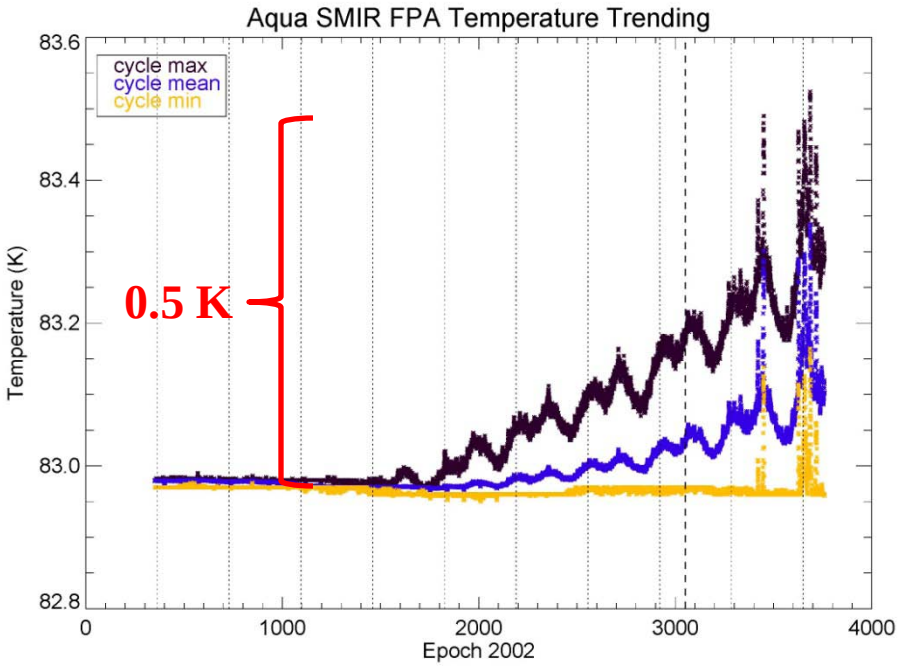
Granule average

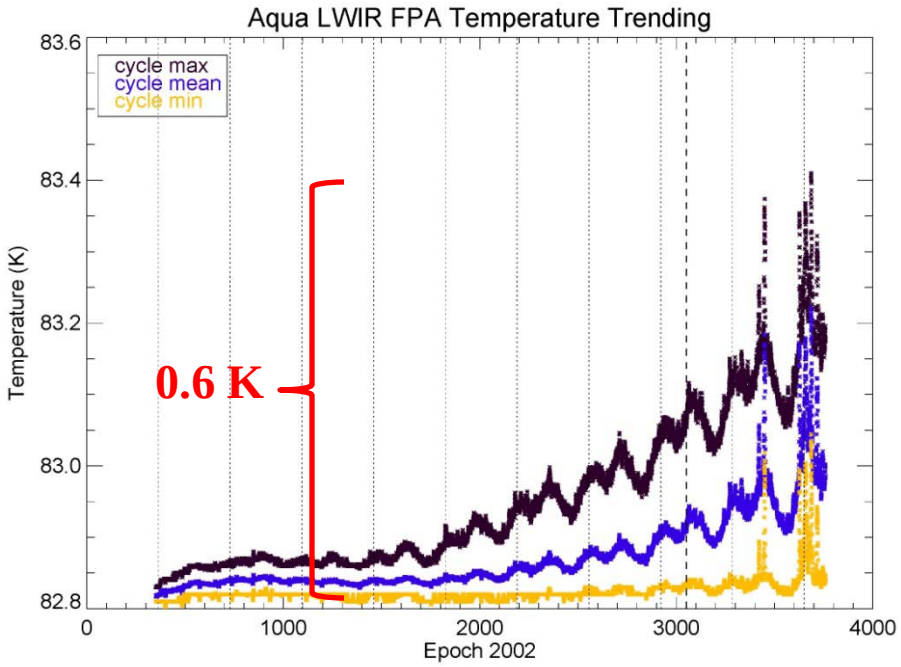
Aqua CFPA Oscillations
Short Term (1day) trend



Granule average

Aqua CFPA Oscillations
Long-term trend

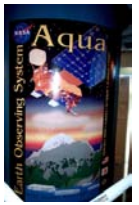




Solid vertical lines indicate calendar years, dashed vertical line time of last CFPA workshop.

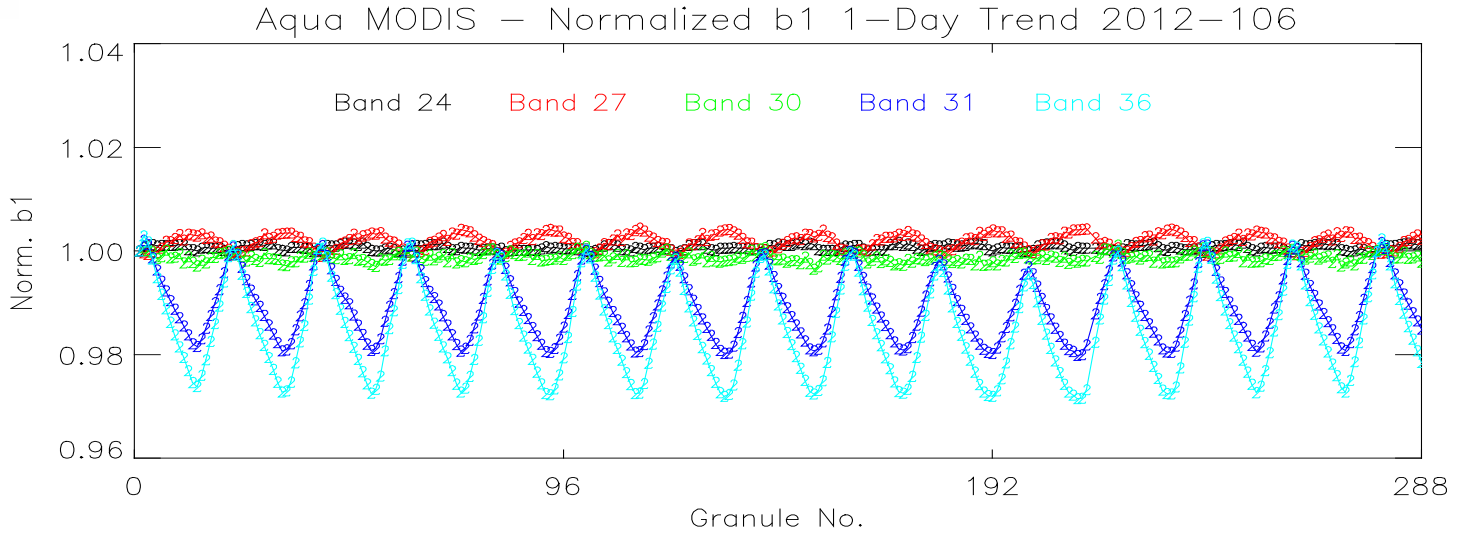
Max/Min of 4 orbits, every 8 hours

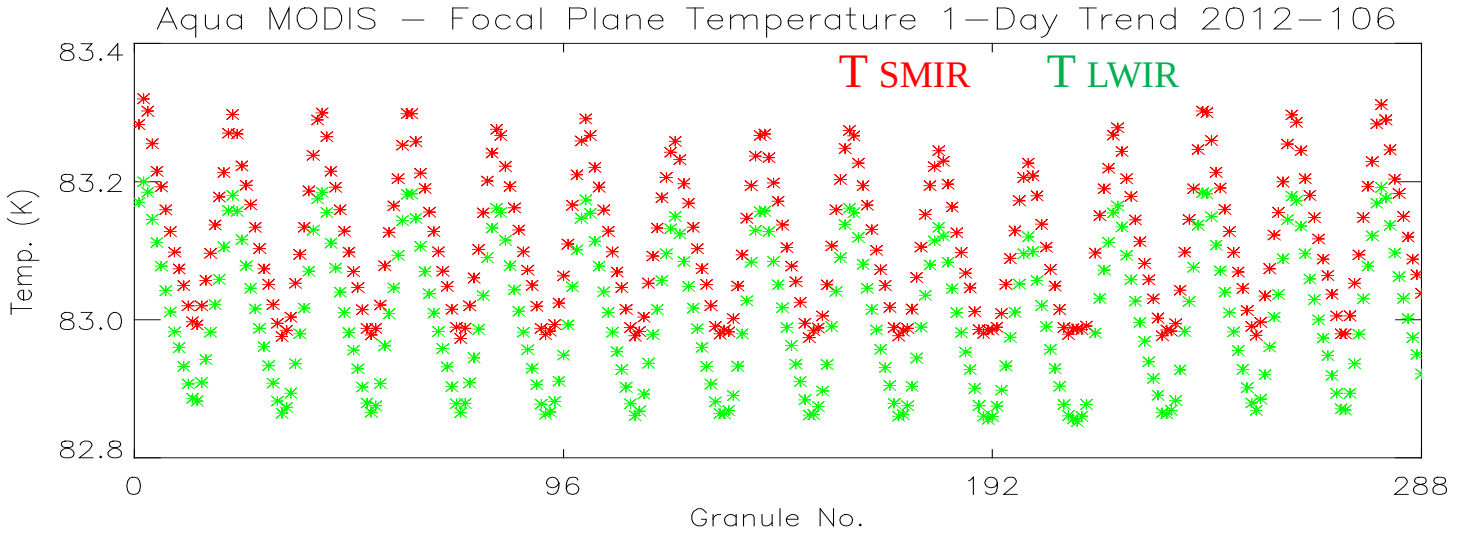
Observed Impacts



- 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)
  - Bands 33, 35 & 36 T_{BB} Saturation
    - FPA temperature dependent default b1 algorithm implemented for C6
    - Increased instances of EV saturation
- Band 27 – Temperature dependent filter bandpass shift
  - Not included in discussion here

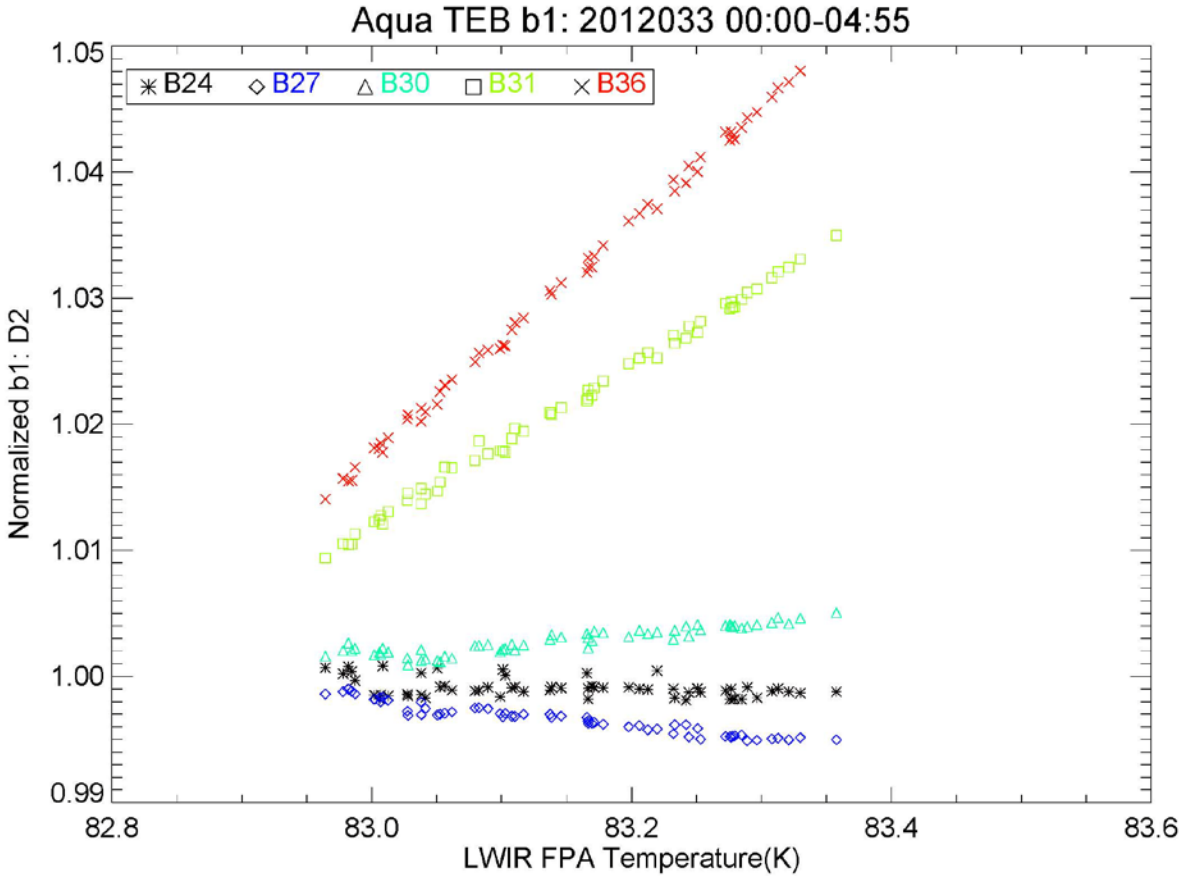
Gain variation with CFPA Temperature





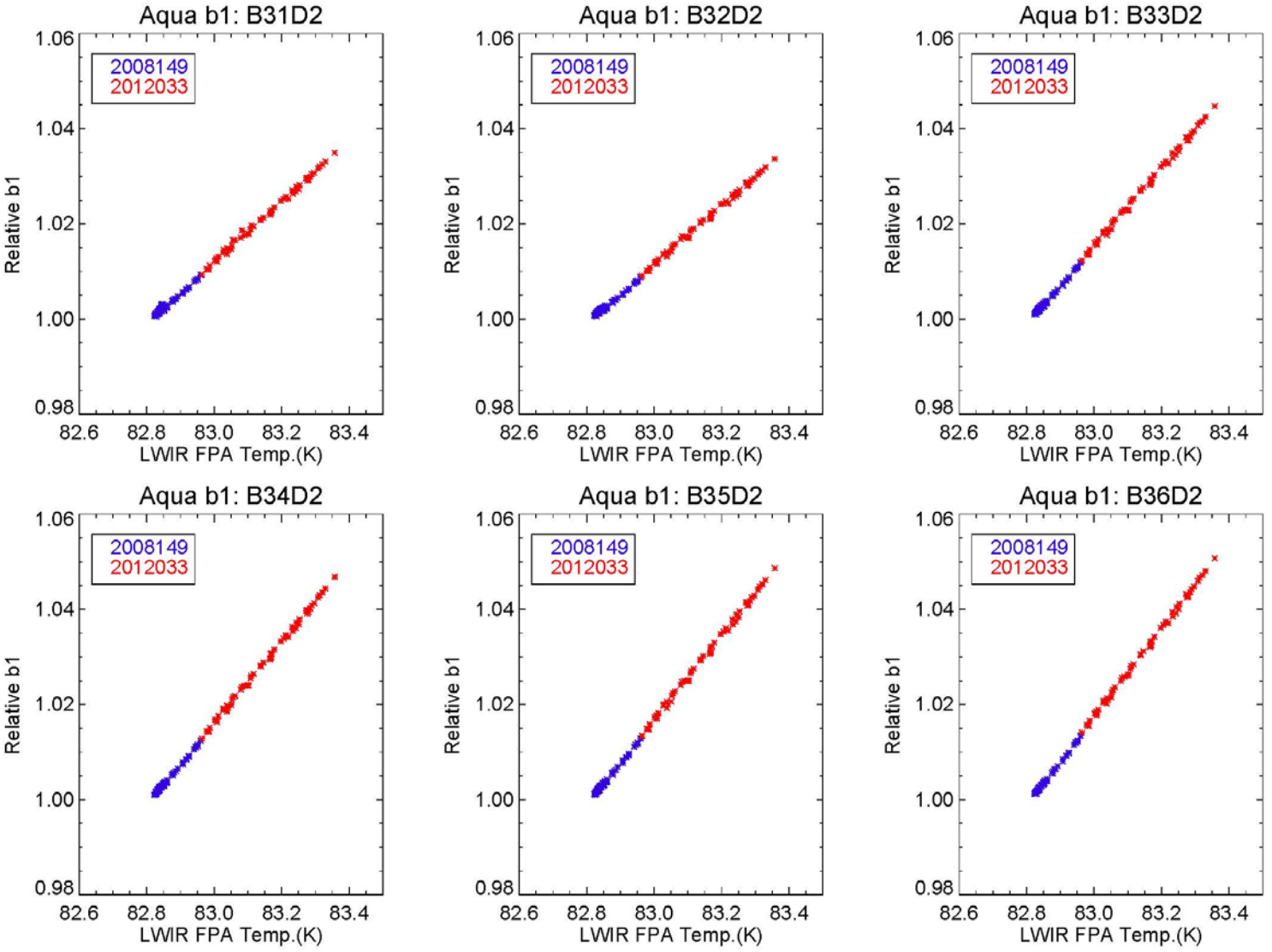
Granule average, top plot: detector 2 for each band

b1 vs CFPA Temp



3 orbits, granule average, detector 2 for each band, normalized by b1 at CFPA = 82.8 K

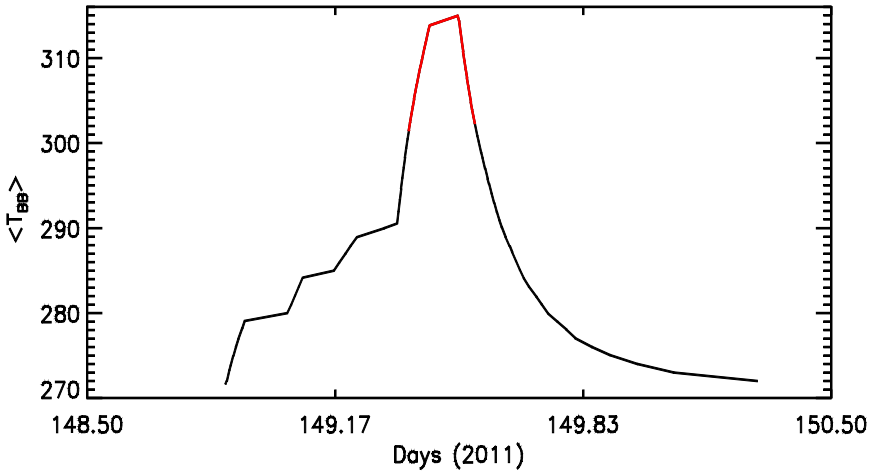
b1 vs CFPA Temp



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

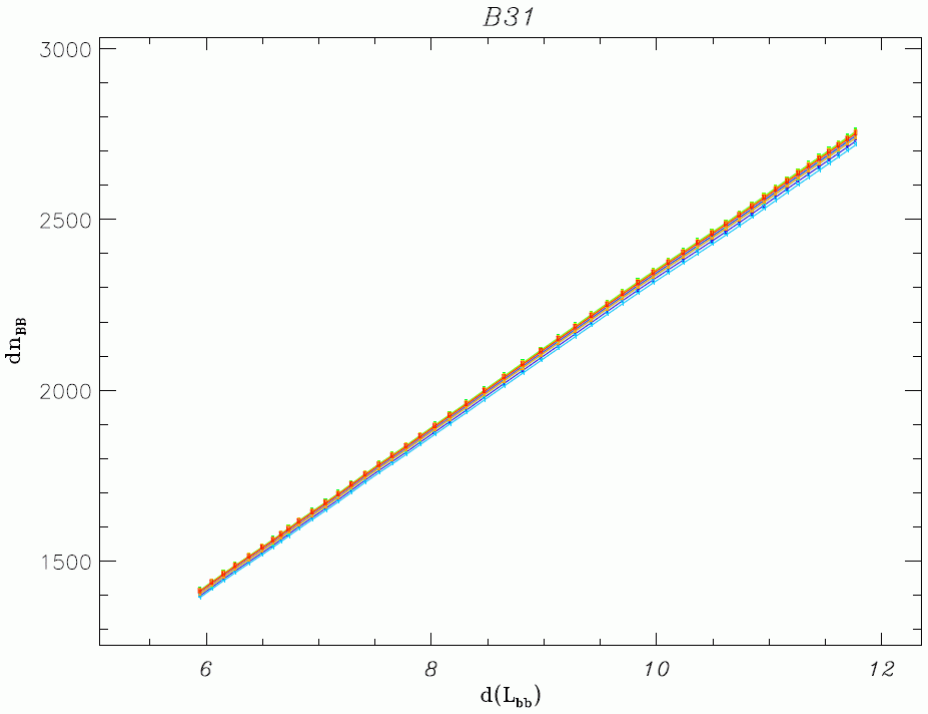
BB Warmup/Cooldown

- BB Warmup/Cooldown activities
  - Performed quarterly
  - Temperature range: 270-315 K
  - Used for a0/a2 derivation/trending
  - Bands 33, 35 & 36 saturate for TBB > ~300 K
    - Default b1 used in L1B
- Impact of CFPA Temperature
  - a0/a2 fitting residuals
  - Default b1 derivation
  - EV saturation

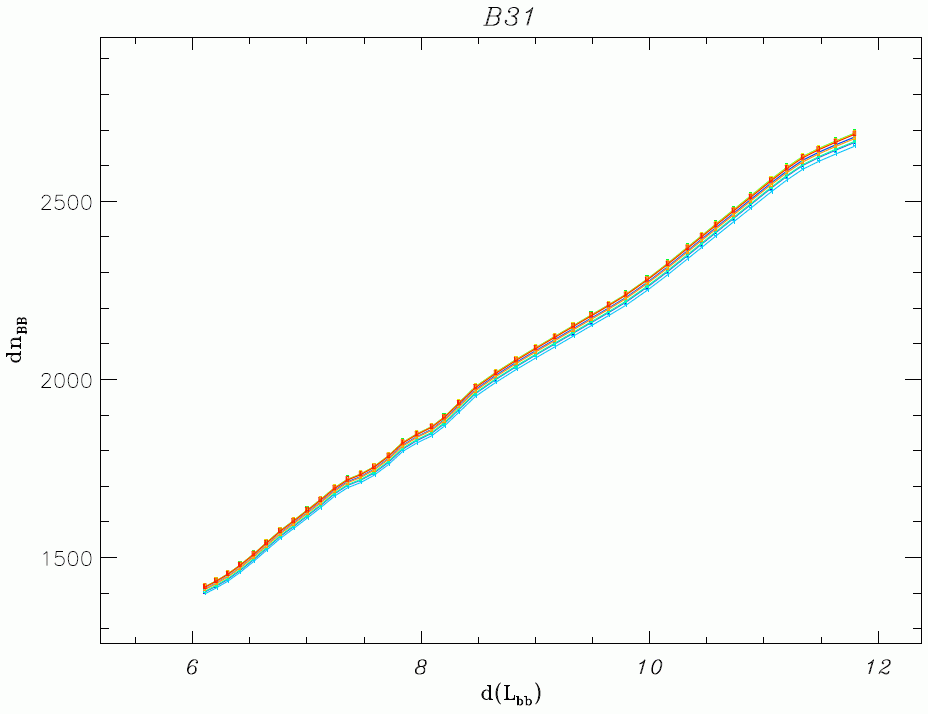


BB Warmup/Cooldown

2004/202



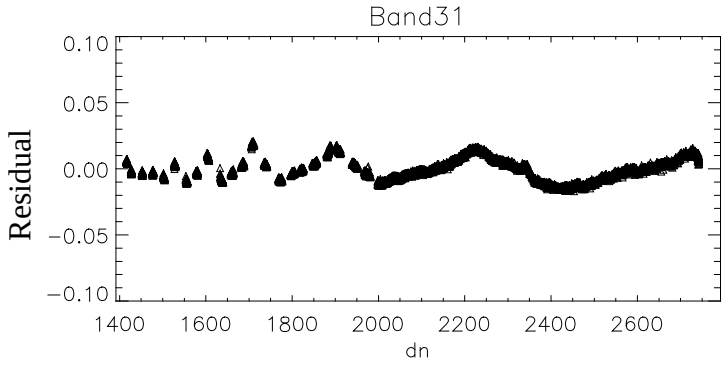
2012/035

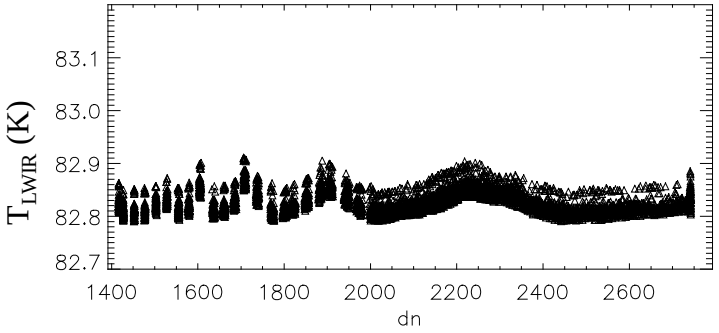


Fluctuation in CFPA Temp during WUCD influenced detector response to T_{BB}
Only bands 31 & 32 relied on the on-orbit derived a2 coefficients – all other bands from pre-launch

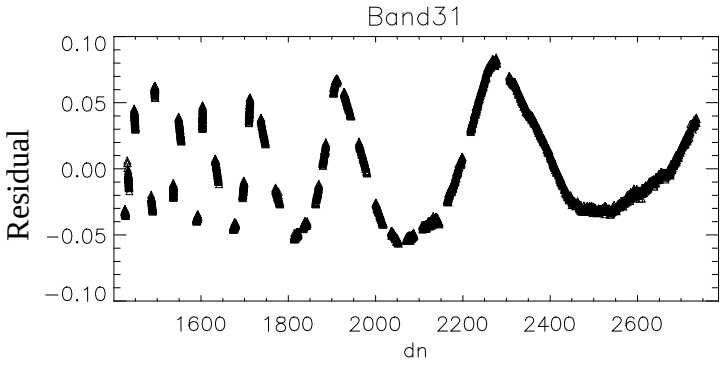
Aqua fitting residuals

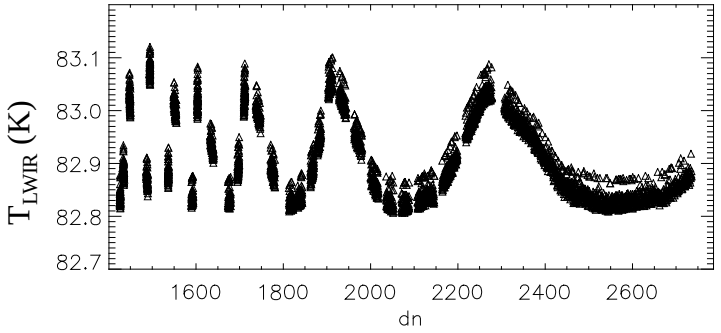
2006/200



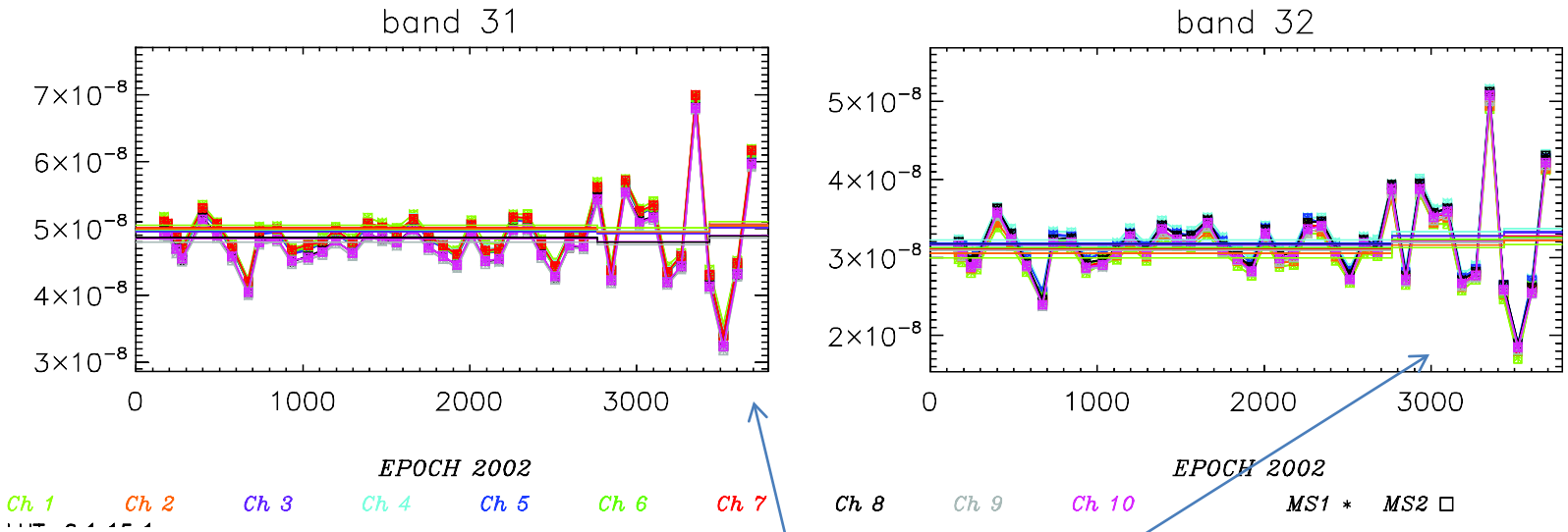


2011/233





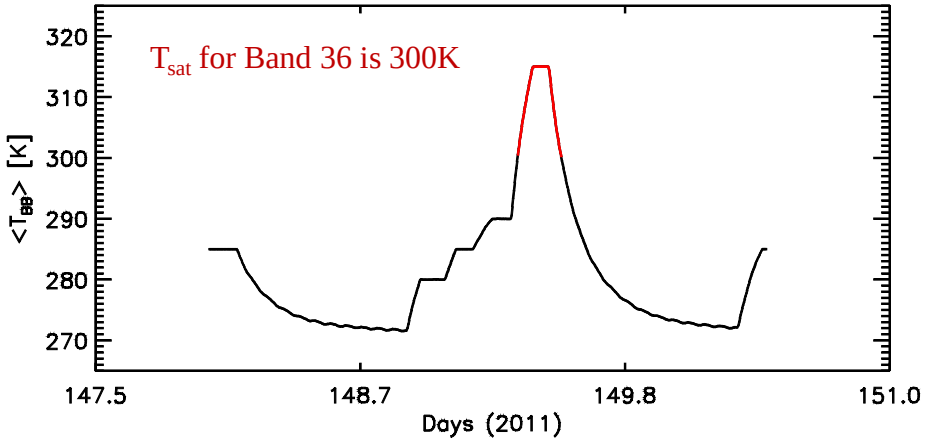
WUCD a2 trending



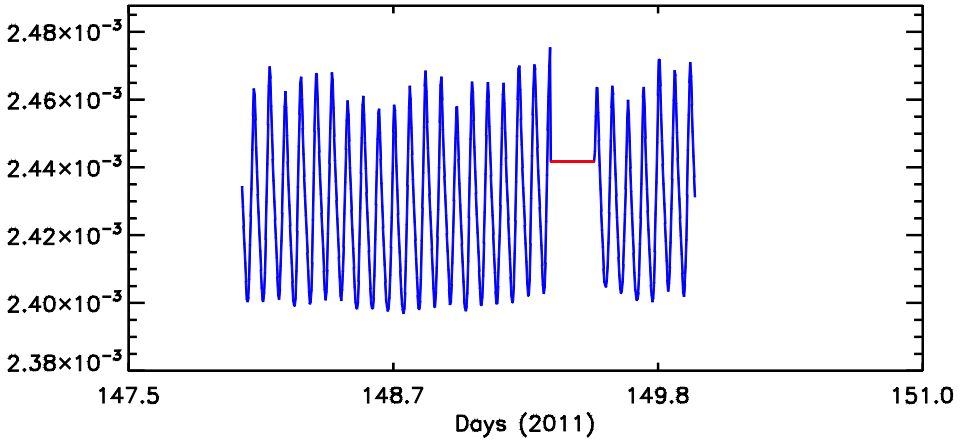
On-orbit derived coefficients show increased variability
(flat line indicates LUT value derived as yearly average)

B33, 35 & 36 Saturation

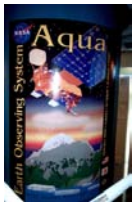
- During WUCD activities bands 33, 35 & 36 saturate for T_{BB} > ~300 K (known issue at launch)
- A constant 'default b1' used for scan-by-scan calibration during these periods.



Band 36 b_1 for D1, M1; Constant b1 L1B methodology



Default b1 Algorithm Modified for C6



- Revised approach to compensate for CFPA temperature variations

Algorithm details

1. For each WUCD cycle, select three continuous orbits data (~ 5 hrs) from a previous day. Calculate *b1* & T_{LWIR}
2. Calculate the rate (*c1* in percent) of relative *b1* change with T_{LWIR} by linear fitting for each detector and mirror side.
3. Calculate default *b*1 ($b1_{Tsat}$) and $T_{LWIR,Tsat}$ using scans with T_{BB} close to T_{SAT}
4. For each scan, when $T_{BB} > Tsat$[Band]:

$$b1_{Tsat,corrected} = b1_{baseline}[1 + c_1(T_{LWIR} - T_{baseline})]$$

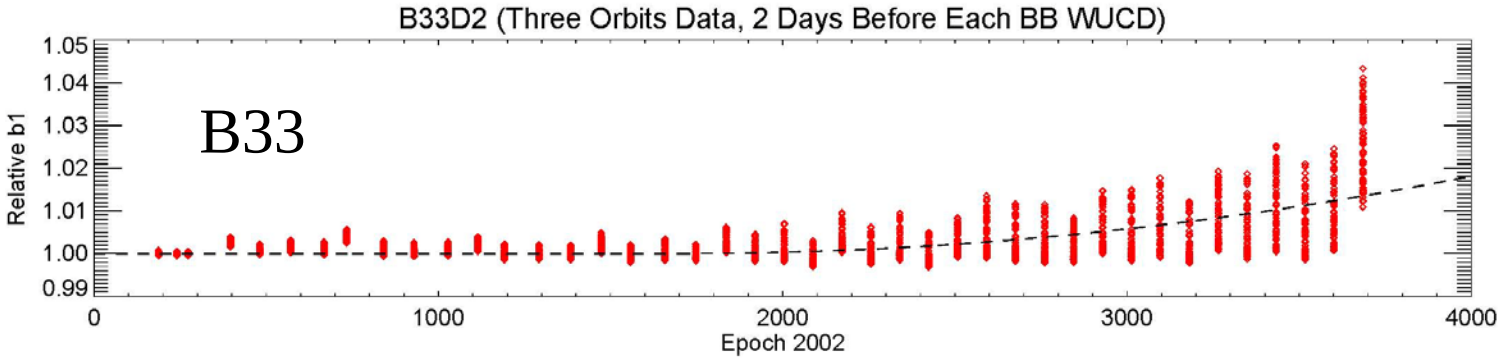
$$b1_{baseline} = b1_{Tsat} /[1 + c_1(T_{LWIR,Tsat} - T_{baseline})]$$

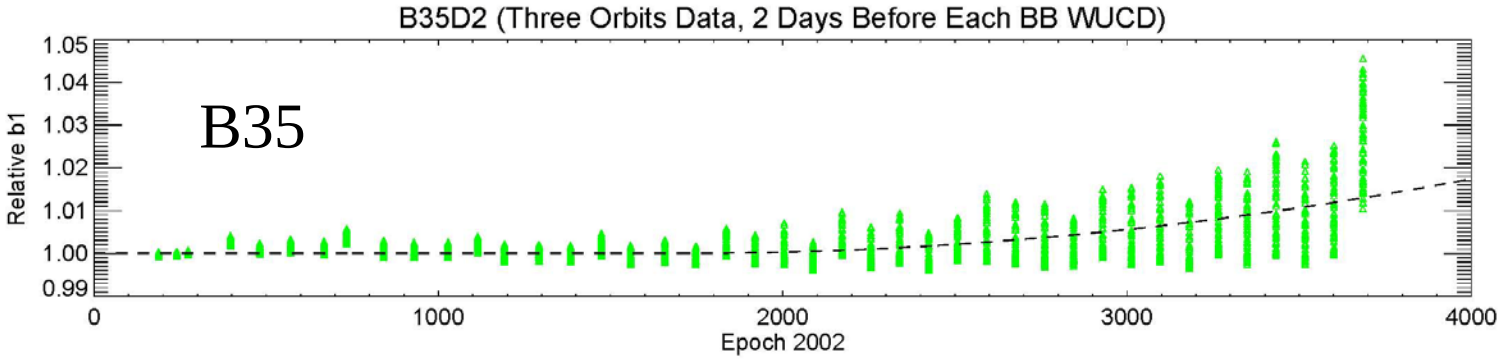
LUT Inputs and Order:

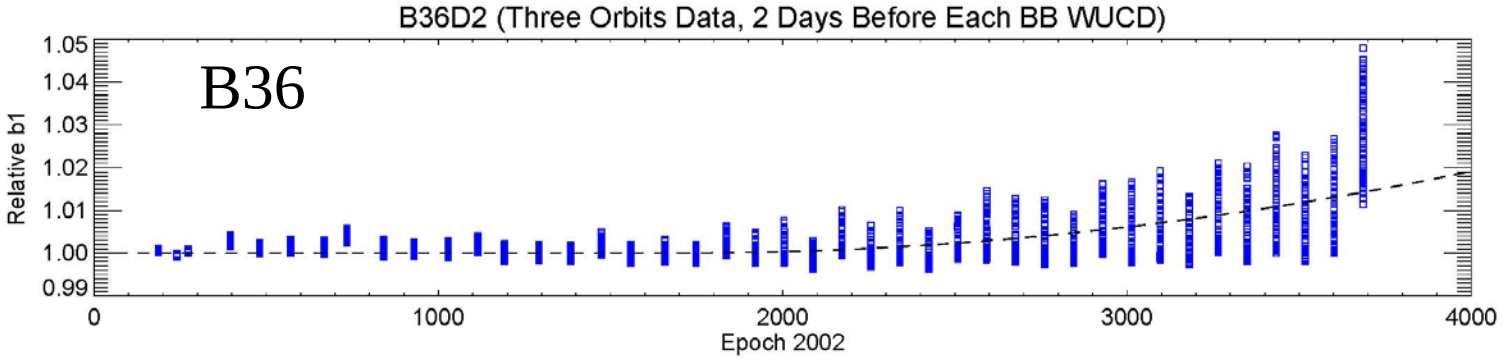
$b1_{Tsat}$ = [Band, Detector, Mirror Side]
c1 = [Band, Detector, Mirror Side]
$T_{baseline}$ = [Band], Currently set at 83.0
$T_{LWIR,Tsat}$ = [Band, Mirror Side]

T_{LWIR} is the focal plane temperature for each scan and is read from TA_RC_LWIR_CFPAE

Default b1 Algorithm

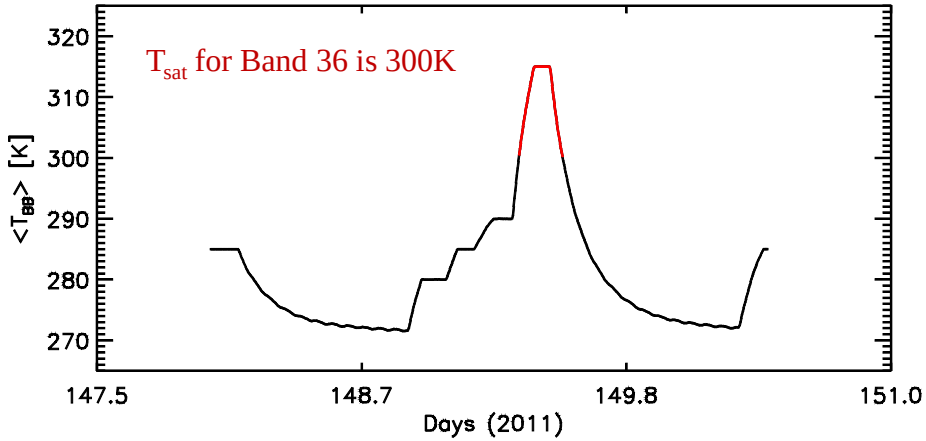




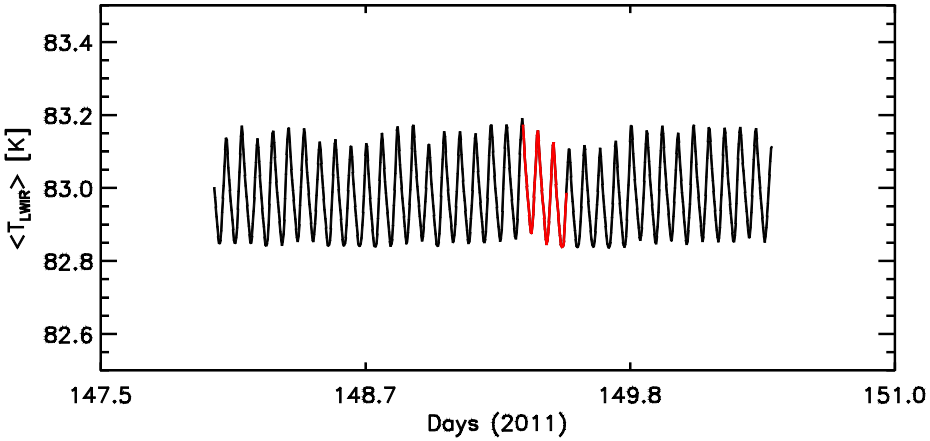


Aqua TEB: C6 default b1 example

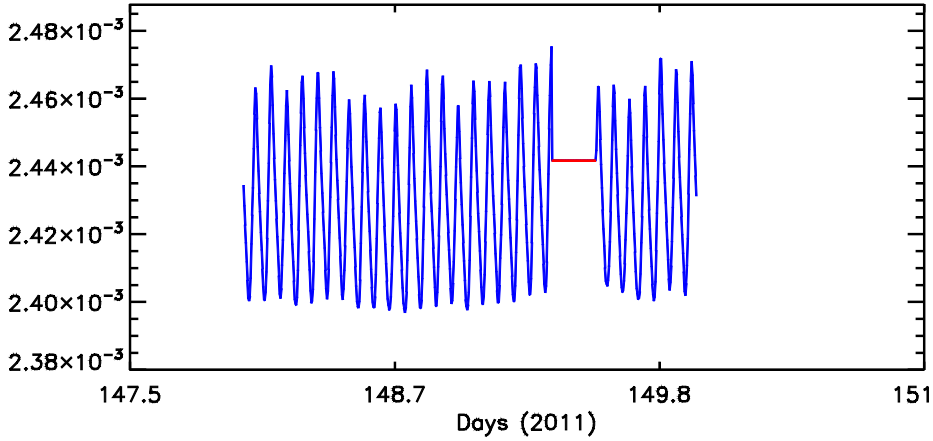
Black-Body Temperature



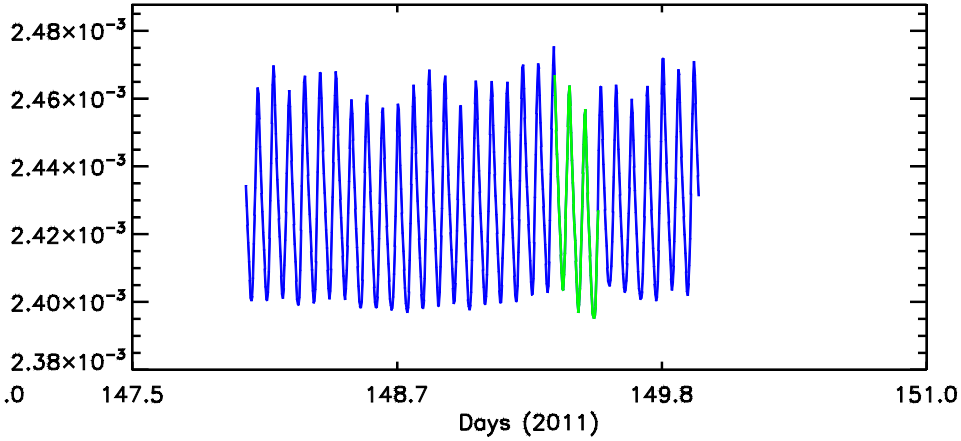
LWIR FPA Temperature



Band 36 b_1 for D1, M1; Previous L1B methodology



Band 36 b_1 for D1, M1; Modified default b1

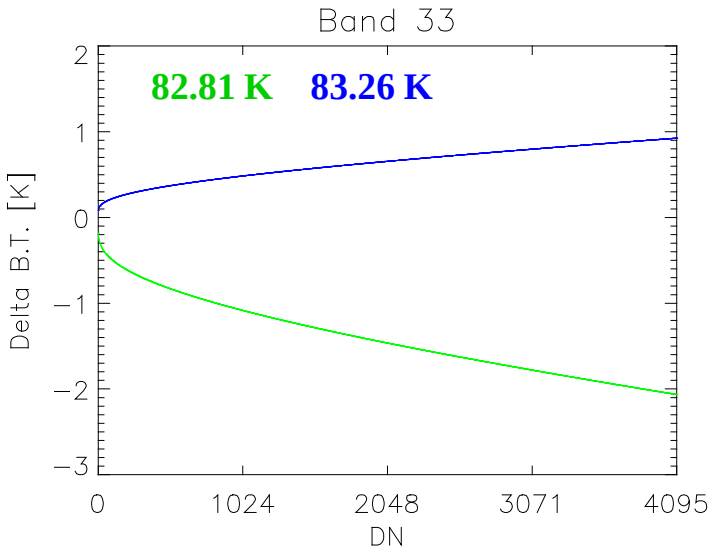


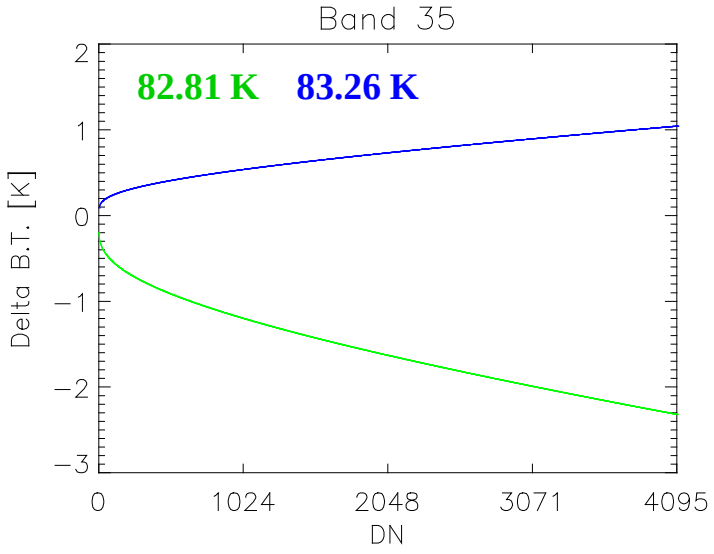
All Data shown are granule averaged

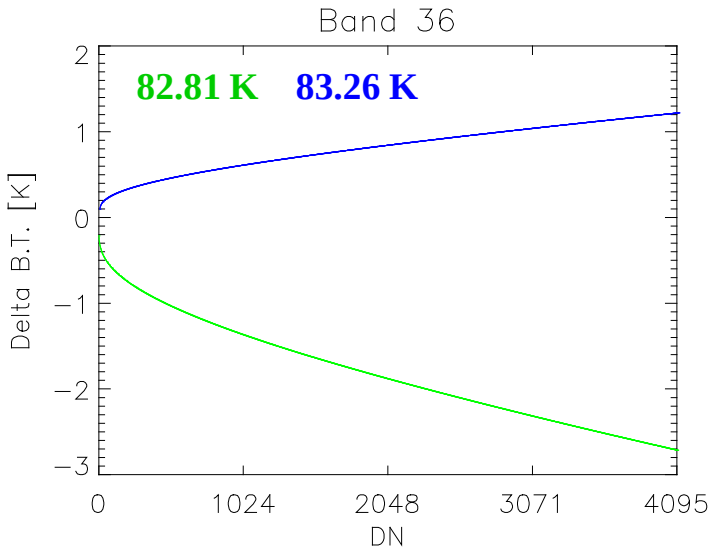
C6 default b1 impact assessment

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

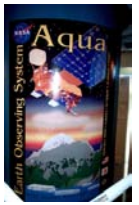
Example shown here indicates the range of difference expected for the 2011/149 WUCD activity.





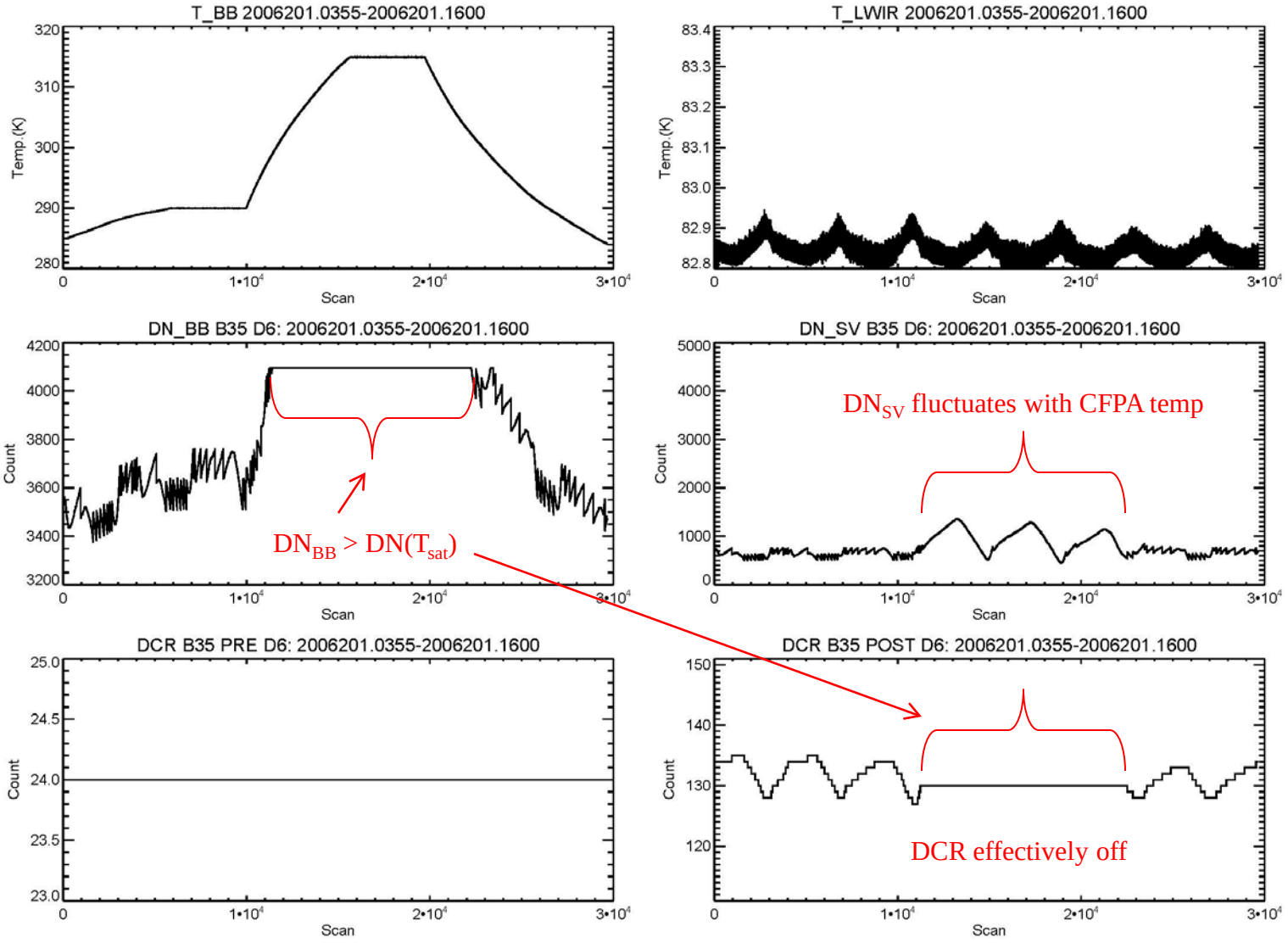


EV Saturation

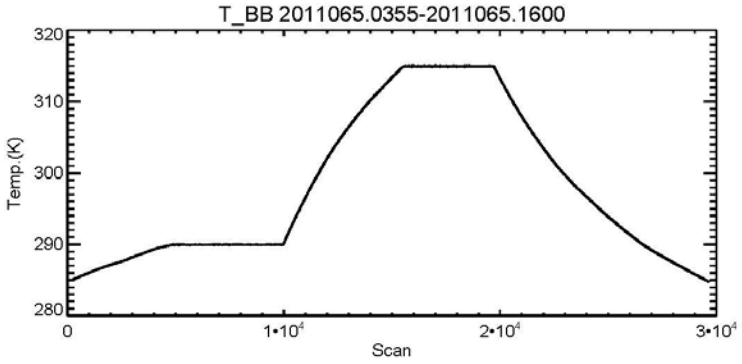


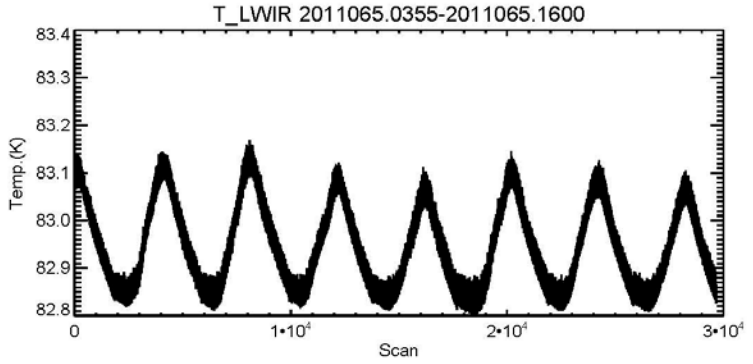
- During WUCD when the $T_{BB} > T_{sat}$ the DCR algorithm is effectively 'off' for bands 33, 35 & 36
  - $DN_{BB} = DN_{Ideal} = 4095$
- DN for all other sectors (e.g. Space View) will begin to oscillate with the CFPA temperature due to temperature dependent gain change of detectors.
- EV sector will saturate periodically when $DN_{EV} + DN_{SV} > DN(T_{sat})$ 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.

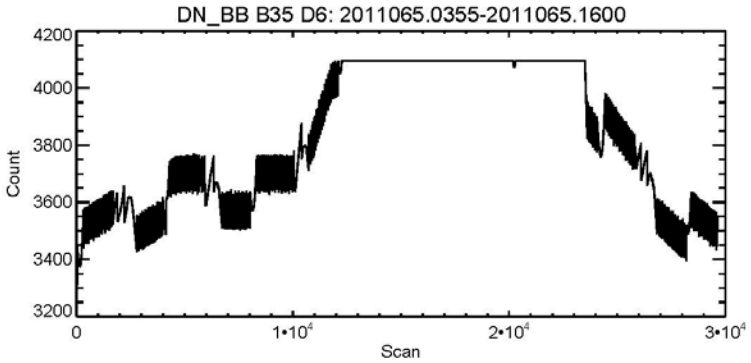
EV Saturation: 2006 case (Band 35)

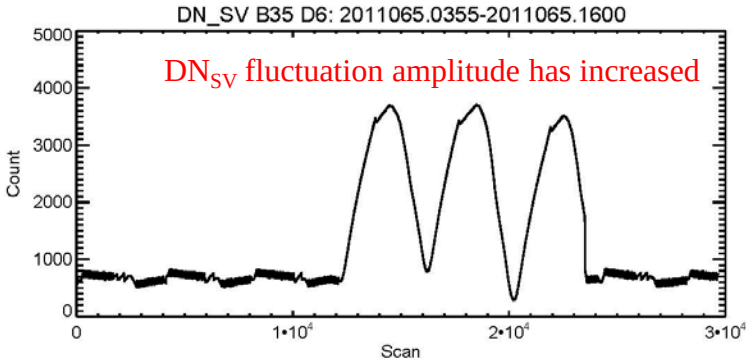


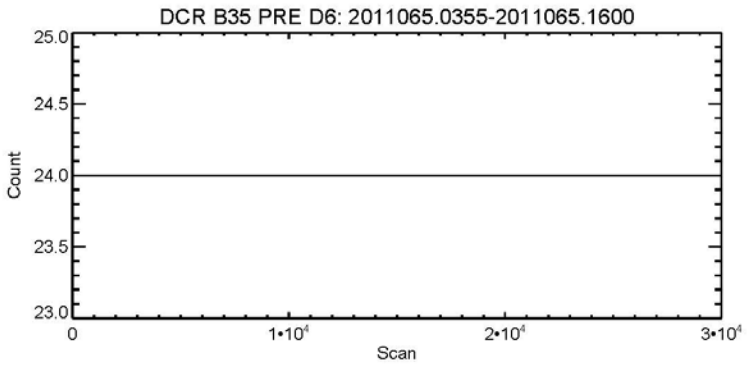
EV Saturation: 2011 case (Band 35)

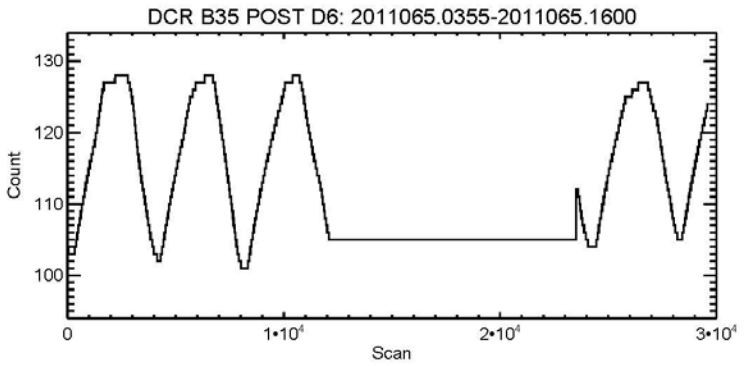




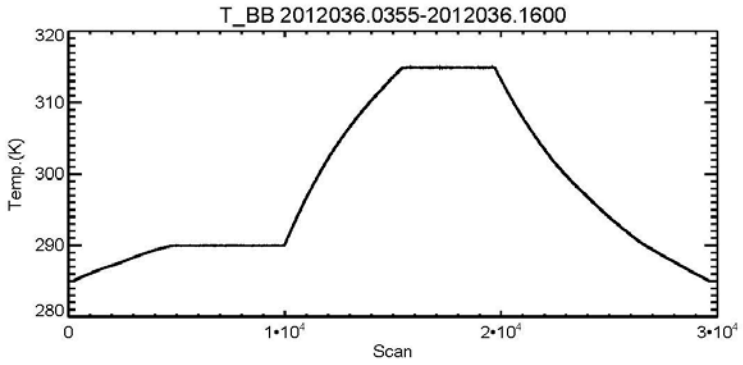


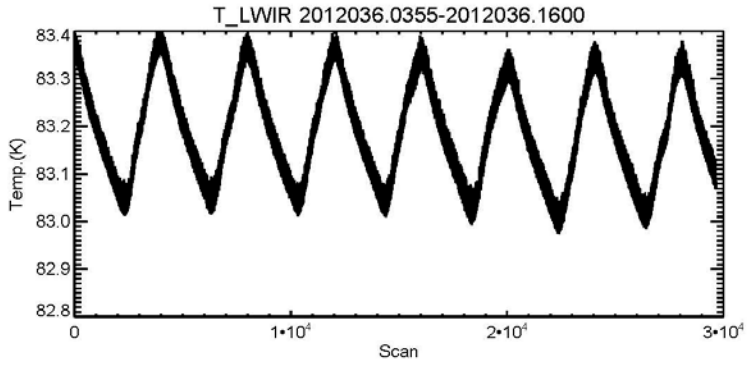


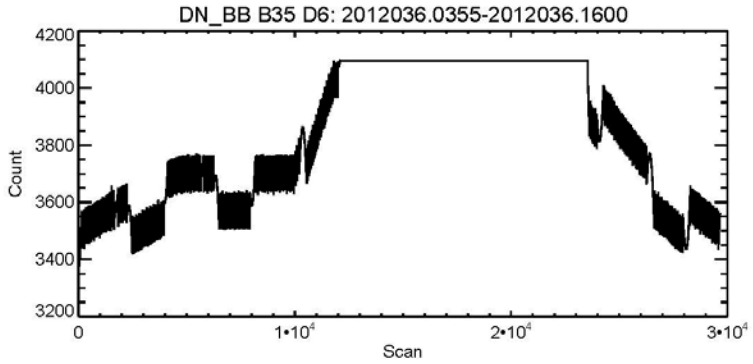


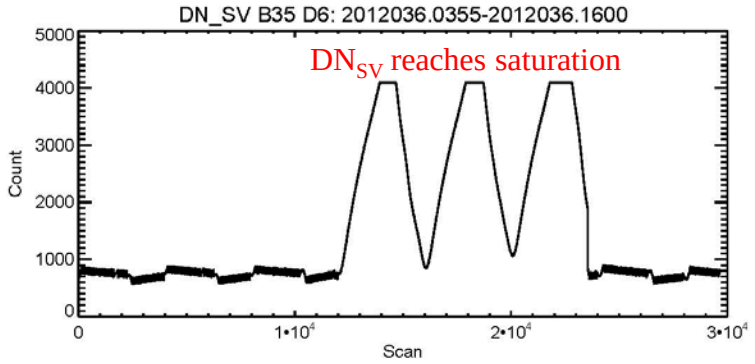


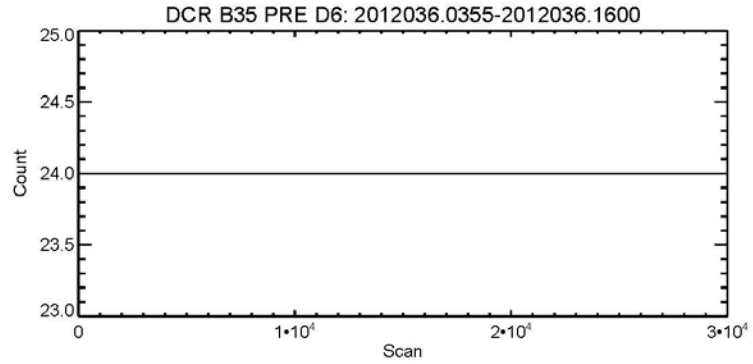
EV Saturation: 2012 case (Band 35)

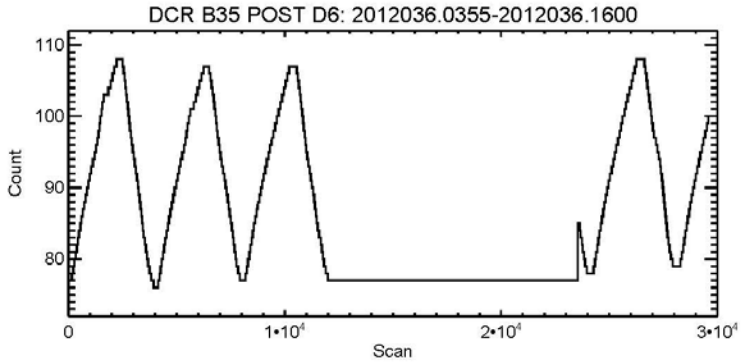






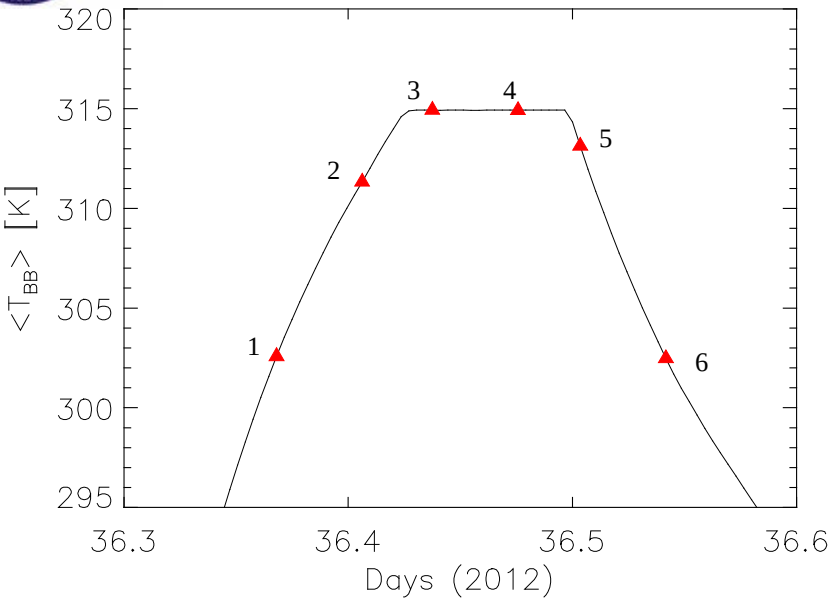


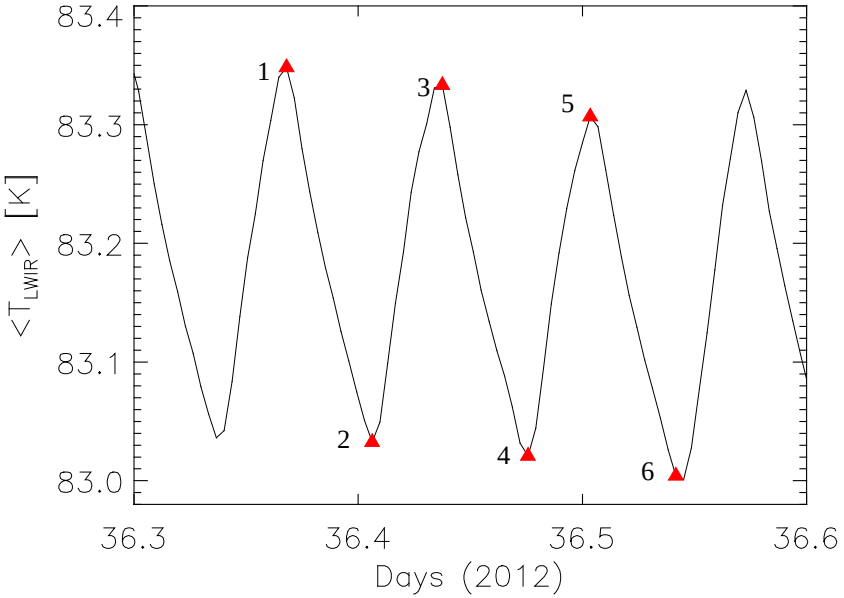




Saturation Example: Band 36

T_{sat} is conservatively determined to be 301 K





Black-Body

302 K	311 K	315 K	315 K	313 K	302 K
1	2	3	4	5	6
2012036.0850	2012036.0945	2012036.1030	2012036.1125	2012036.1205	2012036.1300

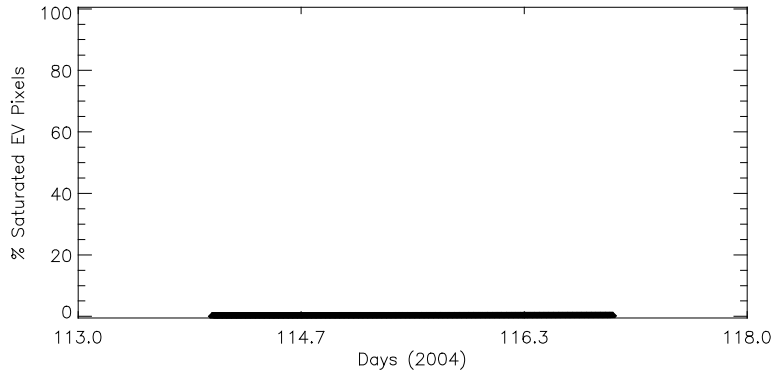
LWIR Temp.

83.35 K	**83.03 K**	**83.33 K**	**83.02 K**	**83.31 K**	**83.00 K**

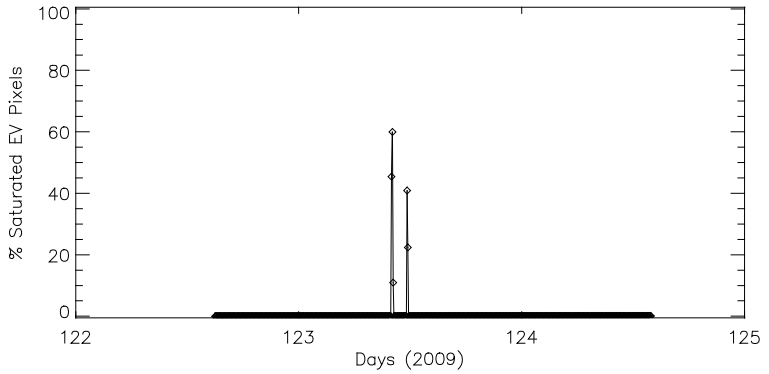
B36 Saturation Trends

- The number of saturated pixels during the WUCD has increased

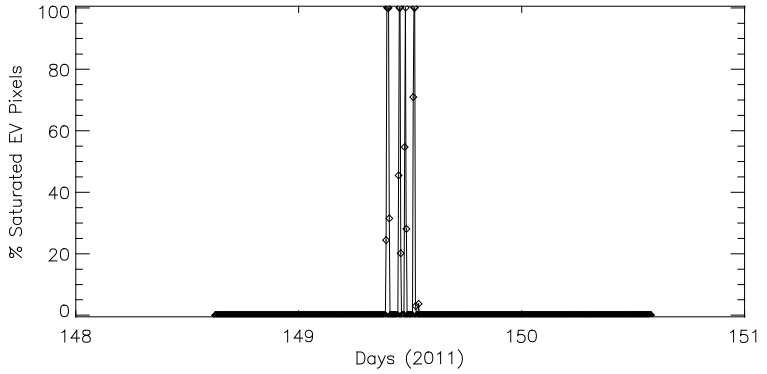
2004-114



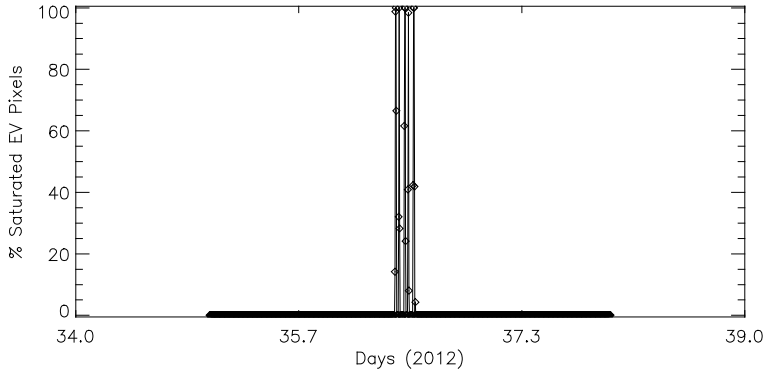
2009-123



2011-149

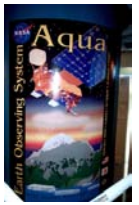


2012-036



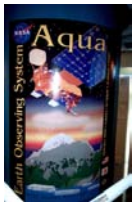
All granules during WUCD

Mitigation Strategies



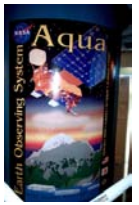
- Scan-by-scan calibration captures much of the impact of the CFPA variation.
  - CFPA temperature dependent default b1 algorithm implemented in C6
- Options under consideration to address temperature fluctuations the same as previous meeting
  1. No change – continue operations in current configuration
  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
     - Temporary: Set to 85K for limited period to assess impact before final decision
     - Permanent: Set to 85K for all future operations
  4. Outgas
     - Permanent: Set to 83K

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 2 – Change CFPA Set Point to 85K



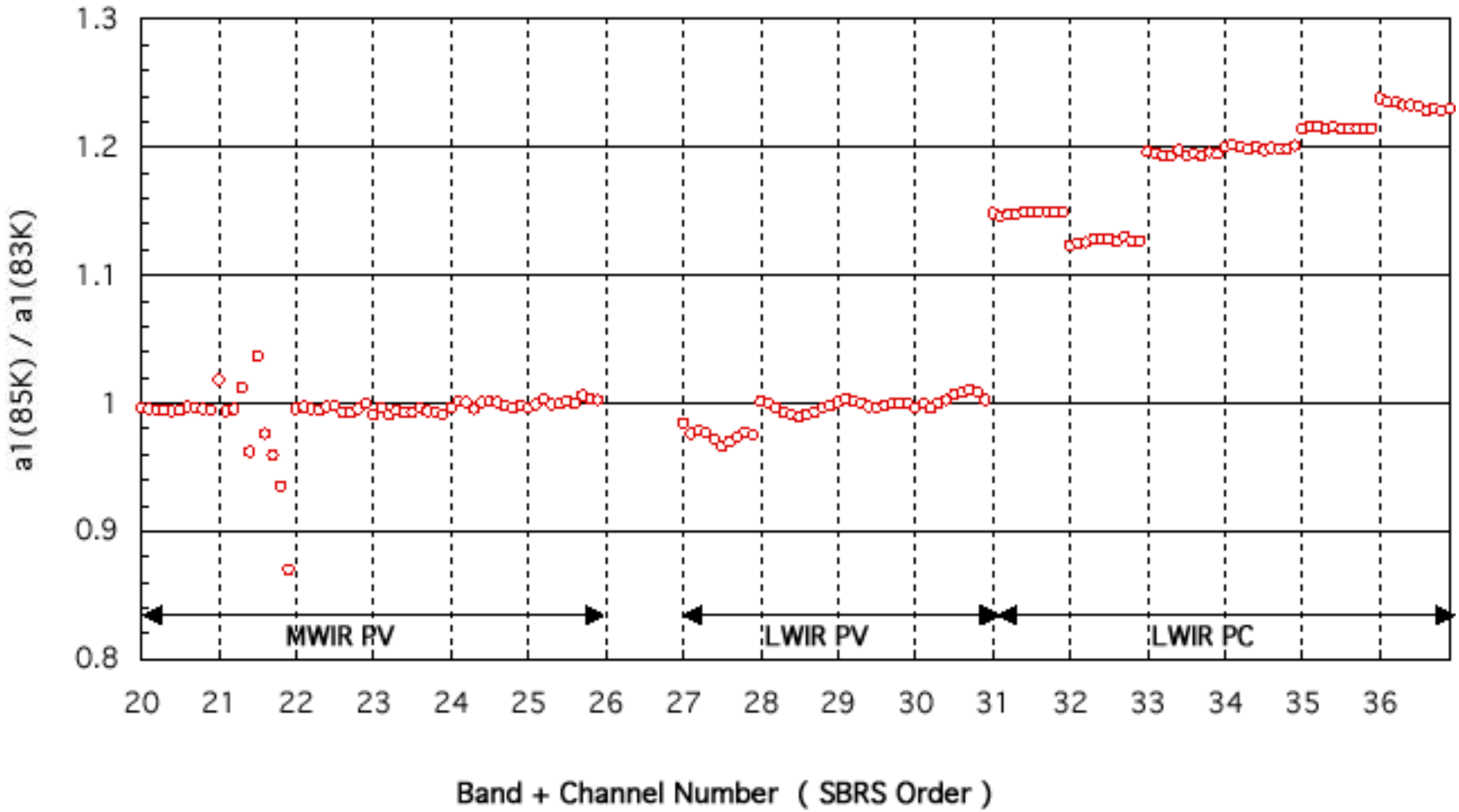
- S/C needs to be in “nominal mode” for this activity
- Ensure that CFPA heater B is in the ON state
- Send the following commands:

  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)

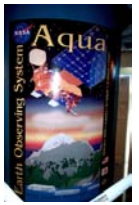
- Concerns:
  - Majority of pre-launch LUT tables based on 83 K set point
  - DCR table for 85 K
  - Loss of dynamic range for TEB
  - Increased detector noise
- Advantages:
  - Gain stably controlled
  - EV saturation during WUCD removed

Option 2 Cont'd...



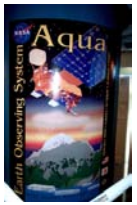
MCST has at its disposal the P.L. calibration coefficients for Aqua CFPA @ 85K

Option 3 - 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

Discussion



- Issues
- Actions
- Recommendations