MCST Calibration Workshop

MCST Calibration Workshop at
Science Team Meeting

June 6, 2000

Workshop Agenda

- Introduction
- Remarks from Science Team members (representatives)
- Brief Description of Calibration Testing
- Electronic Crosstalk
- PC Optical Crosstalk
- ADC Issue
- RVS Review
- Polarization Issue
- Band 21 Calibration
- Band to Band Registration (from MCST, SDST)
- SRCA Results (Spatial & Spectral)
- Remaining FM1 Testing Objectives

INTRODUCTION
Objectives of this Workshop

- Recommendations for operating configuration
- Communication of our progress/Science Team concerns
- Recommendation of FM1 spacecraft T/V objectives
- Identify Key Operations Milestones
- Validate/challenge MCST Preliminary Conclusions

General Sensor Status

- There are no significant surprises in Terra-MODIS on-orbit performance
- Non-optimum characteristics have been accepted by NASA in waivers and deviations
- The task remaining to MCST and SBRS System Engineering is optimization of the L1B data set for the best science from MODIS
- This instrument meets specifications

Recent/Planned Level 1B Code Deliveries

Version	Date	Comments	Status
V2.2.0	May 30, 1999	Launch ready version.	
V2.3.2	Jan 5, 2000 Feb 25, 2000	Changes to: reflective calibration algorithm, uncertainty algorithms, SWIR OOB leak correction algorithm. Can process without a leading or trailing Level 1A granule.	**In operations at GDAAC**
V2.4.1	May 5, 2000	Process up through 208 scans in granule	In SSI&T at GDAAC
V2.5.0 (?)	(?)	Delete obsolete metadata, Incorporate time-dependent LUTs, Incorporate other changes TBD.	

Level 1B Lookup Table Updates Sent to GDAAC

Version	Date	Comments	LUTs Changed
V2.3.2.0	Jan 5, 2000	Pre-launch calibration	
V2.3.2.1	Feb 16, 2000	Derived from on-orbit data, pre-launch (Vdet/Itwk) configuration. *(not used in operations)*	Emissive and reflective bands calibration and uncertainty LUTs, uncertainty index scaling factors
V2.3.2.2	Feb 25, 2000	Update to previous table. Entered operations for data collected on day 056.	Detector quality flag values. (includes V2.3.2.1 update)
V2.3.2.3	Mar 15, 2000	Derived from on-orbit data, current (Vdet/Itwk) configuration. Entered operations for data collected on day 078. (“St. Patrick’s Day” update)	Reflective bands calibration and uncertainty LUTs (no changes to emissive LUTs)

Identify Key Operations Milestones

Terra Launch	1999/352
MODIS 1st turn-on	2000/003
NAD Open	2000/055
Vdet/Itwk to Operational Configuration	2000/066
LUT up-date	2000/078
Moon-in-Space-View-Port	2000/084
Lunar Yaw Mapping (NAD closed)	2000/116-1408
Day-mode data collection at night	2000/152

A graphic timeline of important MODIS events being developed
All relevant detail exists on MCST Webpage under "Terra MODIS History"

Recommendations for operating configuration

- Focal Plane detector bias selection represents a trade-off between electronic cross-talk and detector operability in SW/MWIR focal plane.
- ADC/bin-fill non-uniformity varies with selection of primary side/back-up side of selected electrical sub-systems.   FM1 testing indicates best performance from all B-side and mainly B-side operations.

Preliminary Conclusions

- Electronic Cross-talk (based on M-SV data set)

  At Operational Configuration (110/226)

  – MWIR effects seem to be about 3%
    - Bias may be function of scene temperature
    - Effect "incorporated" into calibration coefficient determination

  – SWIR effects may be typically 1 - 3%
    - Must be very careful for scenes with low dn signals in a SWIR band
    - Need verify DN_{SV} not contaminated

  – PV LWIR effect gone

- Band 31 Optical Leak
  – Improved (1st-order) leak correction coefficients into Bands 32 - 36

Preliminary Conclusions (2)

CAUTION - THESE RESULTS CAME FRIDAY, 2 JUNE, AND MUST BE VERIFIED. ESPECIALLY PC RESULTS SURPRISE US

- ADC On-orbit
  - A-side (PC Bands, 31 - 36) 3 or 4 of 10 channel pairs for SST (Bands 31 & 32) meet Differential Non-Linearity (DNL) requirement
  - A-side (PV Bands, 20 - 25) 3 of 10 channel sets for SST-4µm (Bands 20, 22 & 23) meet DNL requirement
- ADC Spacecraft Thermal Vacuum (S/C T/V) testing
  - Useful data for Band 36 only
  - A-side 1 of 10 channels meets DNL requirement
  - B-side 6 of 10 channels meets DNL requirement

Expect significant improvements operating on B-side

Need investigate NIR behavior now too

Preliminary Conclusions (3)

- SRCA Spectral
  - Little to no apparent λ shift (< 0.5 nm)
  - Need look more carefully at Band 5 λ_c; it may be function of temperature
- SRCA Spatial
  - Scan direction shows no significant launch shifts
  - Track direction

VIS	to NIR	about + 40 m
SMIR	to NIR	about - 45 m
LWIR	to NIR	about - 55 m

  - No FPA rotation
  - PFM stability suggests one more look at FM1 co-registration results warranted

Preliminary Conclusions (4)

- Calibration strategies ➻ Image effects
  - Vulnerable to RSB ch-ch stripes due to SIS100 calibration uncertainty
  - Vulnerable to TEB MWIR stripes due to SAM resistor change
  - Vulnerable in SMIR focal plane data if electronic cross-talk varies by channel

  - Striping effects more pronounced than expected

Credits

The entire MCST staff has contributed in significant ways to the materials prepared for presentation here.

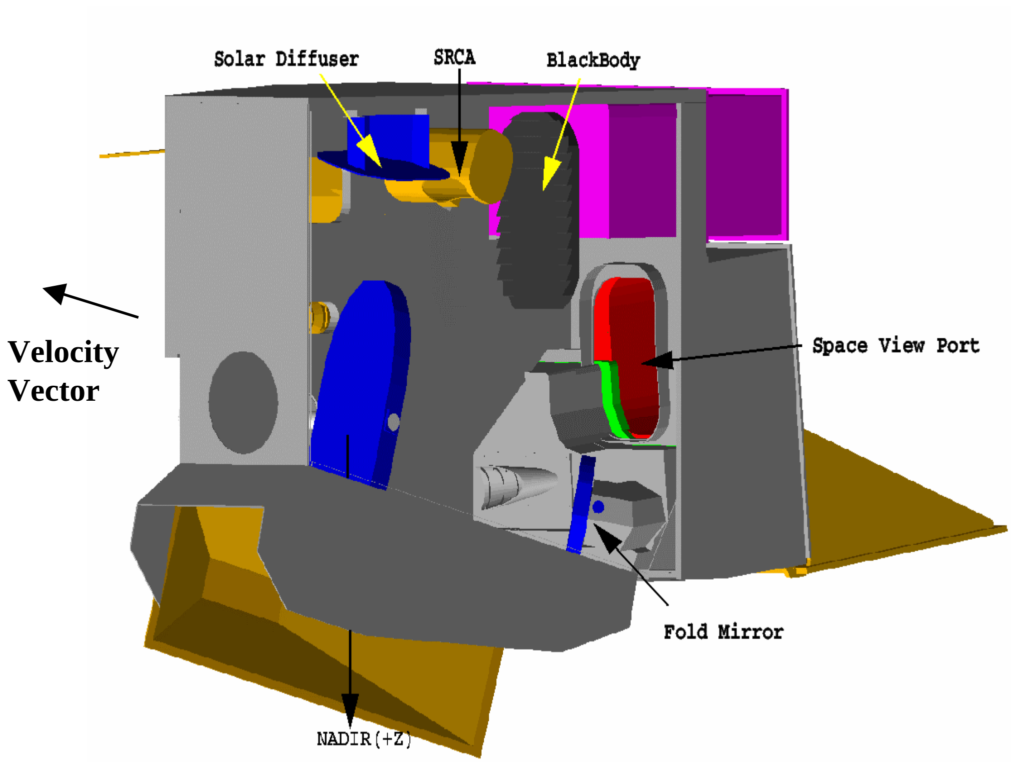
Significant contributions have been made by SBRS Systems Engineering here too.

Brief Description of Calibration Tests (Pre-launch)

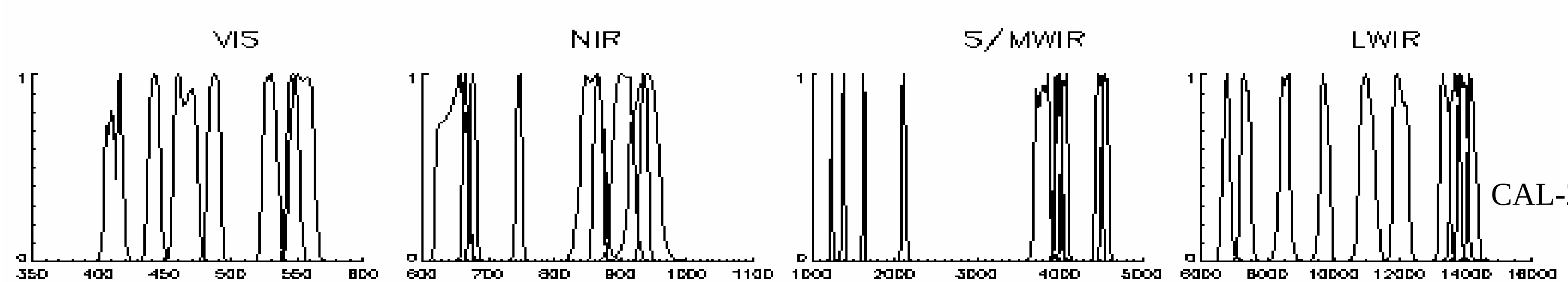
- Sensor thermal vacuum configuration
- RSB: linear calibration, through zero
  - Each detector, sub-frame and mirror side treated independently
- TEB: primarily quadratic
  - Each detector and mirror side treated independently
- General Sensor Status

Focus of this section is relationship of calibration realities to data applications in MODIS images

MODerate Resolution Imaging Spectroradiometer (MODIS)

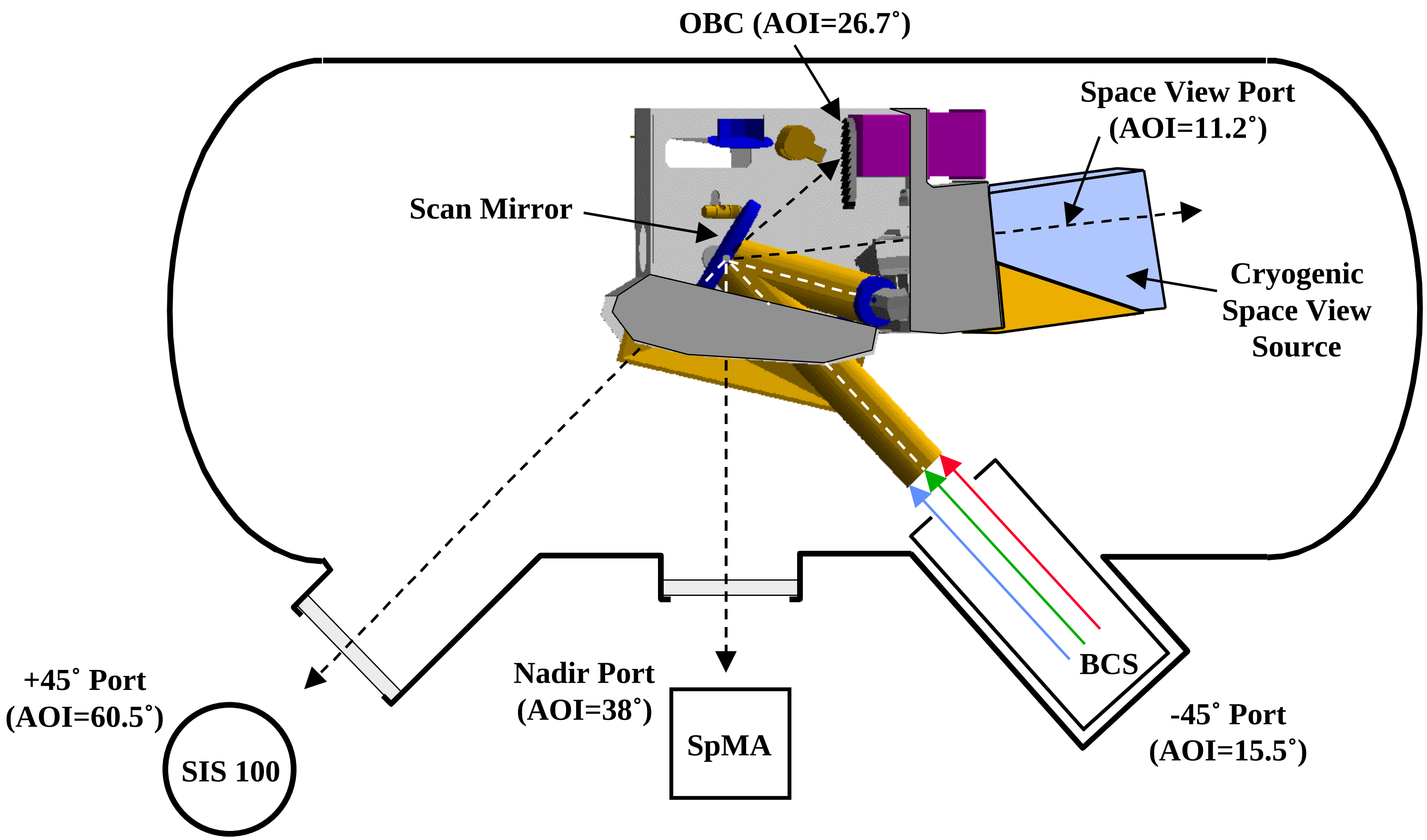


- 36 Spectral Bands (490 detectors) cover the wavelength range from 0.4 to 14.5 µm
- Spatial resolution at nadir: 250, 500 and 1000 meters (depending on band)
- SD/SDSM, SRCA, and Blackbody On-Board Calibrators
- 12 bit (1:4096) dynamic range
- 2-sided Paddle Wheel Scan Mirror scans 2330 km swath



CAL-2

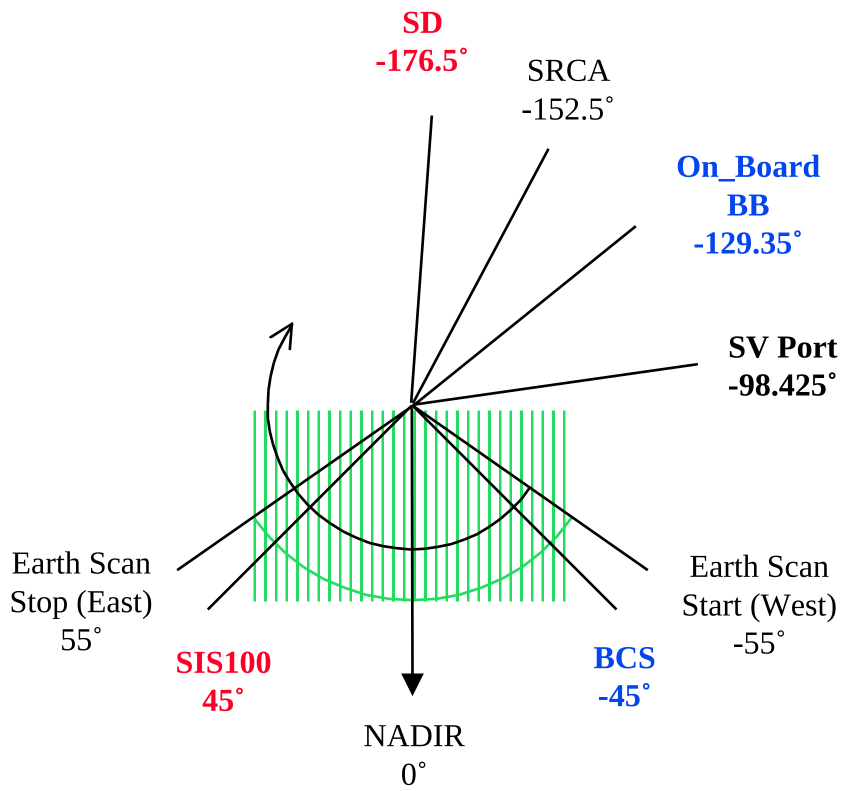
Thermal Vacuum Configuration for MODIS Pre-launch Calibration

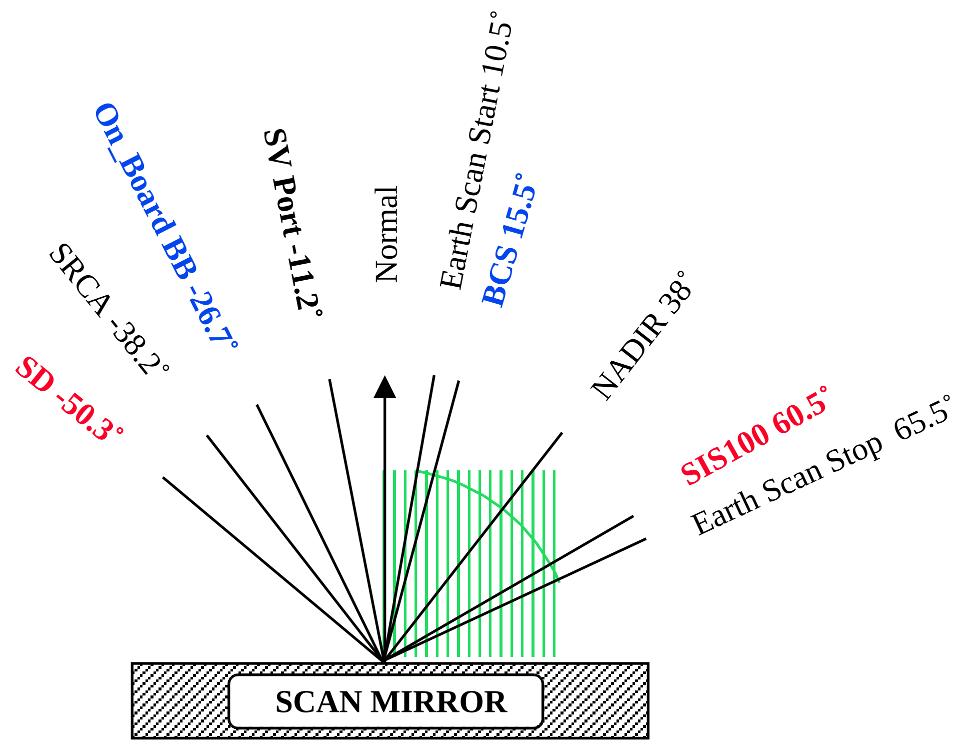


Calibrations performed at:

- 3 instrument temperatures (260, 270, and 280K)
- 3 cold focal plane temperatures (83, 85, and 88K)
- 21 BCS levels (170K to 340K); many SIS-100 lamp configurations

Principal Scan Angles Mapped to Scan Mirror Angles of Incidence





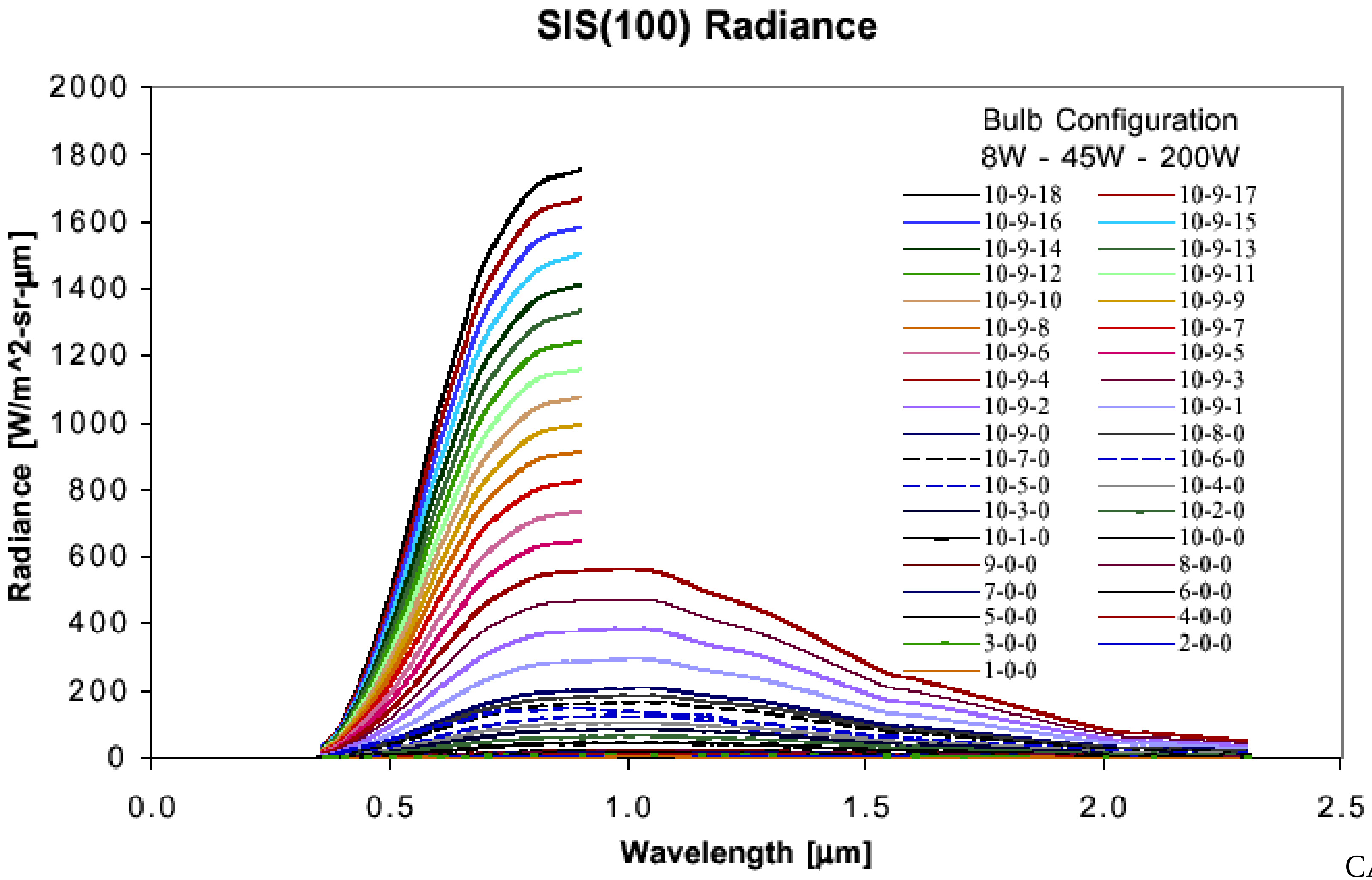
Principal Scan Angles
(Earth View: -55˚ to 55˚)

Angles of Incidence
(Earth View: 10.5˚ to 65.5˚)

RSB
SIS-100 Round Robin (RR)

- SIS(100) was calibrated at SBRS for the RR in 1996 (PFM) and 1998 (FM1)
- Due to burnout of the 45W bulbs, the PFM SIS(100) calibration has not been RR validated
- The 1998 data has been turned in for the RR and the FM1 calibration will be RR validated when results are published.
- Preliminary results indicate consistency between NIST standards and the SBRS SIS(100) scale at about 2-3% for FM1 Testing

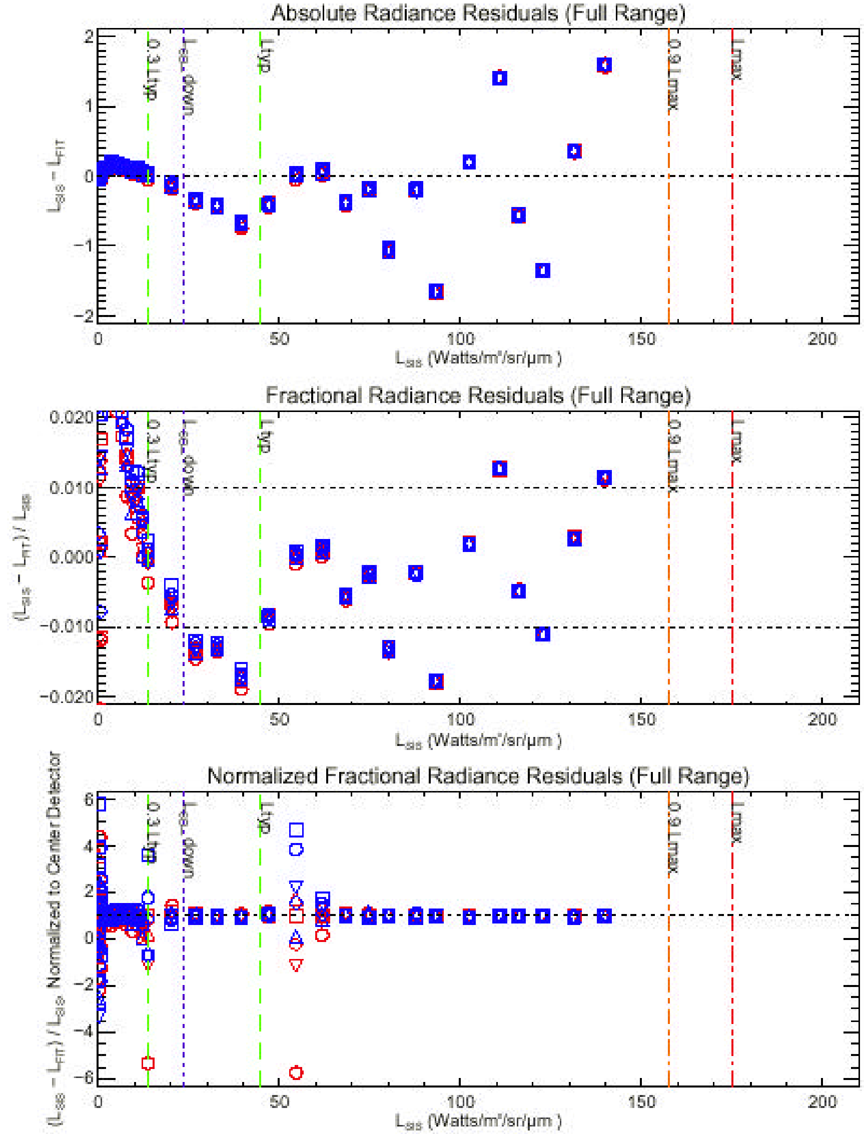
SBRS SIS(100) Radiance as used for FM1



PFM Band 8 Dets 1−10 MS 1

Jun 5, 2000

R* and K_inst fit sequentially in range 0.3 Ltyp to 0.9 Lmax,
exclusive of saturation, with constraint at origin.
From PFM T/V RC01 UAIDs 1338, 1339, 1504, 1442, 1443



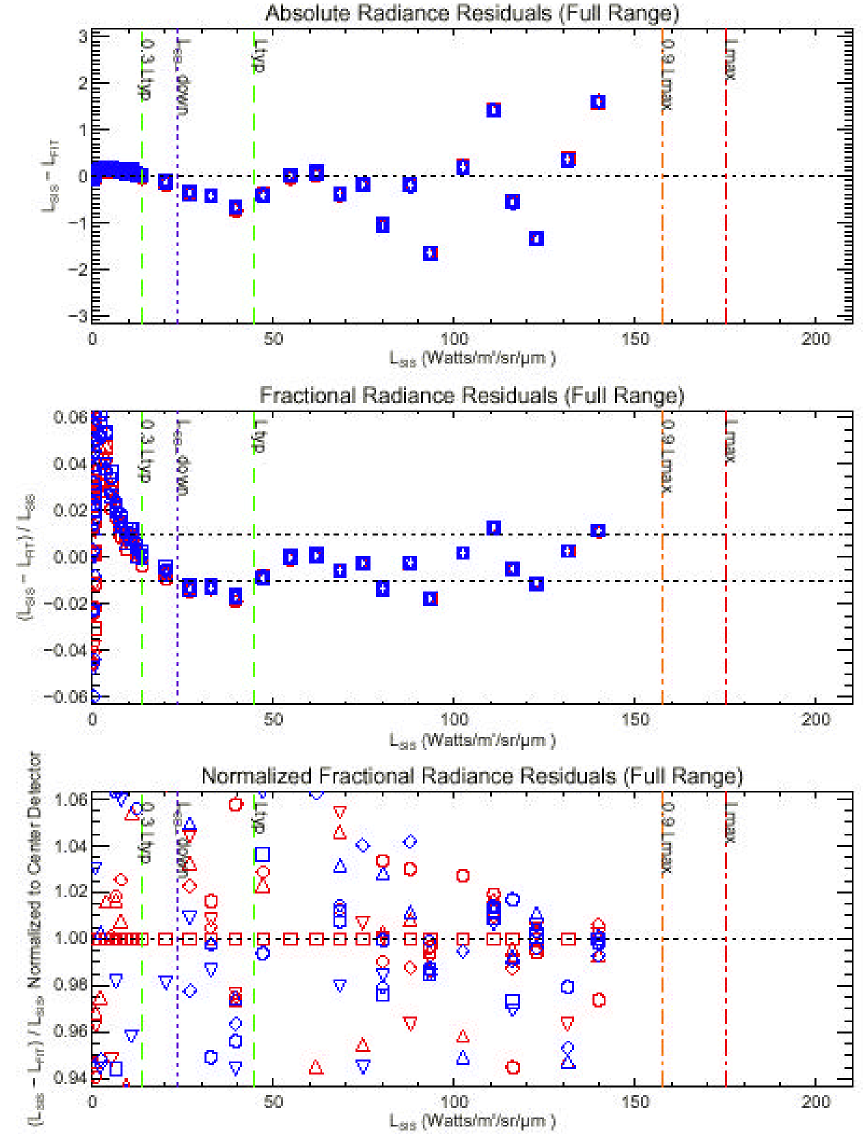
PFM Band 8 Dets 1−10 MS 1

R* and K_inst fit sequentially in range 0.3 Ltyp to 0.9 Lmax, exclusive of saturation, with constraint at origin.

From PFM T/V RC01 UAIDs 1338, 1339, 1504, 1442, 1443

Expanded Vertical Scale

Jun 5, 2000

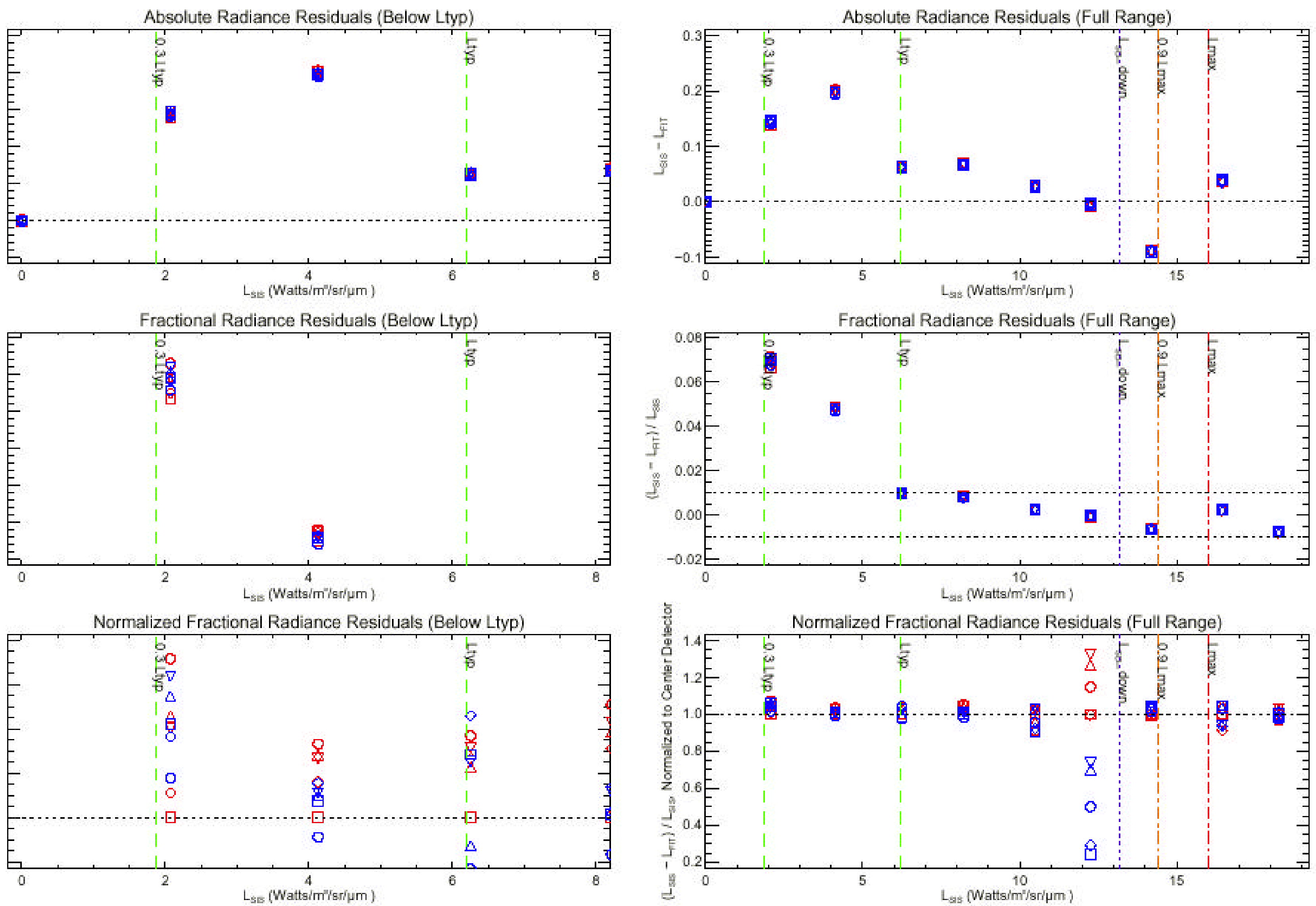


PFM Band 16 Dets 1−10 MS 1

R* and K_inst fit sequentially in range 0.3 Ltyp to 0.9 Lmax, exclusive of saturation, with constraint at origin.

From PFM T/V RC01 UAIDs 1338, 1339, 1504, 1442, 1443

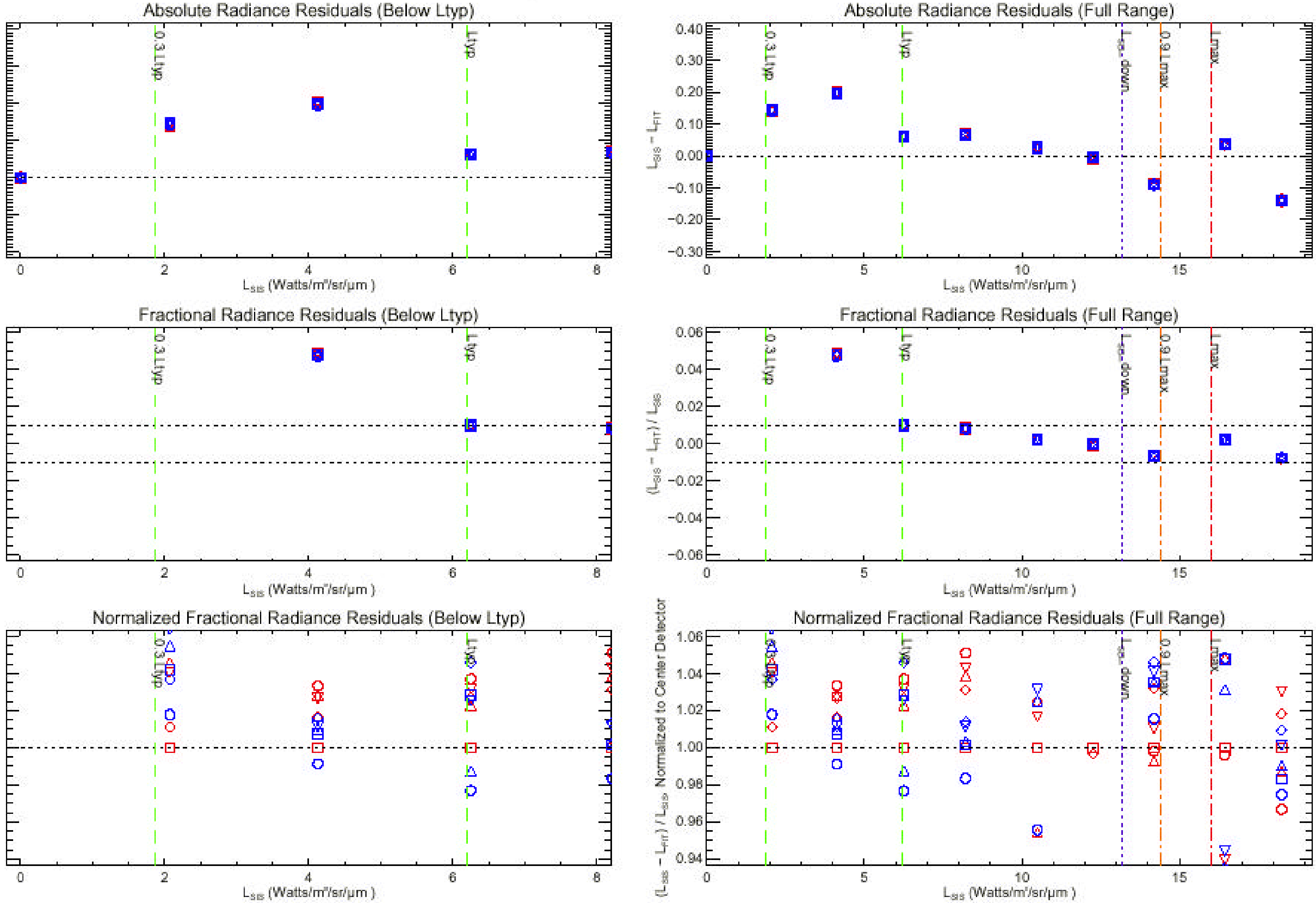
Jun 5, 2000



PFM Band 16 Dets 1−10 MS 1

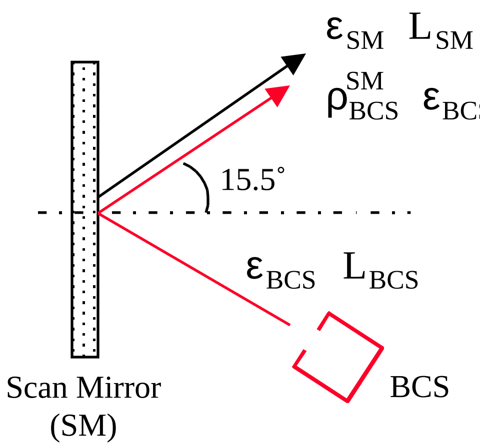
Jun 5, 2000

R* and K_inst fit sequentially in range 0.3 Ltyp to 0.9 Lmax, exclusive of saturation, with constraint at origin.
From PFM T/V RC01 UAIDs 1338, 1339, 1504, 1442, 1443
Expanded Vertical Scale



TEB
Calibration Algorithm Derivation

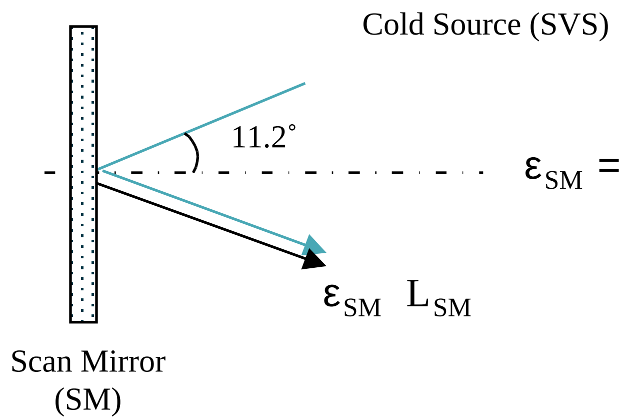
When Viewing the BCS



$$\varepsilon_{SM} = 1 - \rho_{BCS}^{SM}$$

$$L_{BCS\_PATH} = \underbrace{\rho_{BCS}^{SM}\ \varepsilon_{BCS}\ L_{BCS}}_{\text{BCS Source Reflected}} + \underbrace{\varepsilon_{SM}\ L_{SM}}_{\text{Scan Mirror Emission At BCS Angle}} + \underbrace{L_{BKG}}_{\text{Instrument Background}}$$

When Viewing the Space View Source (SVS)



$$\varepsilon_{SM} = 1 - \rho_{SVS}^{SM}$$

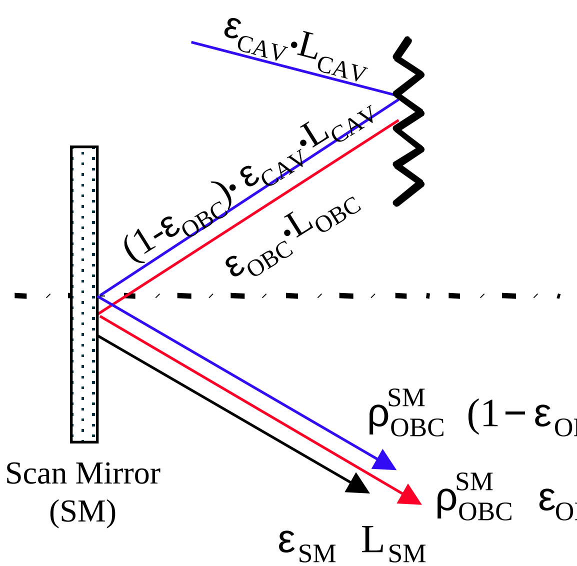
$$L_{SVS\_PATH} = \underbrace{\varepsilon_{SM}\ L_{SM}}_{\text{Scan Mirror Emission At SV Port Angle}} + \underbrace{L_{BKG}}_{\text{Instrument Background}}$$

Equate the Difference Signal to a Quadratic Fitting Function:

$$\rho_{BCS}^{SM}\ \varepsilon_{BCS}\ L_{BCS} + \left(\rho_{SVS}^{SM} - \rho_{BCS}^{SM}\right)\ L_{SM} = a_0^{BCS} + a_1^{BCS} dn_{BCS} + a_2^{BCS} dn_{BCS}^2 \qquad (1)$$

TEB Calibration Algorithm Derivation
(Continued)

When Viewing the On-Board Blackbody (OBC)



$$L_{OBC\_PATH} = \rho_{OBC}^{SM} \; \varepsilon_{OBC} \; L_{OBC} + \rho_{OBC}^{SM} \; (1 - \varepsilon_{OBC}) \; \varepsilon_{CAV} \; L_{CAV} + L_{BKG}$$

OBC Source Reflected — Scan Cavity Contribution — Instrument Background

$$\varepsilon_{SM} = 1 - \rho_{OBC}^{SM}$$

Subtracting the Space View Path

$$\rho_{OBC}^{SM} \; \varepsilon_{OBC} \; L_{OBC} + \left(\rho_{SVS}^{SM} - \rho_{OBC}^{SM}\right) L_{SM} + \rho_{OBC}^{SM} \left(1 - \varepsilon_{OBC}\right) \varepsilon_{cav} \; L_{cav} = a_0^{BCS} + b_1^{OBC} dn_{OBC} + a_2^{BCS} \; dn_{OBC}^2 \quad (2)$$

b_1^{OBC} is determined scan-by-scan from OBC measurements

TEB Calibration Algorithm Derivation (Continued)

The linear gain term is continuously determined via the OBC blackbody by

$$b_1^{OBC} = \frac{\rho_{OBC}^{SM}\,\varepsilon_{OBC}\,L_{OBC} + \left(\rho_{SVS}^{SM} - \rho_{OBC}^{SM}\right) L_{SM} + \rho_{OBC}^{SM}\left(1-\varepsilon_{OBC}\right)\varepsilon_{cav}\,L_{cav} - a_0^{BCS} - a_2^{BCS}\,dn_{OBC}^{2}}{dn_{OBC}} \qquad (3)$$

Where $dn_{OBC} = DN_{OBC} - DN_{SVS}$

The Earth view radiance is given by:

$$\bar{L}_{EV(\theta)} = \frac{1}{\rho_{EV(\theta)}^{SM}}\left\{\left(a_0^{BCS}(t) + b_1^{OBC}\,dn_{EV(\theta)} + a_2^{BCS}(t)\,dn_{EV(\theta)}^{2}\right) - \left(\rho_{SV}^{SM} - \rho_{EV(\theta)}^{SM}\right)\bar{L}_{SM}\right\} \qquad (4)$$

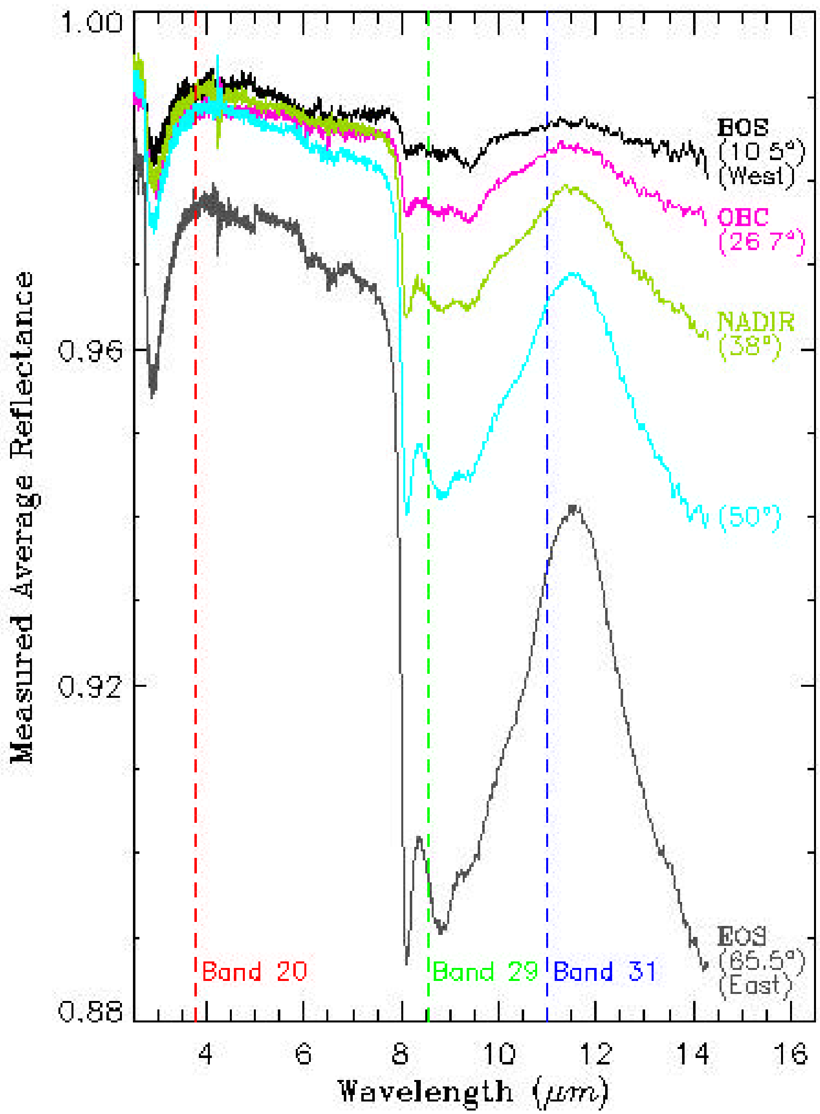
- Wavelength dependent parameters are weighted by the Relative Spectral Response RSR(λ)
- $a_0(t)$ and $a_2(t)$ are functions of the instrument temperature

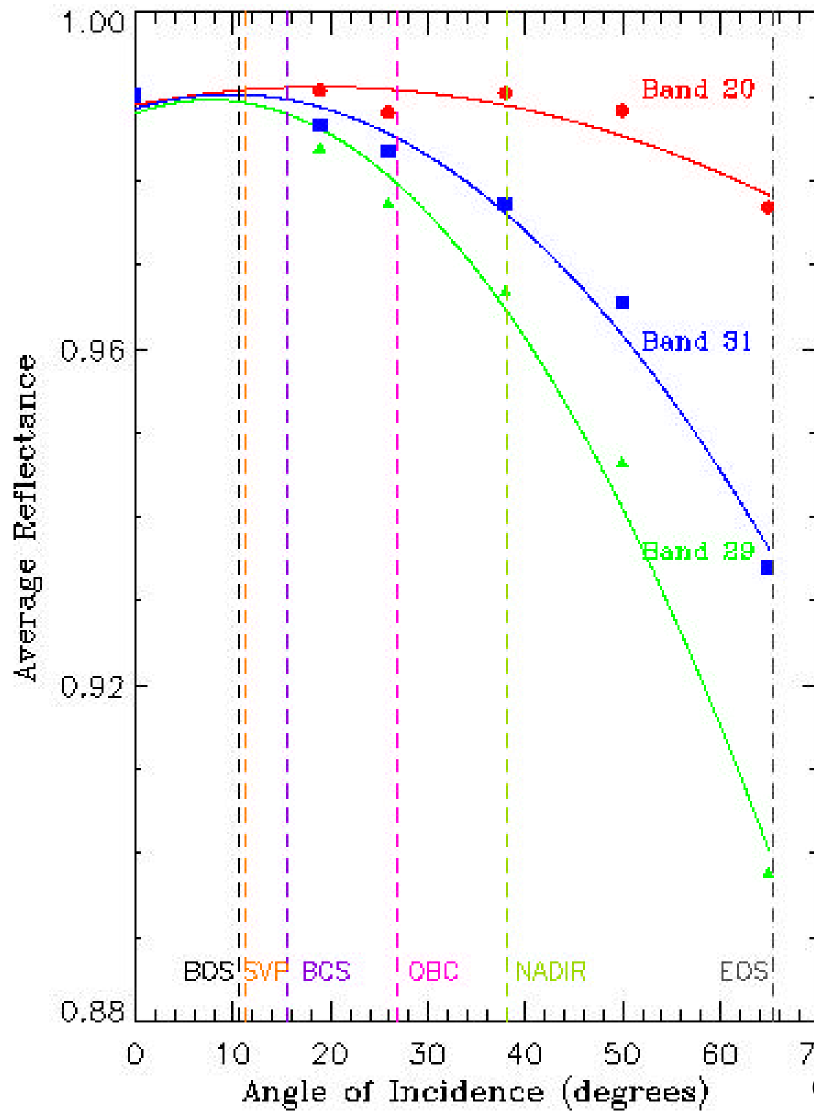
Earth View Radiance Is Retrieved From Both Pre-Launch and On-Board Parameters:

$$\bar{L}_{EV} = \bar{L}_{EV}\left[\underbrace{a_0(t),\, a_2(t)\,\rho_{AOI}^{SM},\, \varepsilon_{CAV},\, \varepsilon_{OBC},\, \Delta T_{OBC},\, RSR(\lambda)}_{\text{Pre-Launch Parameters (7)}},\, \underbrace{t,\, b_1^{OBC},\, T_{OBC},\, T_{SM},\, T_{CAV},\, DN_{OBC},\, DN_{SV},\, DN_{EV}}_{\text{On-Orbit Parameters (8)}}\right] \qquad (5)$$

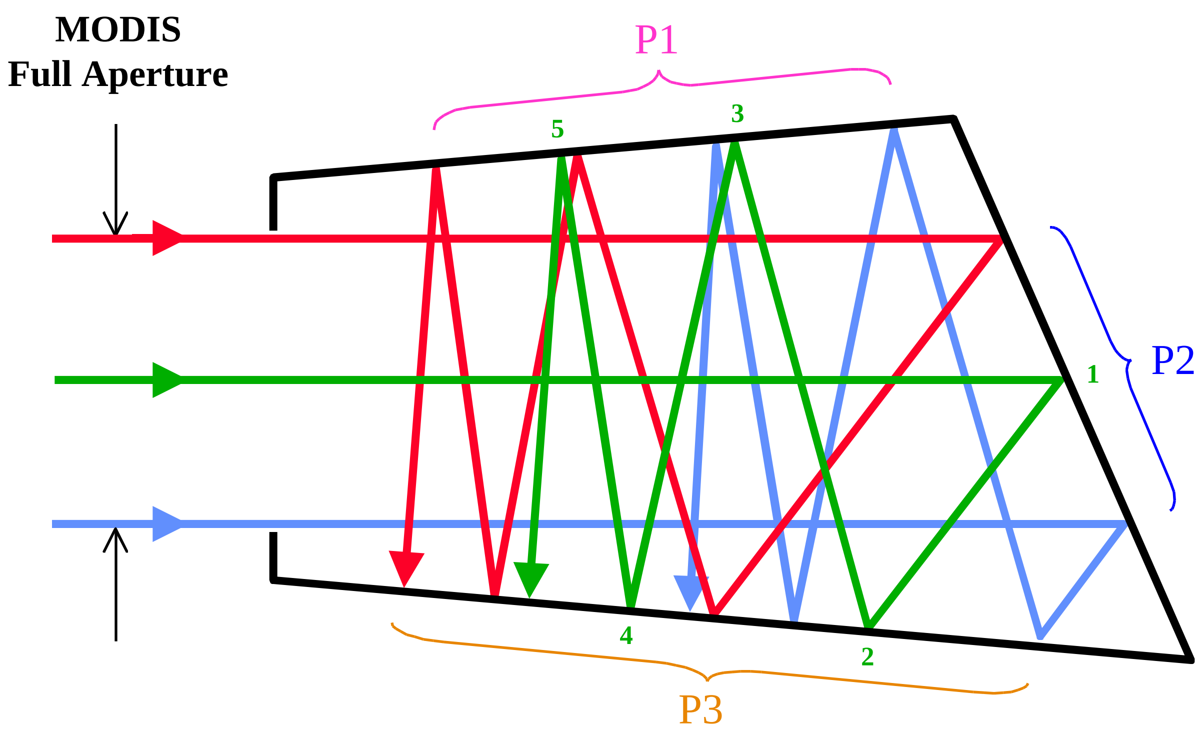
Pre-Launch Parameters (7) **On-Orbit Parameters (8)**

Lincoln Laboratory Measured Scan Mirror Average Reflectance





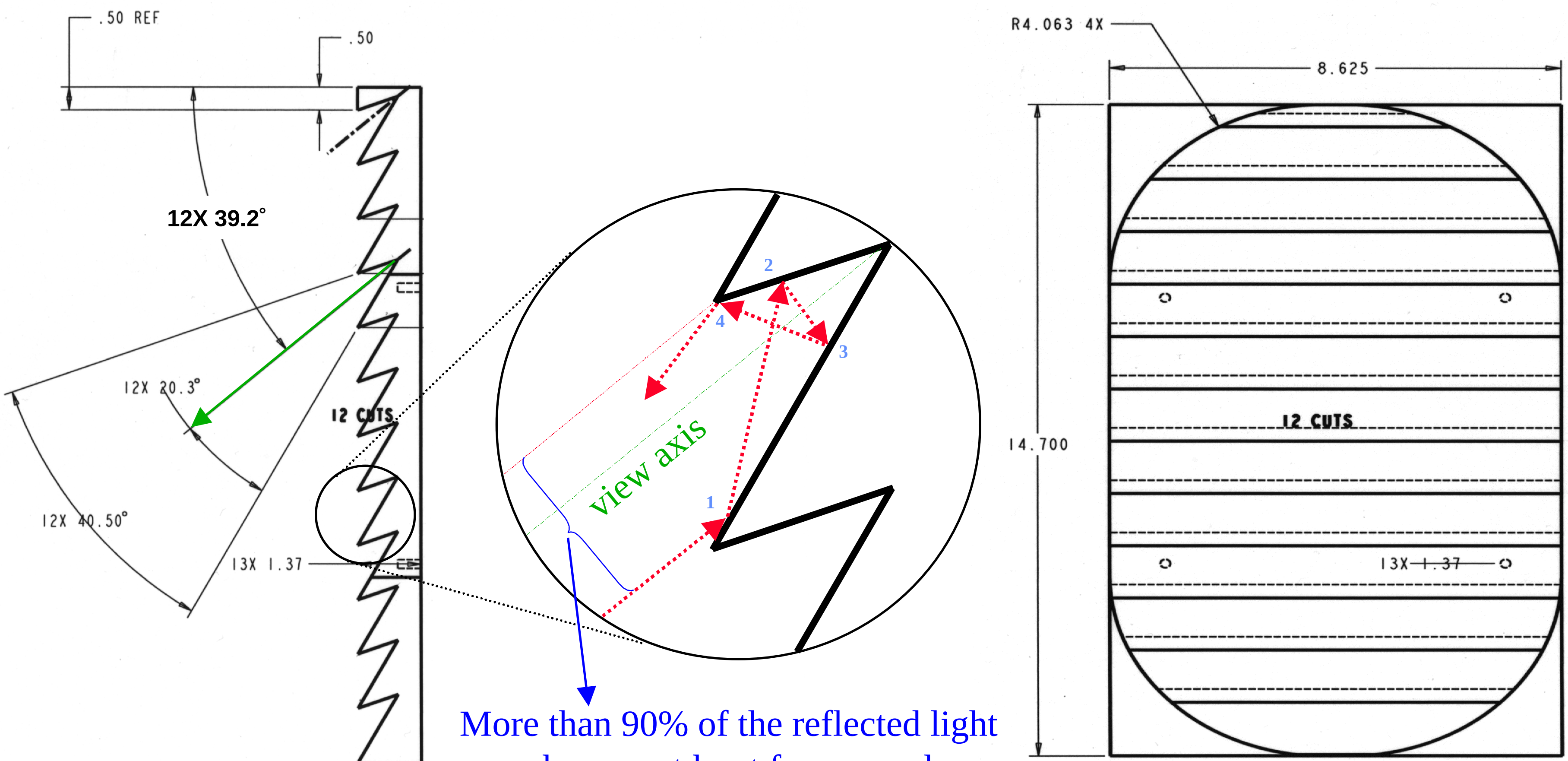
Blackbody Calibration Source (BCS)



$$L_{BCS} = W_{P1} \cdot L(\lambda, T_{P1}) + W_{P2} \cdot L(\lambda, T_{P2}) + W_{P3} \cdot L(\lambda, T_{P3})$$

BCS Trapezoid Configuration Achieves > 0.998 Emissivity (From SBRS)

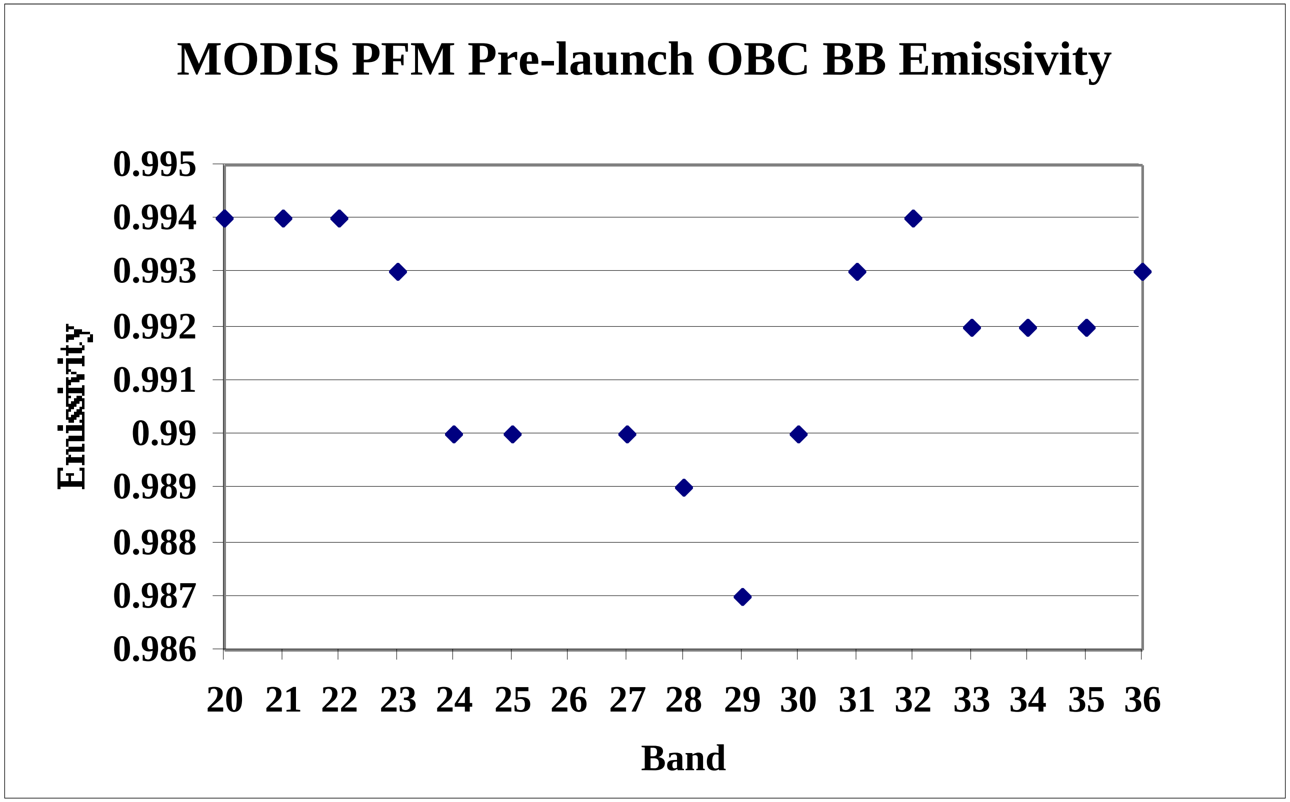
The MODIS On-Board Calibrator (OBC) Blackbody



More than 90% of the reflected light undergoes at least four specular reflections to achieve > 0.992 emissivity

Dimensions: Inches

OBC Blackbody Emissivity



New Calibration Algorithm

To capture the effects of the scan mirror polarized reflectance variation with scan angle, the scan mirror average reflectance is replaced with the system level measured Response versus Scan Angle, RVS(θ), which is normalized to unity at the scan angle for the OBC.

BCS Calibration Equation

$$RVS_{BCS}\ \varepsilon_{BCS}\ L_{BCS} + \left(RVS_{SVS} - RVS_{BCS}\right)\ L_{SM} = A_0^{BCS} + A_1^{BCS} dn_{BCS} + A_2^{BCS} dn_{BCS}^2 \qquad (1')$$

On Board Linear Gain

$$B_1^{OBC} = \frac{\varepsilon_{OBC}\ L_{OBC} + \left(RVS_{SVS} - 1\right)\ L_{SM} + \left(1 - \varepsilon_{OBC}\right)\ \varepsilon_{cav}\ L_{cav} - A_0^{BCS} - A_2^{BCS}\ dn_{OBC}^2}{dn_{OBC}} \qquad (3')$$

New Calibration Algorithm
(Continued)

The Earth View Radiance Retrieval Equation:

$$\bar{L}_{EV(\theta)} = \frac{1}{RVS_{EV}(\theta)} \left\{ \left(a_0^{BCS}(t) + B_1^{OBC} dn_{EV}(\theta) + a_2^{BCS}(t) dn_{EV}^2(\theta) \right) - \left(RVS_{SV} - RVS_{EV}(\theta) \right) \bar{L}_{SM} \right\} \quad (4')$$

On-orbit, for the LWIR bands, the RVS(θ) could be updated by measuring the scan mirror emission against the cold space background and applying the directional form of Kirchoffs Law.

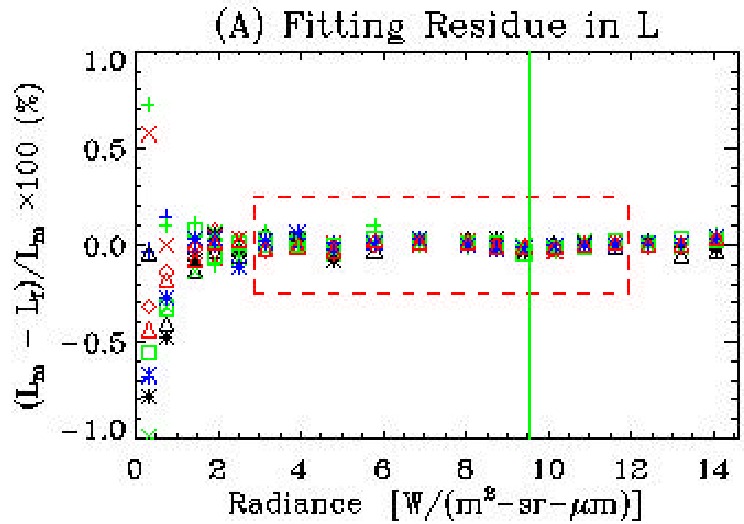
New Calibration Algorithm
(Continued)

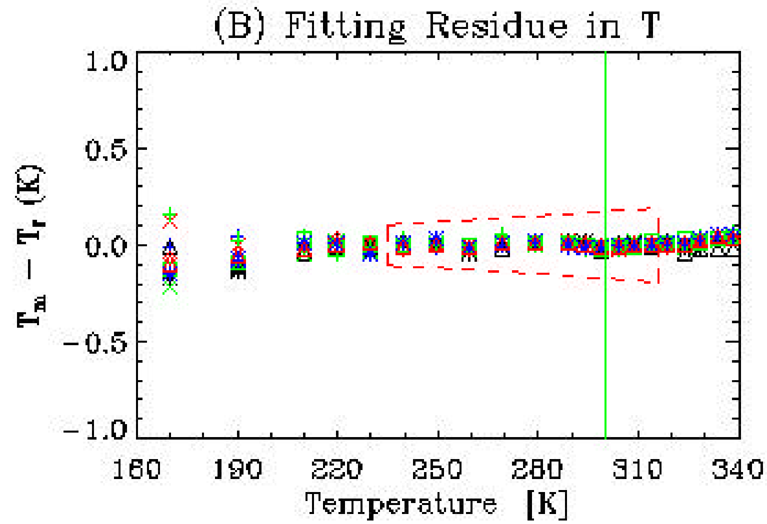
Changes made considering the use of RVS and the reduction of PV electronic xtalk:

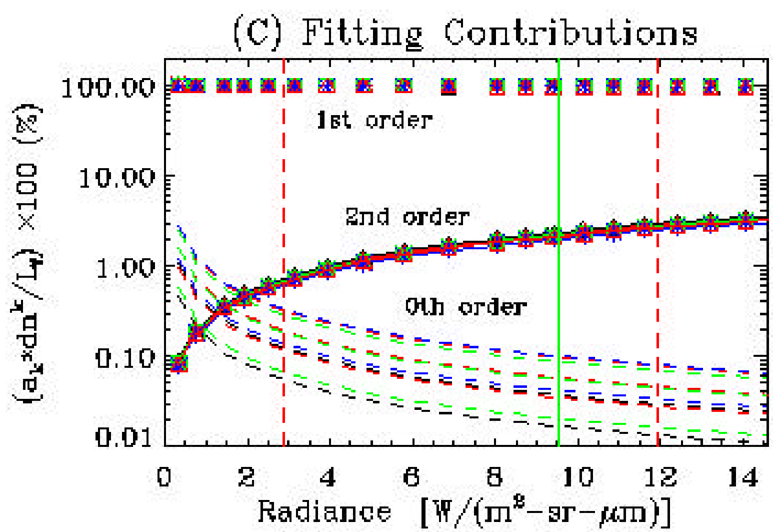
Previous Algorithm:	
$\rho(\theta)$	
B20, 22, 23:	Cubic
All other bands	Quadratic

New Algorithm:	
$RVS(\theta)$	
PV bands :	Linear
PC bands	Quadratic

B31 (11.0 µm) L vs DN Quadratic Fitting Results at Nominal Plateau (273 K)







Solid Line: L_{typ}

Dashed Line/Box: $(0.3L_{typ} - 0.9L_{max})$ ×

± 1/2 Goal

At Launch General Sensor Status

Sensor Characteristic (not accurately represented in L1B algorithm)	Impact on Data Set	Expected Relation to Terra Data Set
Mirror Side Differences (RVS)	10 km stripes; minimum at AOI of OBC device (RSB between NADIR and EOS; TEB between NADIR and BOS); growing at other AOIs	RSB - OK RVS laboratory measurement; expect minimum impact
		TEB-RVS not measured, expect significant impact
Channel-to-channel differences	1 km stripes; minimum at *LOBC-Cal* and increases for radiance values away from *LOBC-Cal*	RSB: using linear calibration; force *a0* (*L0*) to 0; expect bigger effect at low radiance levels (detector non-linearity) and little elsewhere until radiance nears saturation-radiance
		TEB-MWIR/ PV LWIR (Bands 20 - 30); using only linear calibration; likely a problem until "true" *b0*, *b2* determined from OBC-BB elevated temperature cycles and scene data drive fix
		TEB- PC LWIR (Bands 31 - 36); adequate pre-launch calibration, do not expect a problem
Cross-talk (optical or electronic)	Ghosts of surface features appear in atmospheric bands when cross-talk from surface band into atmospheric band	Present in B33-36 if B31 optical leak not preperly corrected; present in SW/MWIR

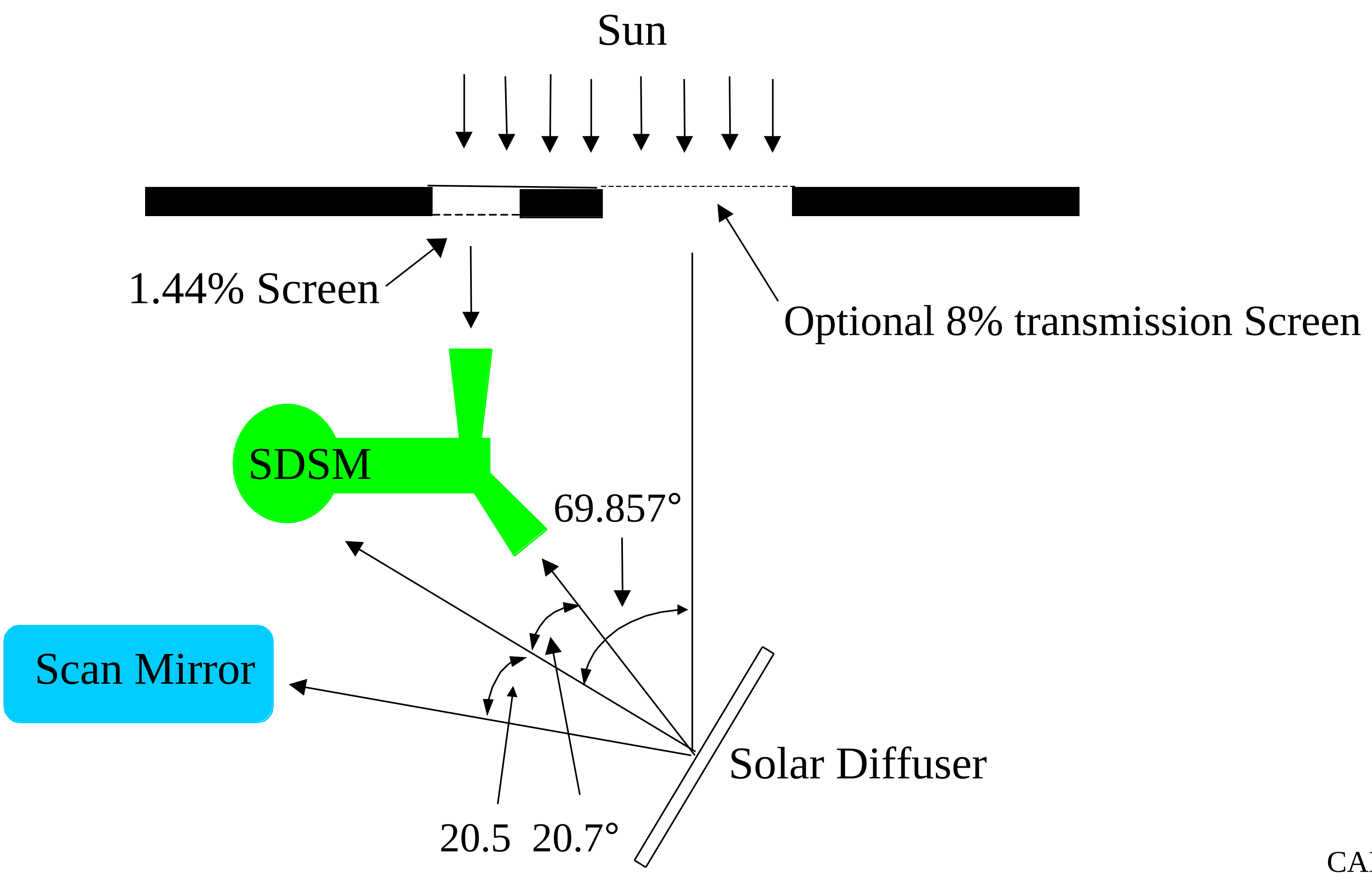
Brief Description of Calibration Testing (On-orbit)

- RSB: from SD; linear calibration, through zero
  - Each detector, sub-frame and mirror side treated independently
- TEB: from OBC-BB
  - Each detector and mirror side treated independently
- General Sensor Status

Solar Diffuser Stability Monitor (SDSM)

- Long term solar diffuser plate trend monitoring
- SDSM contains 9 detectors with cwl close to 9 MODIS bands: 8, 3, 11, 4, 1, 15, 2, 17, and 18 respectively
- The BRDF (or relative BRF) of the SD for the SDSM viewing direction was not measured pre-launch
- On-orbit calibration: MODIS yaw maneuvers (OA-09), April 25 & 26, 2000. On-orbit measurement uncertainty of the SD **relative** BRF for the SDSM viewing direction is less than 0.3%

Solar Diffuser Stability Monitor (SDSM)



BRDF Round Robin

Preprint Results: Validation of SBRS Diffuser Plate Laboratory Measurement Techniques

- The BRDF RR data from SBRS was obtained from three samples: a) Spectralonâ ; b) Pressed PTFE; c) Sintered PTFE
- SBRS BRDF Spectralonâ measurements were validated to have an uncertainty less than 1.4 % for all incident angles
- SBRS BRDF Spectralonâ measurements at 30°, 45°, and 60° indicate better than 0.5% agreement with NIST (Early et al., 2000, accepted by JAOT). The MODIS on-orbit SD-Solar incident irradiance zenith angle 60°
- On-orbit validation of the Solar Diffuser **relative** BRDF agrees with SBRS pre-launch measurements to better than 1%

BRDF Round Robin

Preprint Results: Figure 24, Early et al., 2000

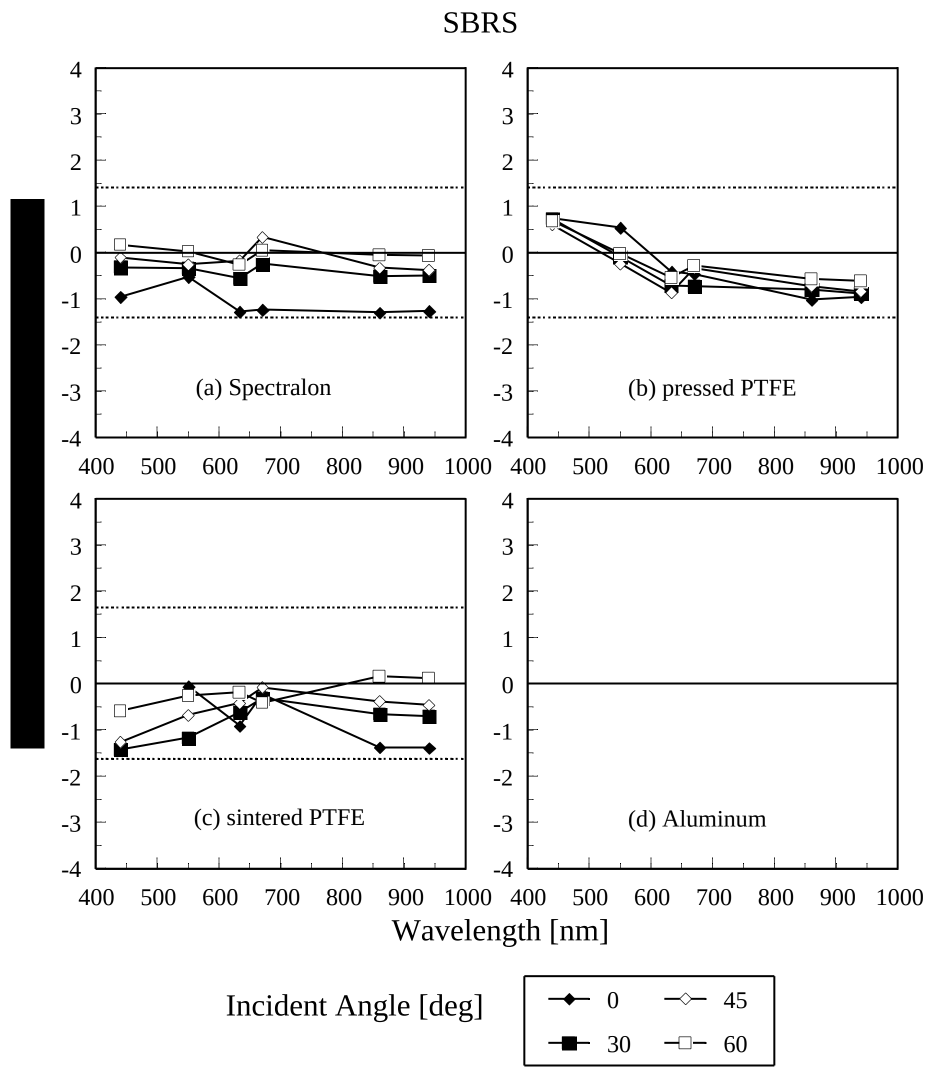
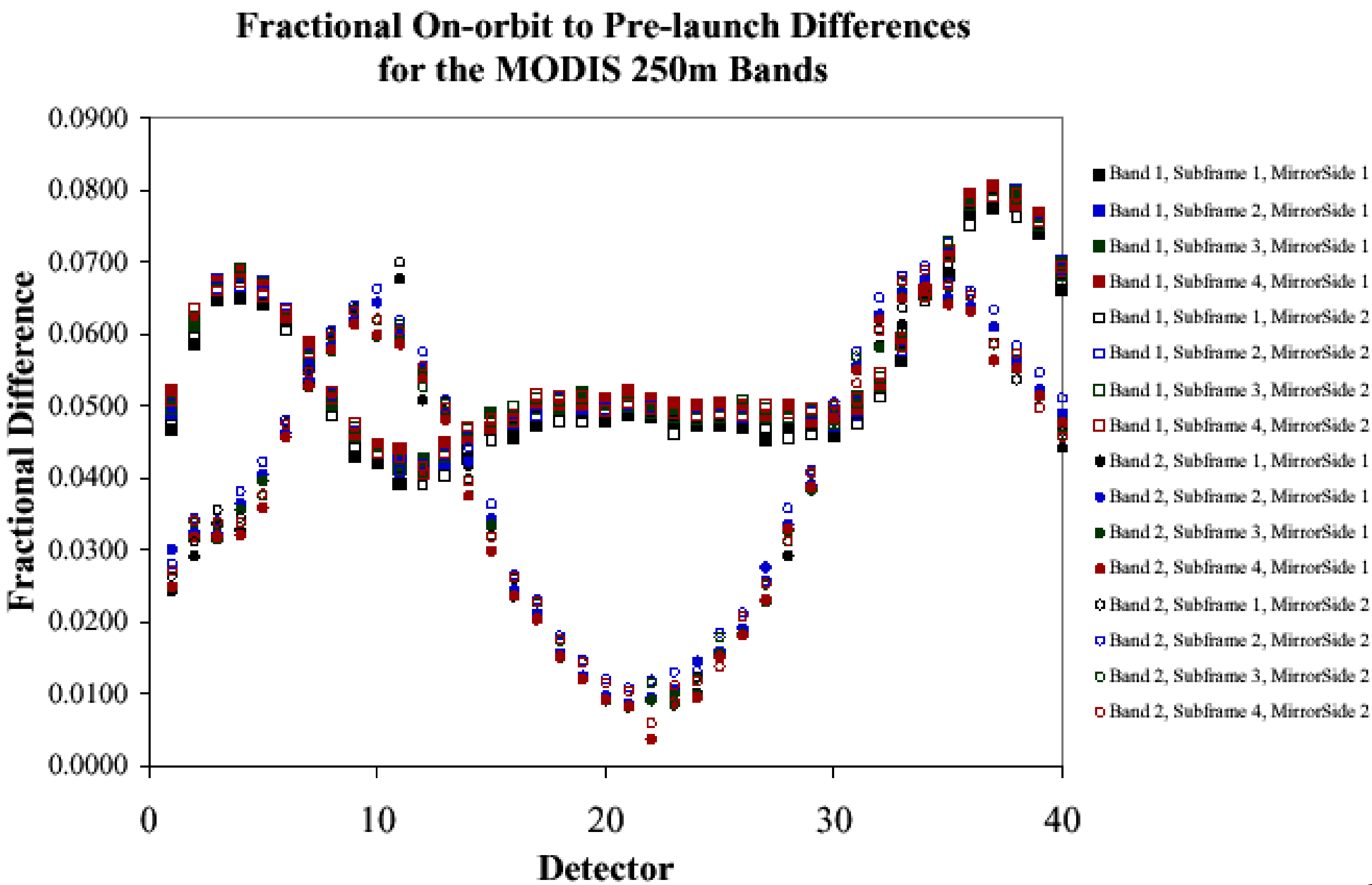
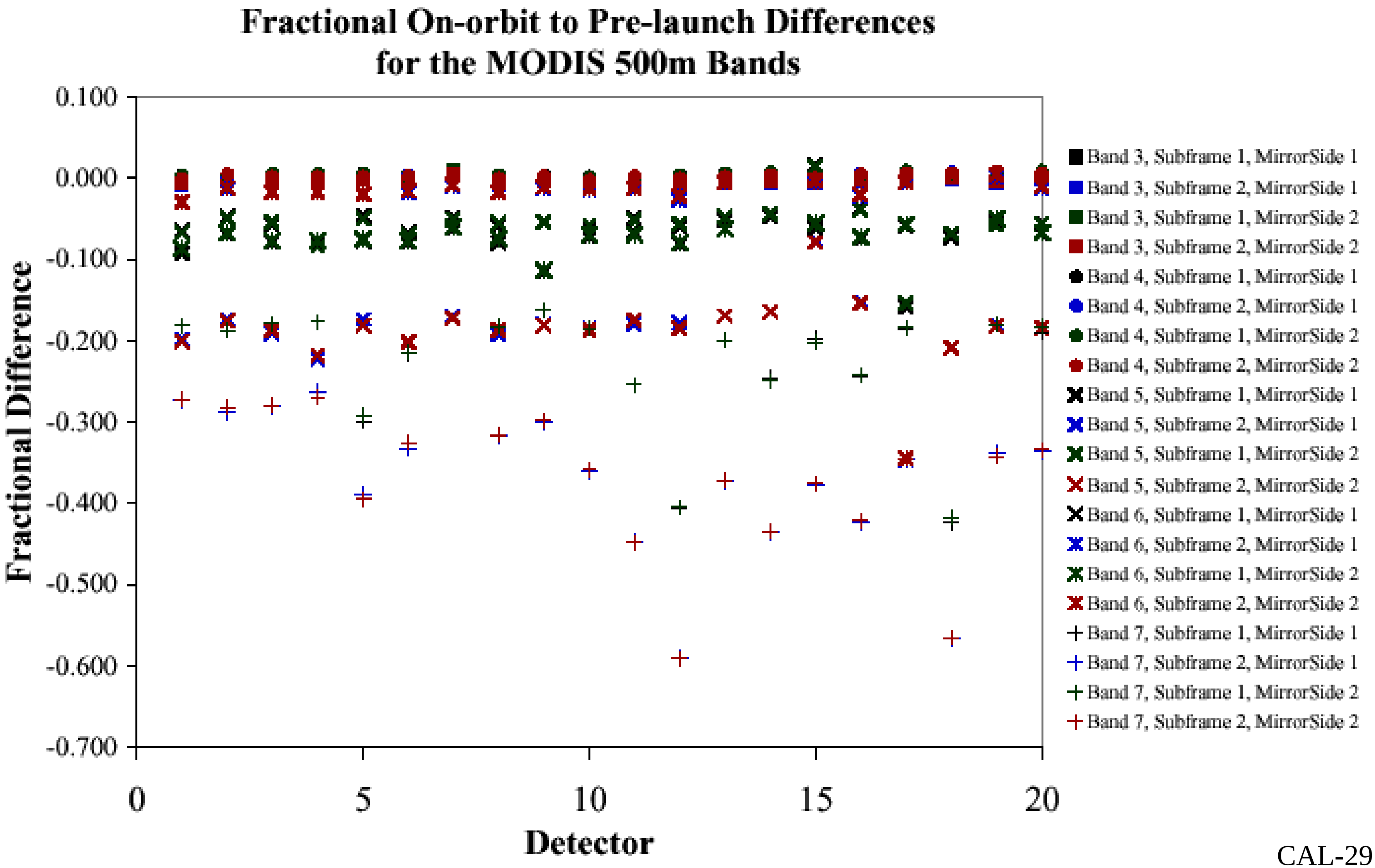


Figure 24

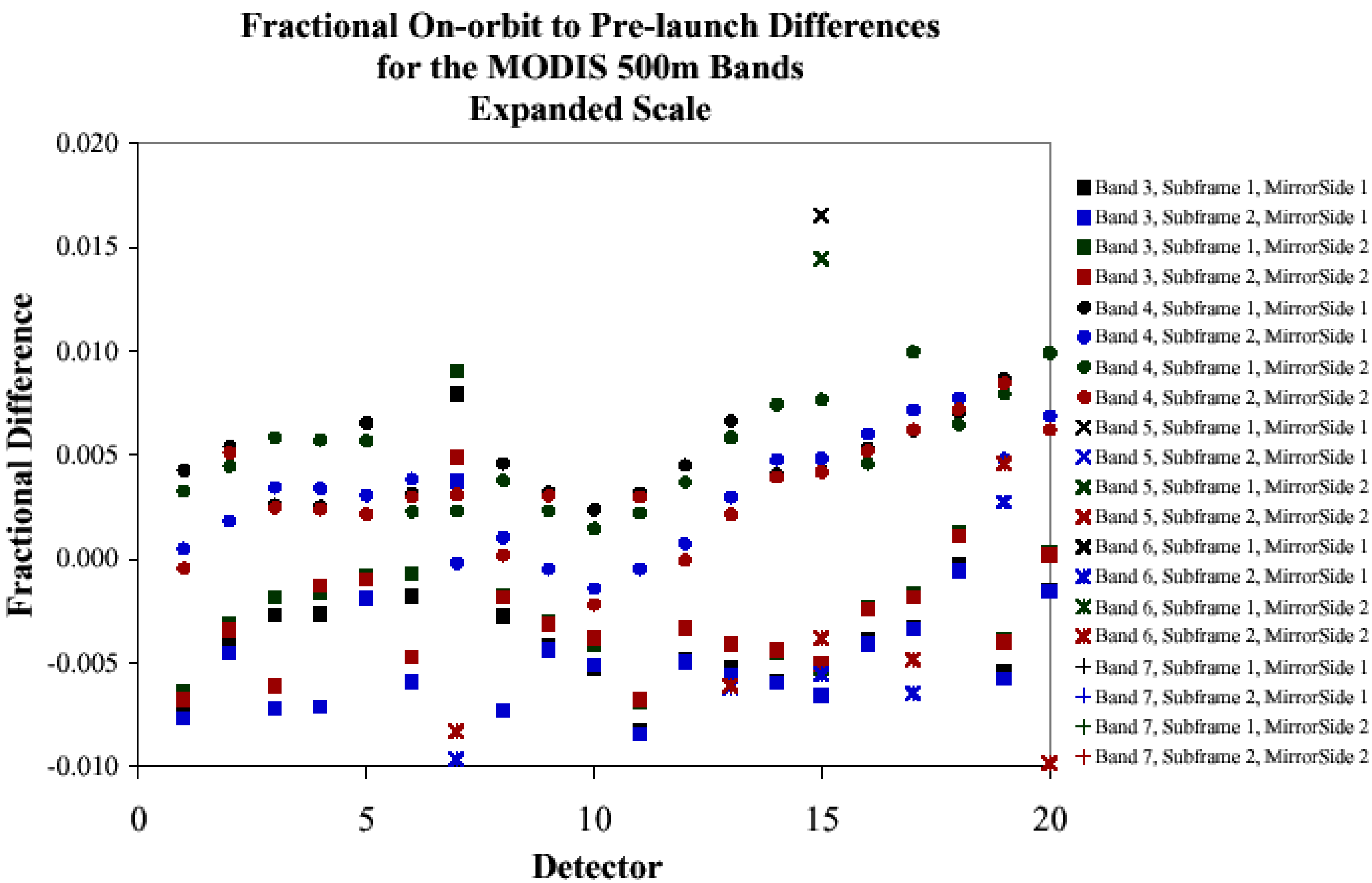
On-orbit to Pre-launch 250m m_1 Coefficients



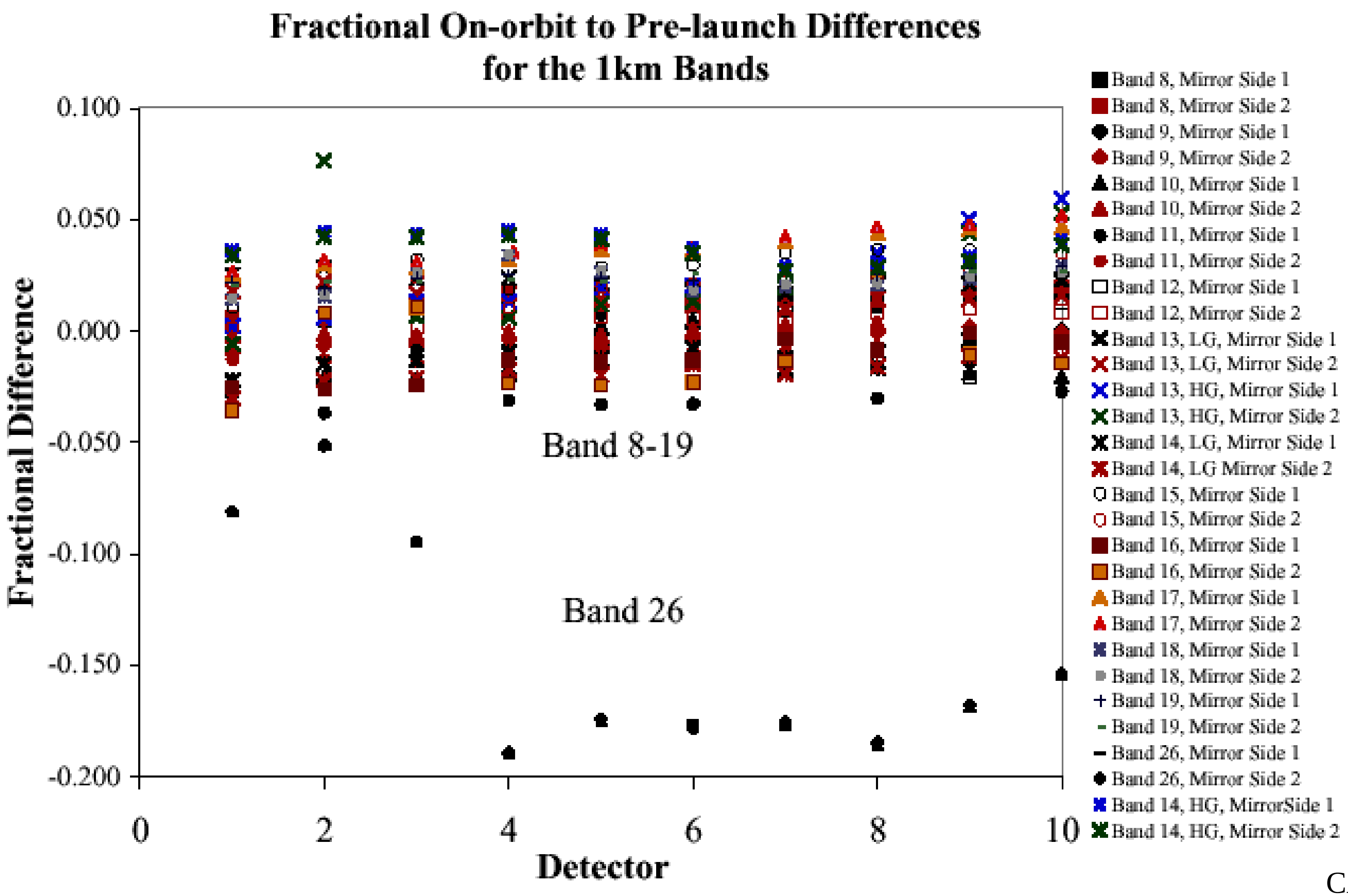
On-orbit to Pre-launch 500m m_1 Coefficients



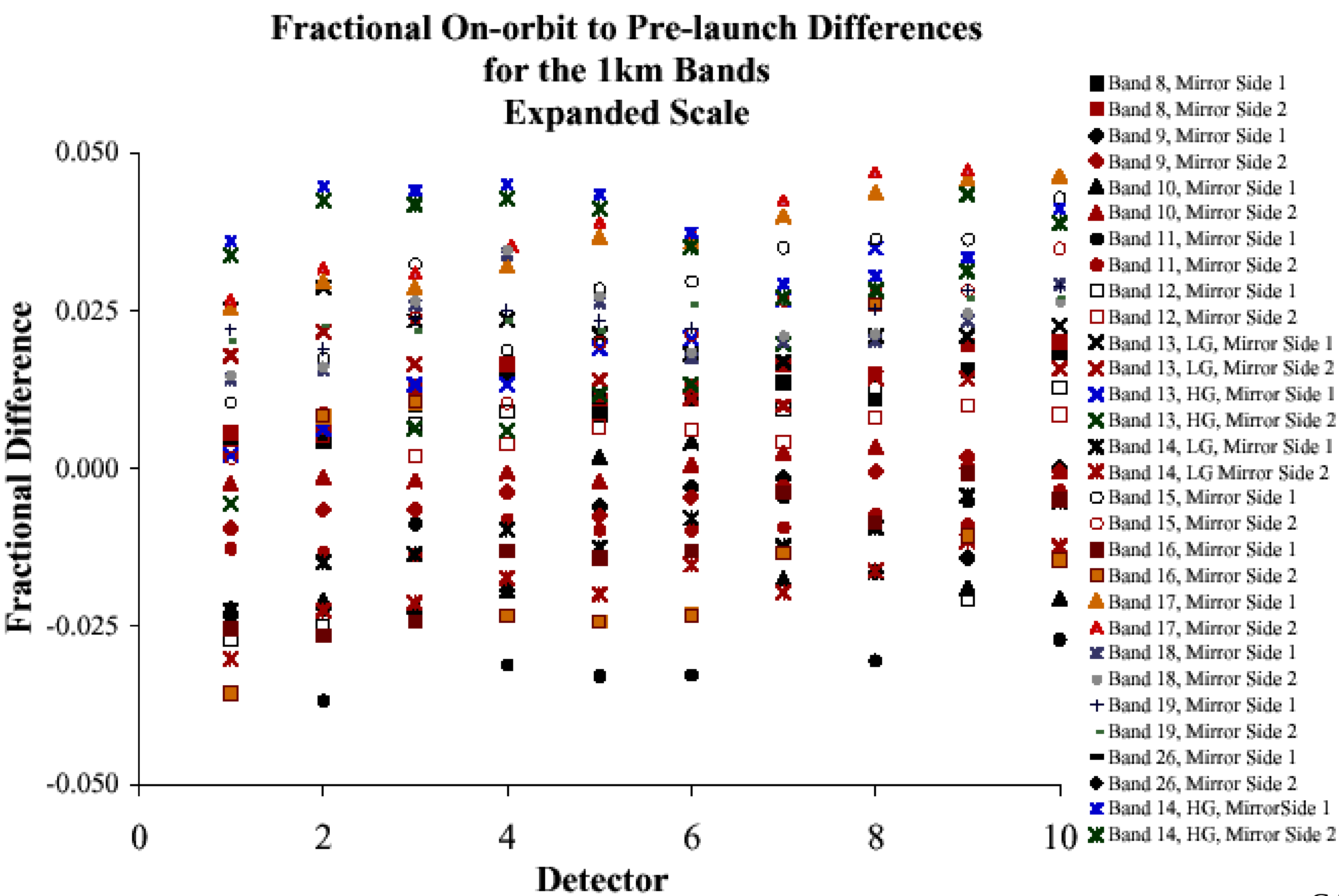
On-orbit to Pre-launch 500m m_1 Coefficients



On-orbit to Pre-launch 1km m_1 Coefficients



On-orbit to Pre-launch 1km m_1 Coefficients

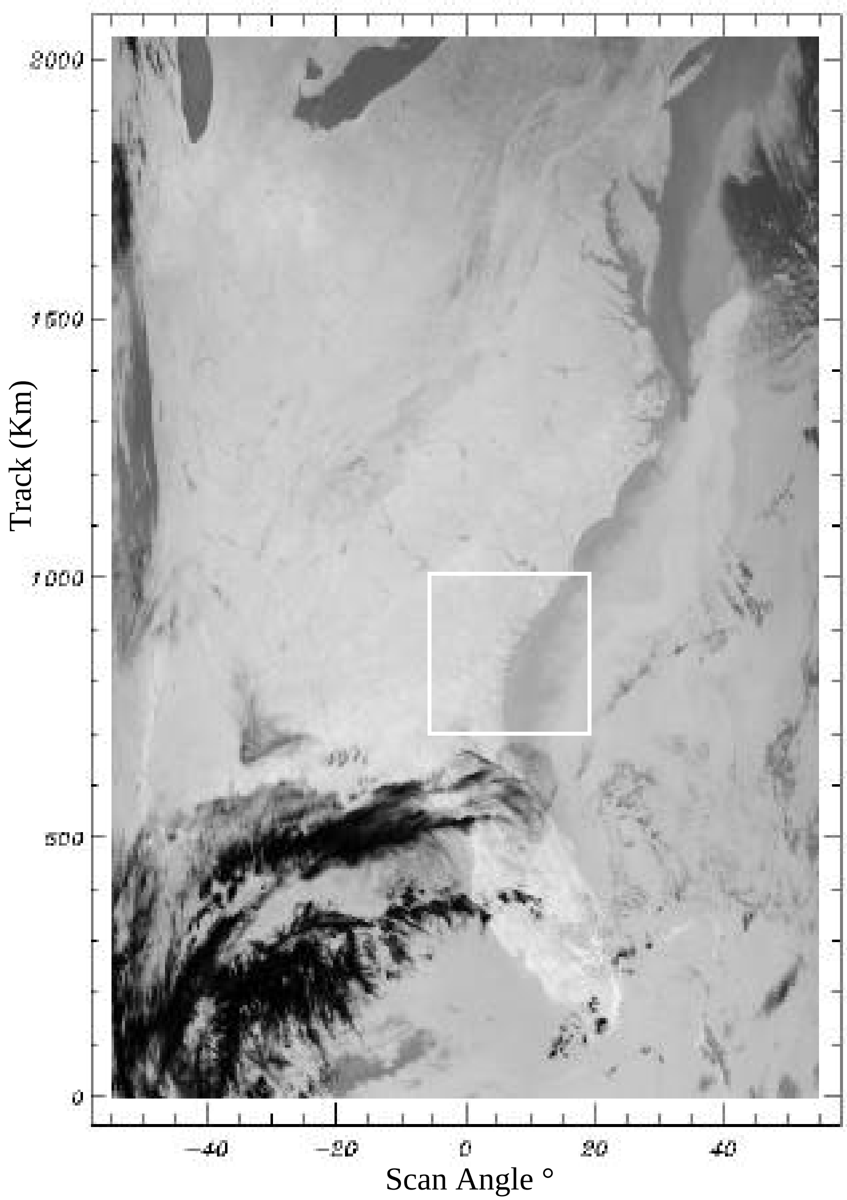


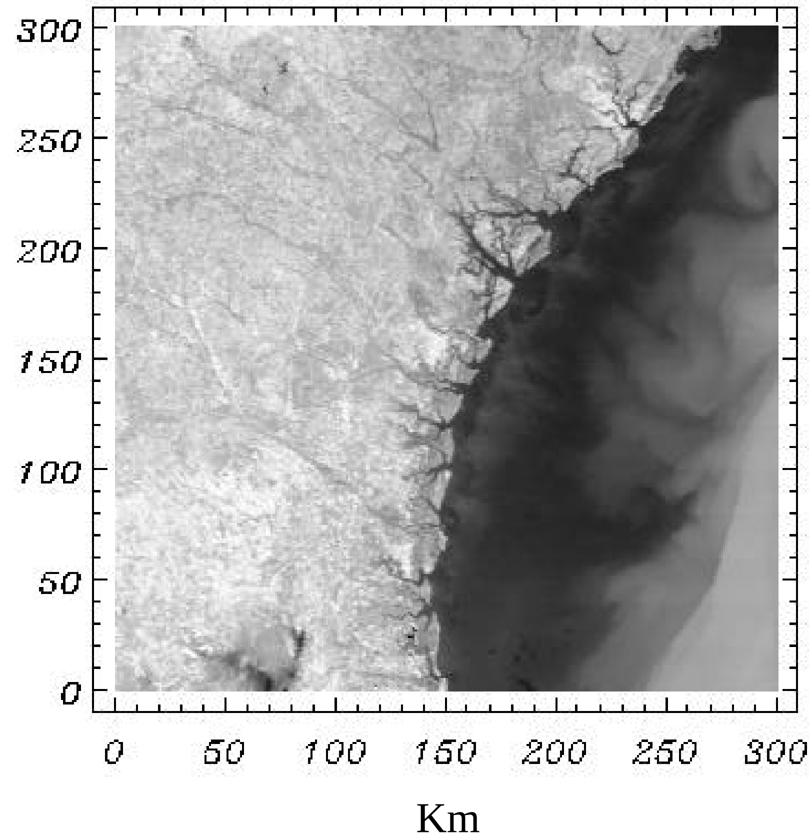
TEB On-orbit Calibration: OBC BB

- Thermal emissive bands were calibrated with a quadratic algorithm at pre-launch
- Set PV bands a0 and a2 to 0 due to SAM resistors change
  - no retest after resistors change
- On-orbit analysis of using OBC retrieved b0 and b2
  - Prelaunch 21 BCS levels from 170K to 340K (not all used for every band)
  - On-orbit OBC BB warm-up & cool-down temperature ranging from 270K to 315K

PFM B31 US East Coat (066.1630; Day Mode)

Enhanced Radiance Images Using Pre-launch a0 and a2

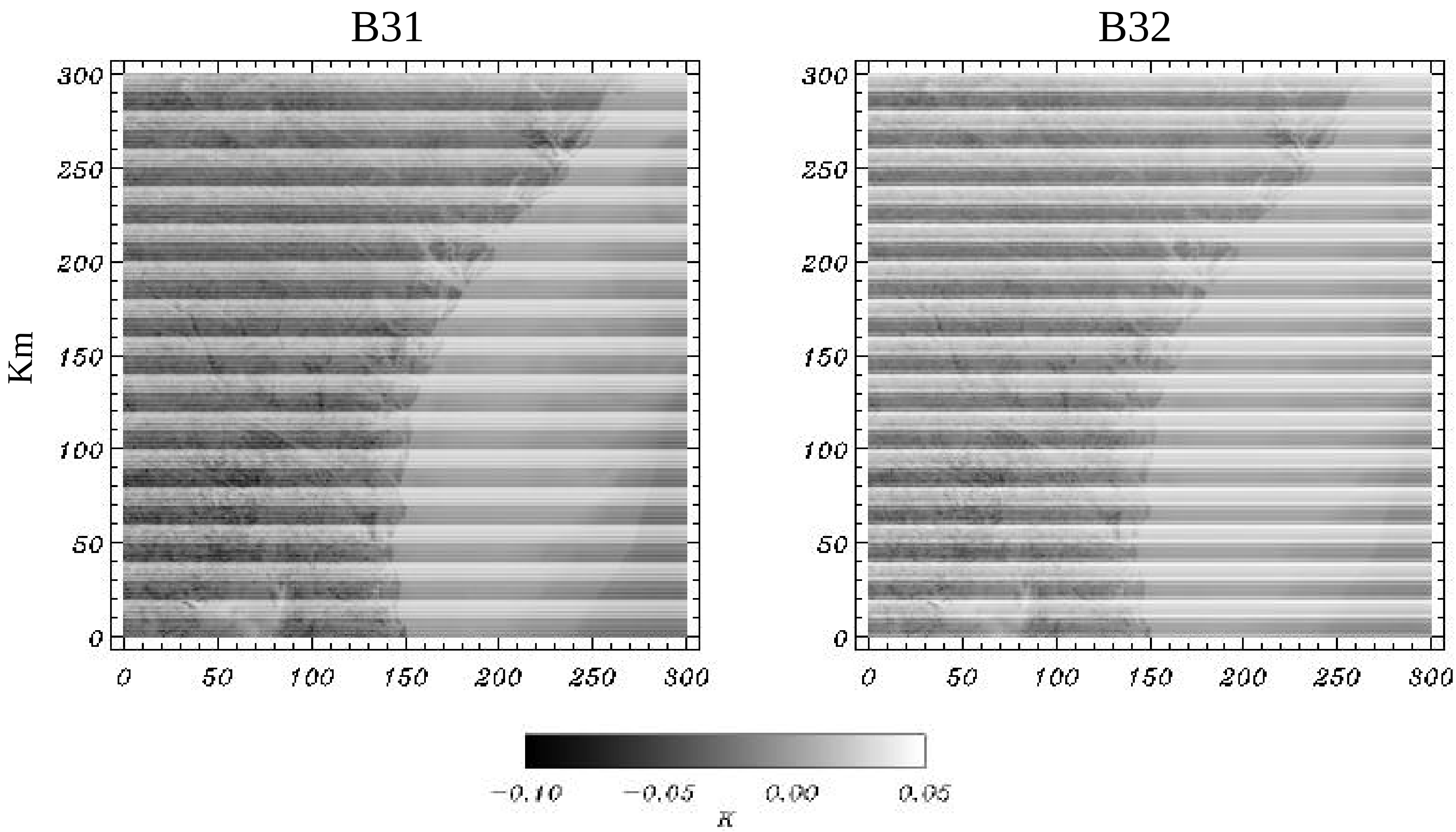




TOA B31 & B32 Temperature Retrieval Difference Between a0, a2 (Pre-launch) and b0, b2 (On-orbit)

$$\Delta T = T_{EV}(b_0, b_2) - T_{EV}(a_0, a_2)$$

Images begin with mirror side 1



General Sensor Status

Sensor Characteristic (not accurately represented in L1B algorithm)	Impact on Data Set	Expected Relation to Terra Data Set	Actually Observed on Terra
Mirror Side Differences (RVS)	10 km stripes; minimum at AOI of OBC device (RSB between NADIR and EOS; TEB between NADIR and BOS); growing at other AOIs	RSB - OK RVS laboratory measurement; expect minimum impact	Yes
		TEB-RVS not measured, expect significant impact	Yes
Channel-to-channel differences	1 km stripes; minimum at *LOBC-Cal* and increases for radiance values away from *LOBC-Cal*	RSB: using linear calibration; force *a0* (*L0*) to 0; expect bigger effect at low radiance levels (detector non-linearity) and little elsewhere until radiance nears saturation-radiance	Yes
		TEB-MWIR/ PV LWIR (Bands 20 - 30); using only linear calibration; likely a problem until "true" *b0*, *b2* determined from OBC-BB elevated temperature cycles and scene data drive fix	Yes
		TEB- PC LWIR (Bands 31 - 36); adequate pre-launch calibration, do not expect a problem	Yes
			Saw-tooth stripes observed within a scan line in Ocean Colar data sets
			20 km banding stripes observed in Ocean Color
Cross-talk (optical or electronic)	Ghosts of surface features appear in atmospheric bands when cross-talk from surface band into atmospheric band	Present in B33-36 if B31 optical leak not preperly corrected; present in SW/MWIR	Technique to remove appearance of effect used for improved B31 leak into B32-36

Calibration Strategies

- Calibration strategies ➻ Image effects
  – Vulnerable to RSB ch-ch stripes due to SIS100 calibration uncertainty
  – Vulnerable to TEB MWIR stripes due to SAM resistor change
  – Vulnerable in SMIR focal plane data if electronic cross-talk varies by channel

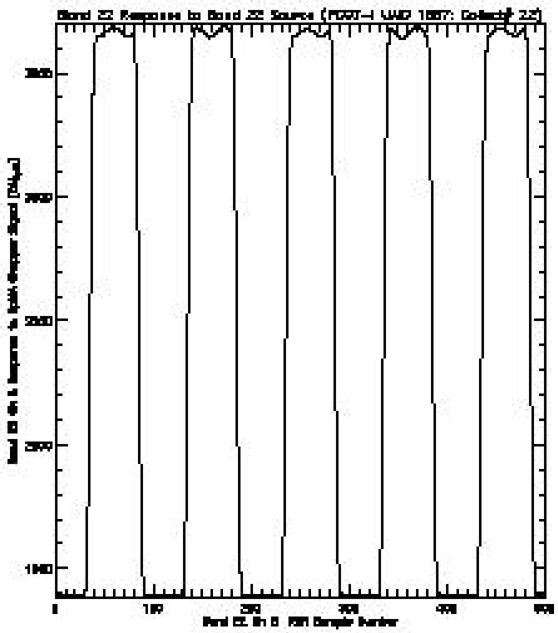
  – Striping effects more pronounced than expected

Electronic Cross-talk

- What is Electronic Cross-talk
- How did we first see it, and what does it look like
- PFM status at-launch
- On-orbit efforts to mitigate behavior
- Configurations selected for further study
- Moon-in-Space-View-Port results
- SRCA (Spatial) results
- Summary of electronic cross-talk performance characterizations - Discussion Aid
- What still needs to be done

What is Electronic Cross-talk

- Readout integrating capacitor fails to return to baseline voltage following signal reset
- First realized nature of problem from RSR testing
  - Actually “seen” as negative dns & sub-frame differences, B5-7
  - Nearly impossible to detect when observing flat scenes; these calibrations in error, but cannot detect that
- Structured scene analysis in 1998 showed effects of 5-10% or more in SWIR bands & several percent in 4-µm SST bands
- Observed in both SW/MWIR and PV LWIR bands (5-7, 20-30)
- Focus here on SW/MWIR bands (5-7, 20-26)



SF1

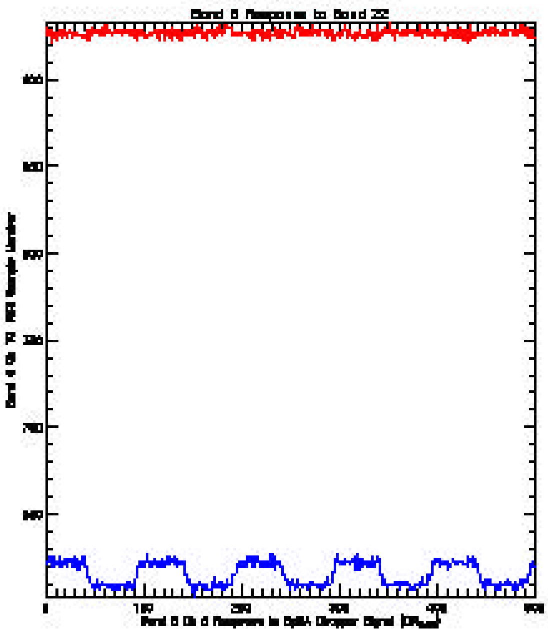
SF2

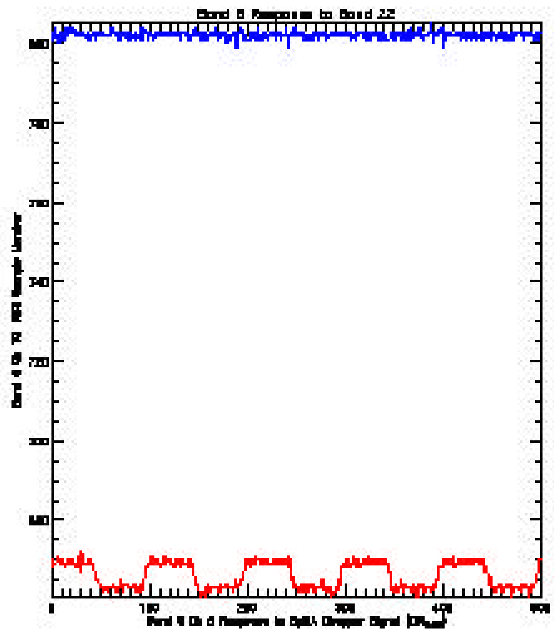
L_{SpMA} = 1.25 Watts/m^2/sr/μm

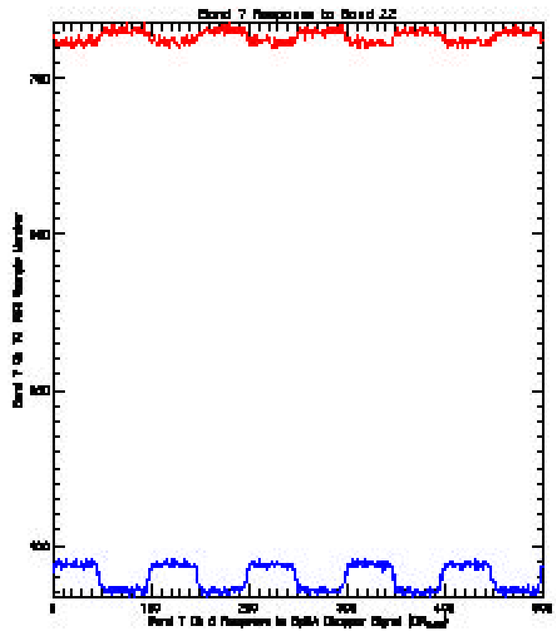
= 0.66 L_{max}

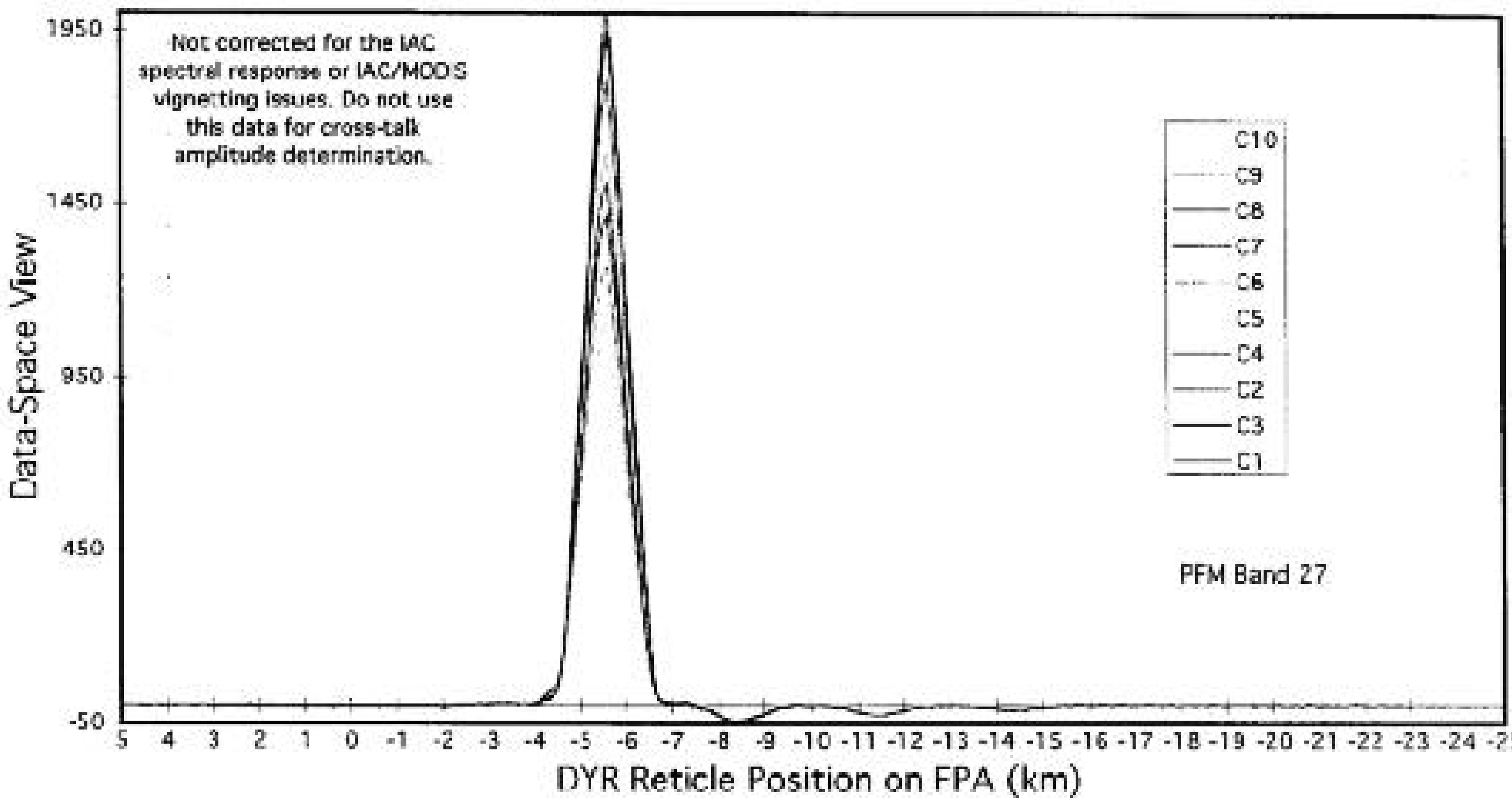
= 1.86 L_{typ}

= 1.86 L_{cloud}

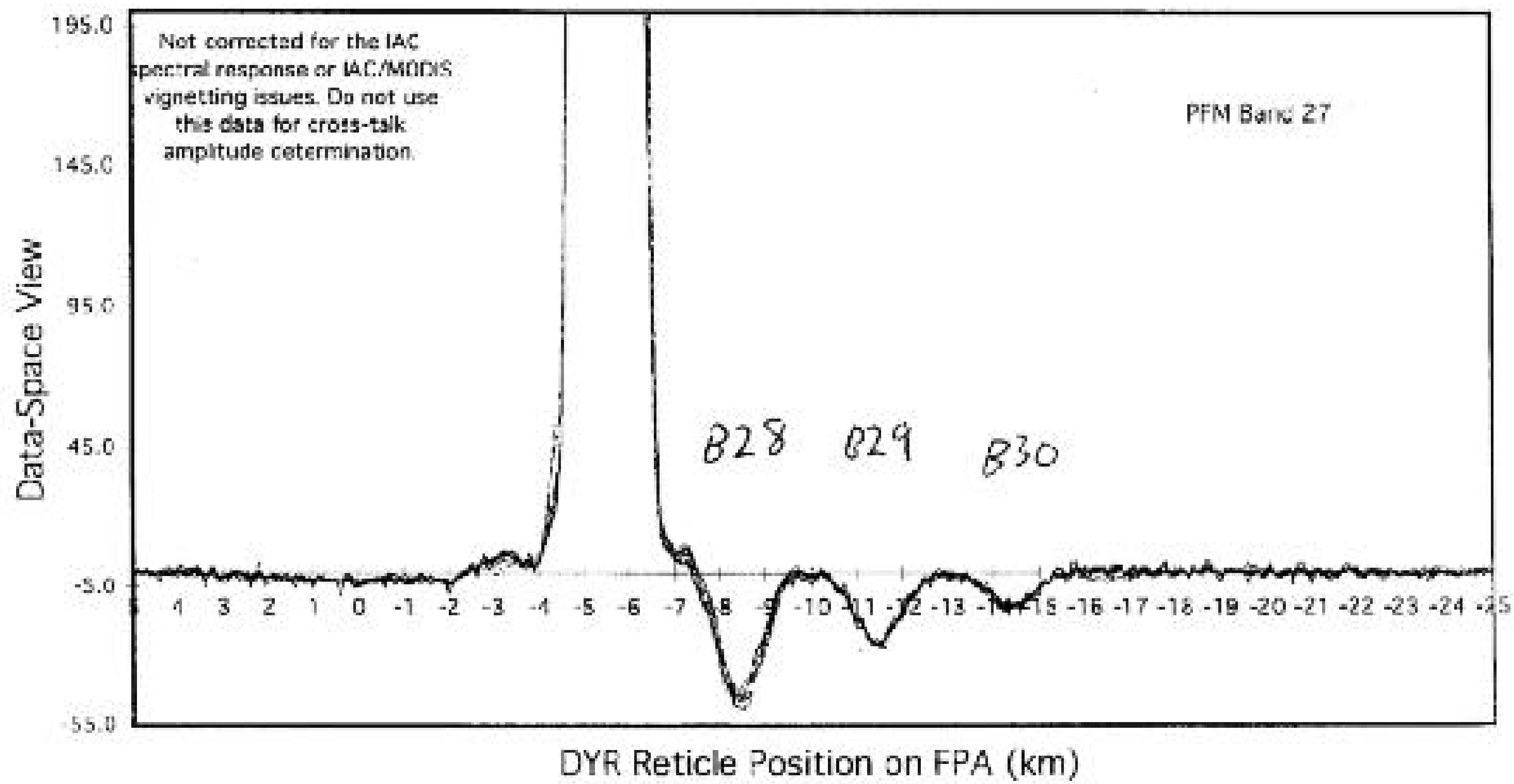






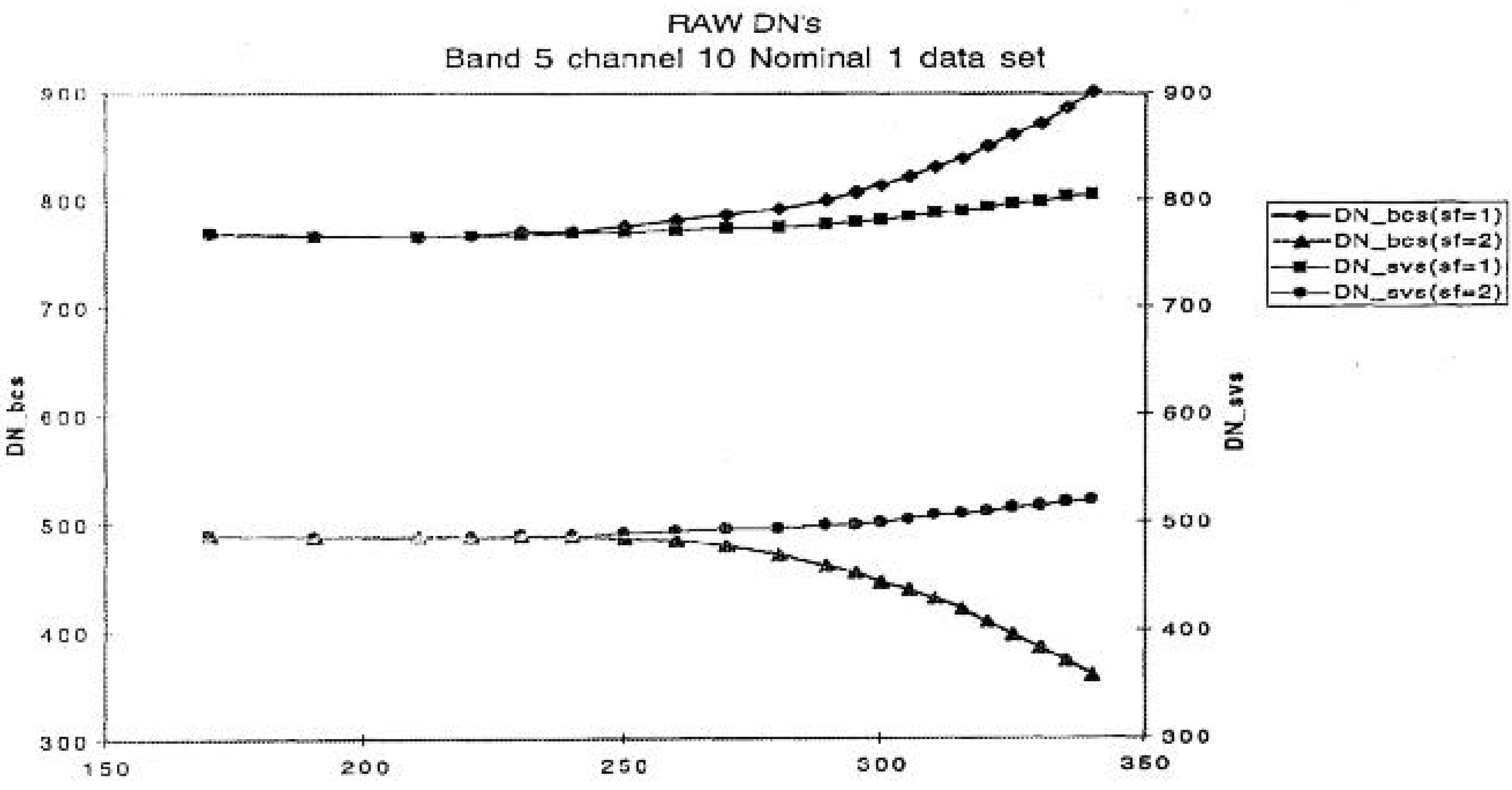


Not corrected for the IAC spectral response or IAC/MODIS vignetting issues. Do not use this data for cross-talk amplitude determination.
1950
1450
950
450
-50
Data-Space View
C10
C9
C8
C7
C6
C5
C4
C2
C3
C1
PFM Band 27
5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -14 -15 -16 -17 -18 -19 -20 -21 -22 -23 -24 -25
DYR Reticle Position on FPA (km)

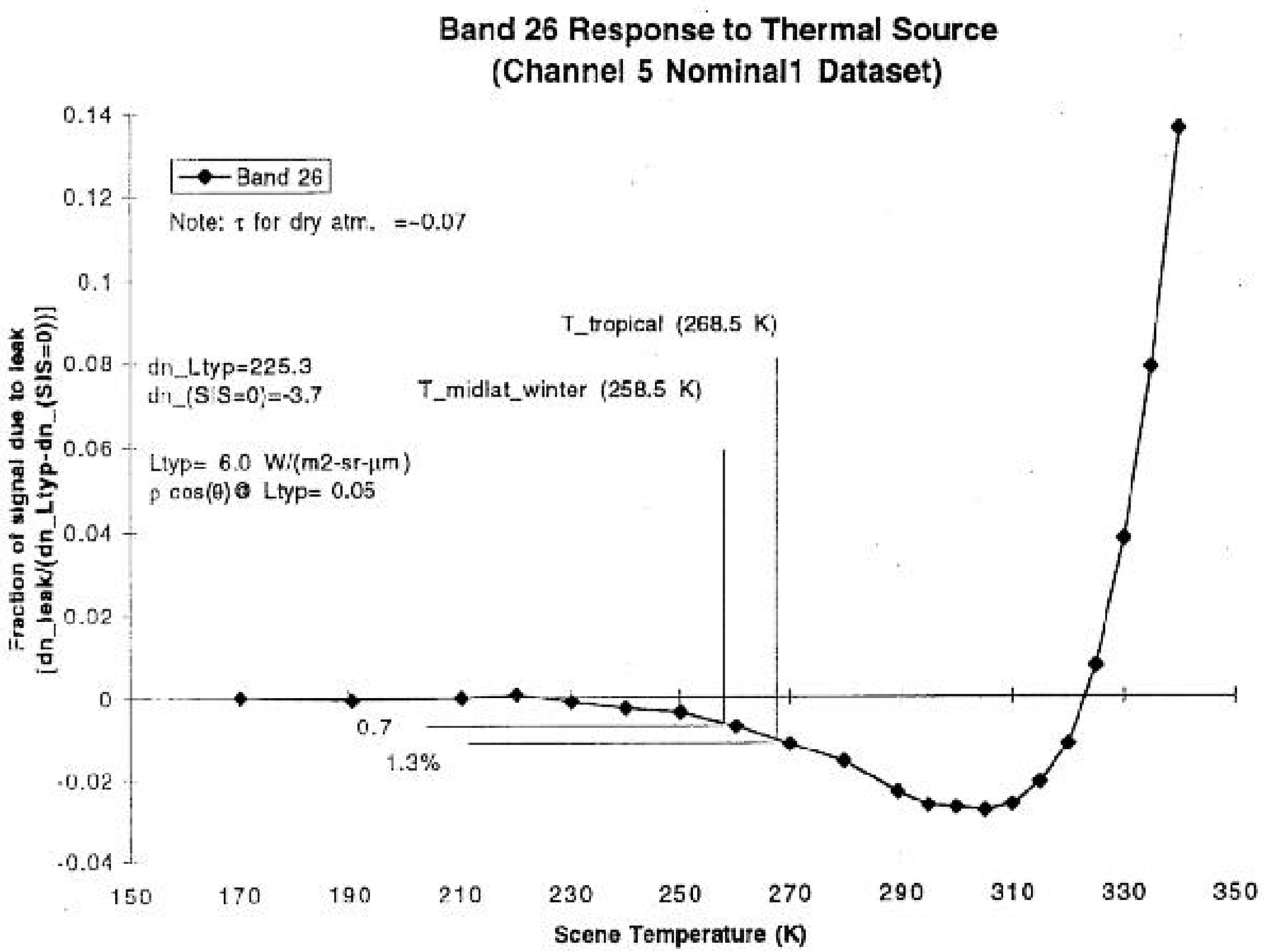


Not corrected for the IAC spectral response or IAC/MODIS vignetting issues. Do not use this data for cross-talk amplitude determination.
PFM Band 27
B28
B29
B30
Data-Space View
DYR Reticle Position on FPA (km)

Band 5 Sub-frame Difference

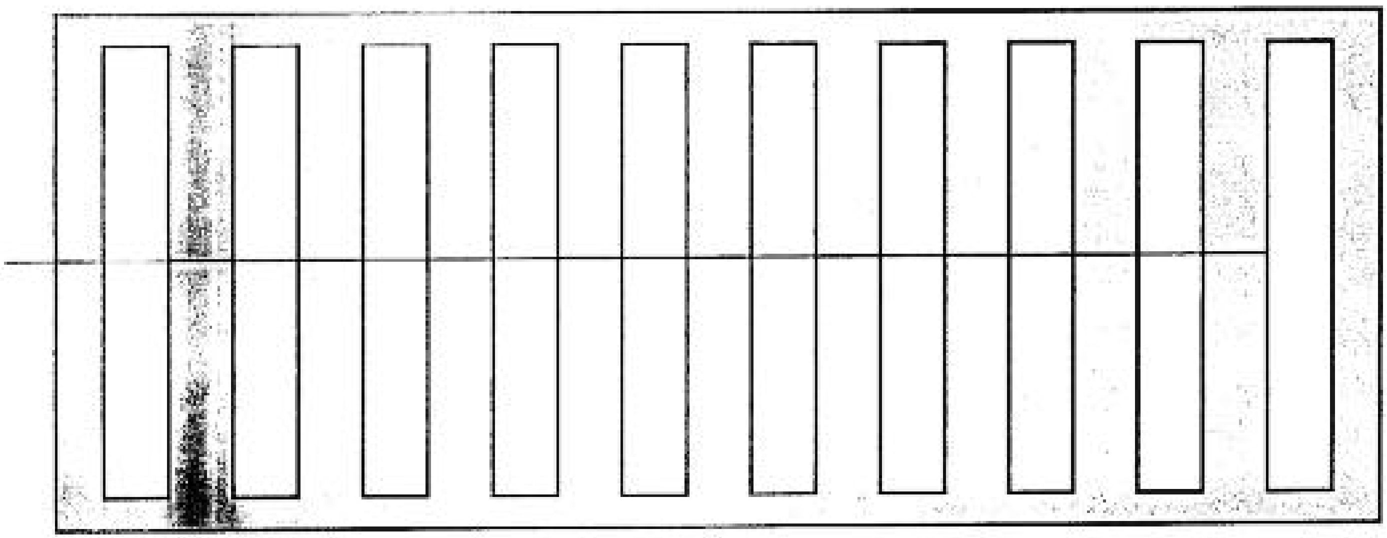


Band 26 Response to Thermal Source



Structured Scene Analysis

Consider a structured scene incident on the FPA 10km (track) x 30km (scan)



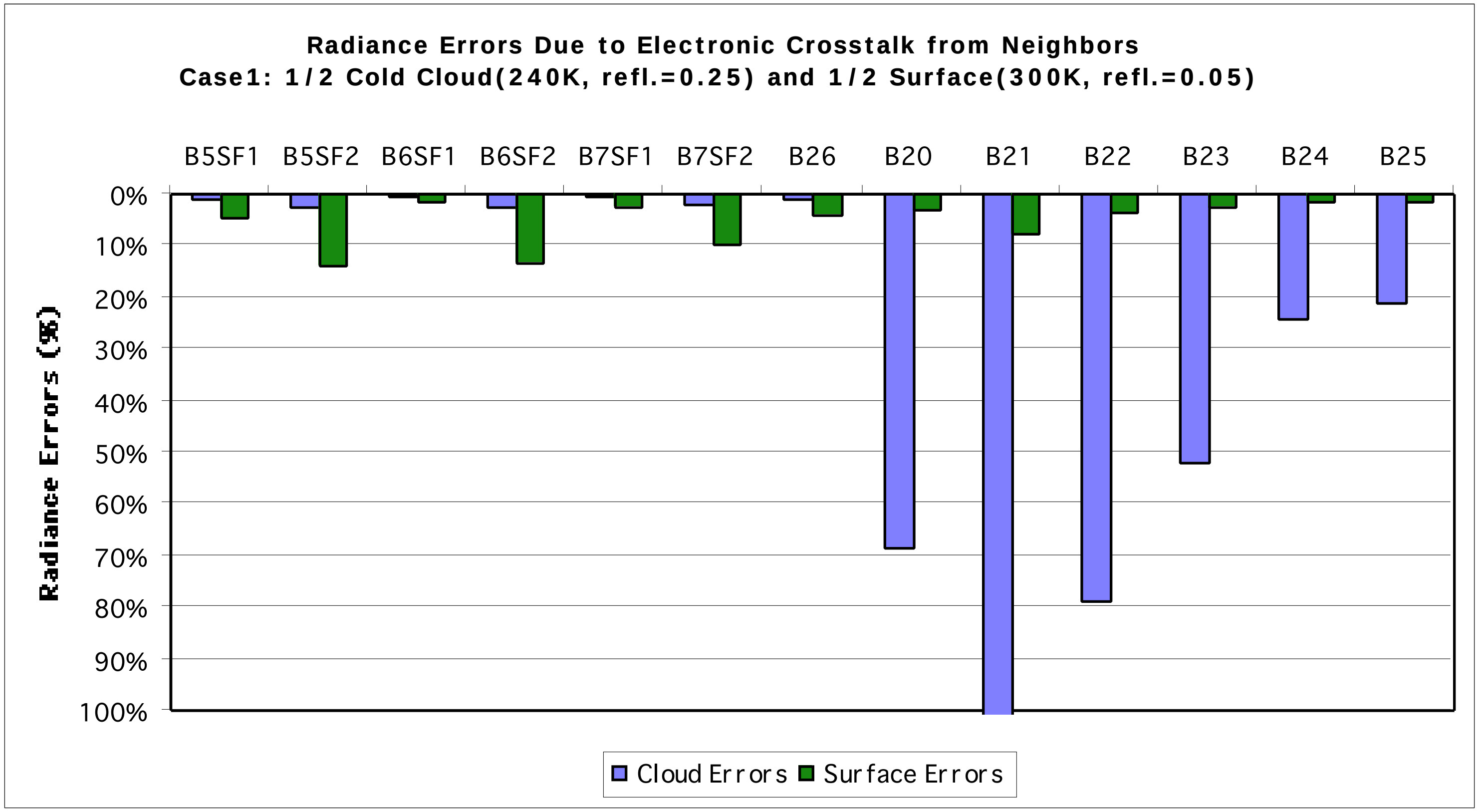
$\rho = 0.25$

$T = 240K$

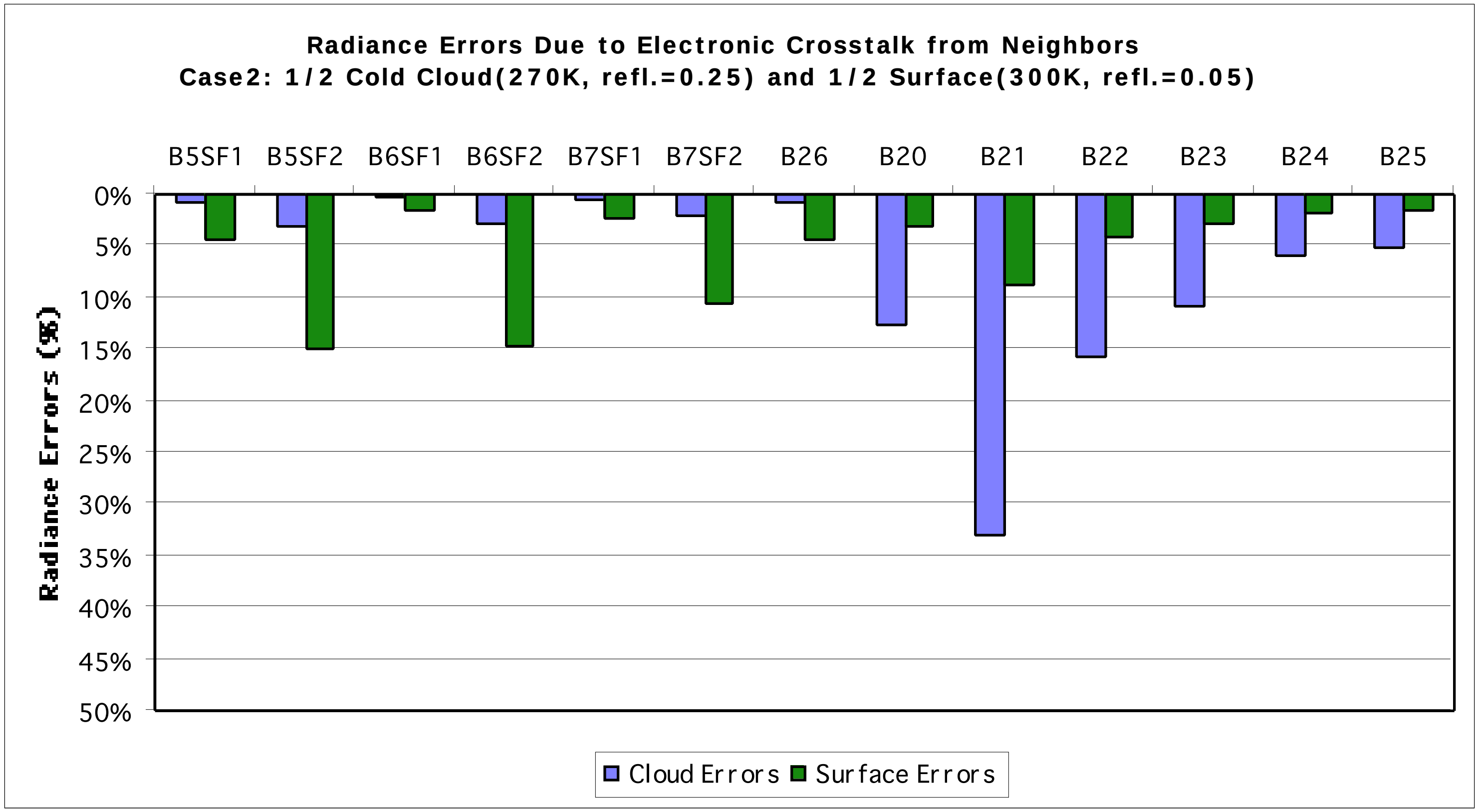
$\rho = 0.05$

$T = 300K$

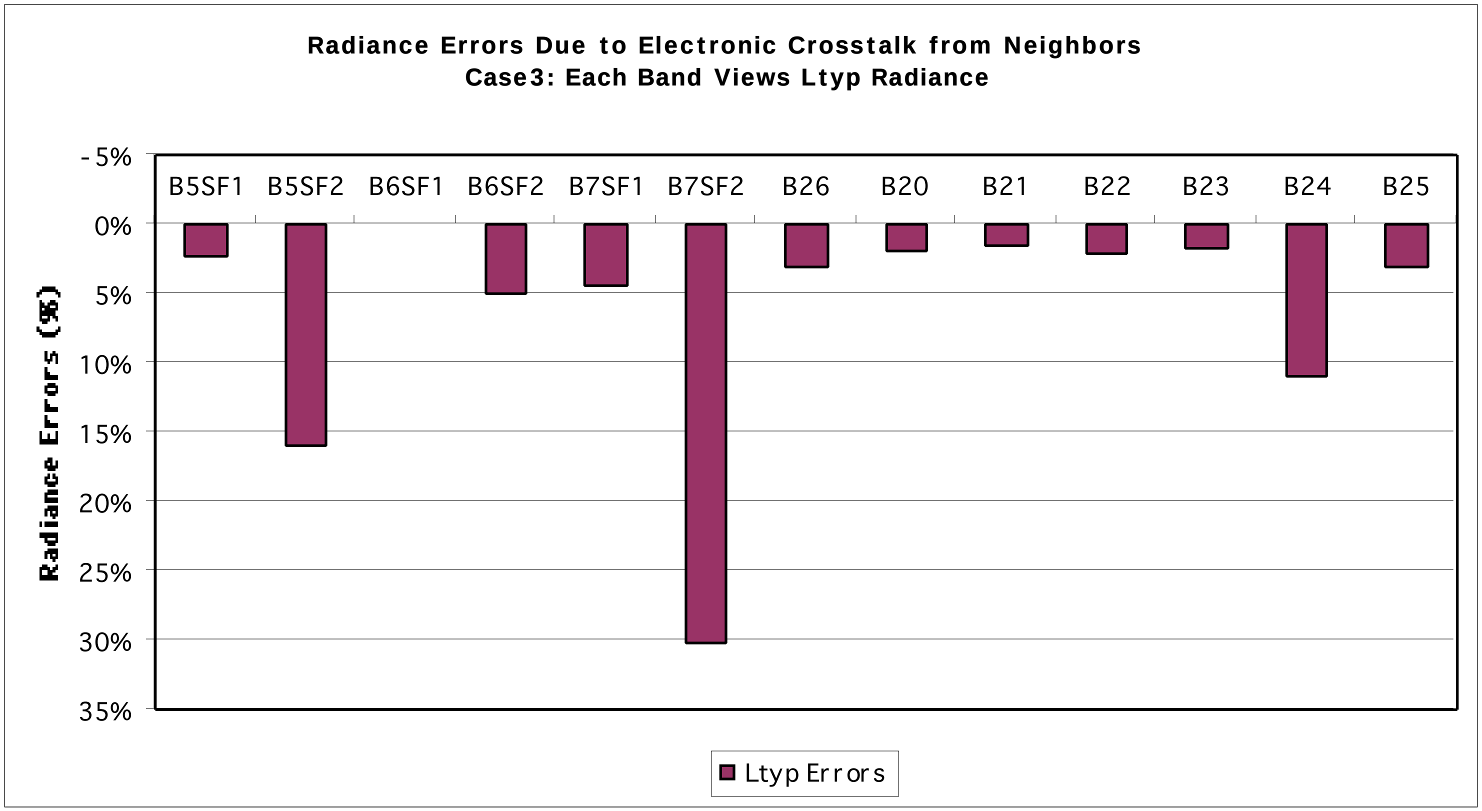
Structured Scene Analysis



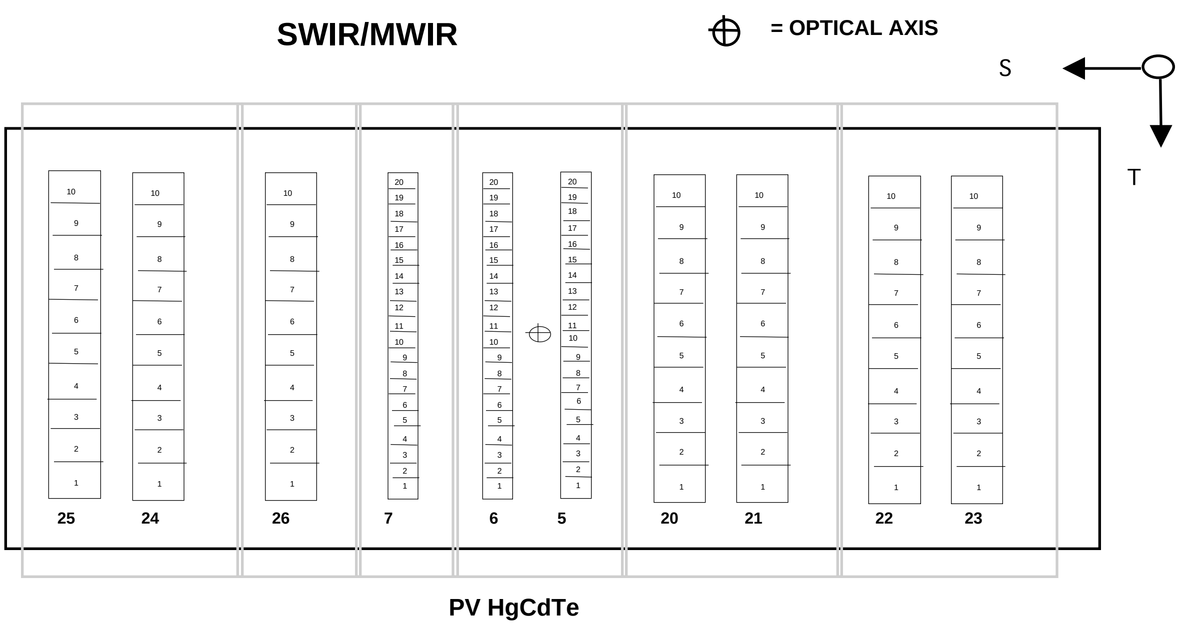
Structured Scene Analysis



Structured Scene Analysis



SMIR FPA



- Bands 5-7,and 26 SWIR (1.2-2.2µm); Bands 20-25 MWIR (3.7-4.5µm)
- S → Scan Direction; T → Track Direction
- FPA Nominal Temperature (83K)

PFM Status At-launch

- Circuit analysis and later sub-system focal plane tests in cryo-dewar indicated inrush current to analog focal plane electronics during reset inadequate
- Replaced resistors (housed in SAM) to increase inrush current
- Did NOT retest to verify fix
- a_0 and a_2 terms for Bands 20-30 set to 0 in L1B code; need establish values on-orbit
- m_1 (linear gain) for SWIR invalid, but always intended replace m_1 on-orbit with SD-based value

Initial On-orbit Performance
(Itwk/Vdet: 79/190)

Comparison of Residual Electronic Cross-talk On-orbit
Compared to Sensor TV Performance

	PFM Sensor TV results		Terra MODIS on-orbit results	
Band 5, sf2	**-33**	**365**	**-27**	**250**
Band 6, sf1	**-14**	**125**	**-13**	**120**
Band 7, sf2	**-52**	**277**	**-30**	**275**
	dn_BB @285K	**DN_SV SF difference**	**dn_BB @285K**	**DN_SV SF difference**

On-orbit Efforts to Mitigate Behavior

- Options limited to adjustment of V_{det} (detector voltage bias control) and I_{twk} (FPA current bias control)
- Performed V_{det}/ I_{twk} sweeps looking for minimum B5-7 sub-frame differences; many configurations tested over 5 minute test period; OBC-BB at 285K for low flux scenes
- Performed elevated blackbody cycle for selected configurations to verify linear gain performance for B20-25); requires 24 hours for each configuration tested; SD observation present each configuration too (high flux scenes)
- Determined minimum residual electronic cross-talk in configuration of 110/226; induced non-functioning and noisy detectors (B5:16; B6:3, 7 & 8; B7:14; B21:9; B22:4, 7 & 8; B23:10; B24:8, 9 & 10; and B25:9 & 10)

Configurations Selected for Further Study

- MODIS operated in I_{twk} /V_{det} of 110/226 since 6 March; call this **Operational Configuration** (for simplicity)
- **Optional Configuration** (100/218) selected on basis of no detector outages in 4 µm SST bands and minimum cross-talk
  - No change in SWIR bands for detector functionality
  - Strong advocacy present from SST team
  - “Turning on” all SWIR detectors moves residual cross-talk to nearly identical level as at-launch operations
- Operational and Optional Configurations tested through Moon-in-Space-View-Port (M-SV) in April
- These two, plus **At-launch Configuration** for M-SV 21 June

Moon-in-Space-View-Port Results (Operational & Optional Configurations)

- Optional Configuration
  - Itwl / Vdet = 100 / 218
  - Lunar observation at 84 17:00

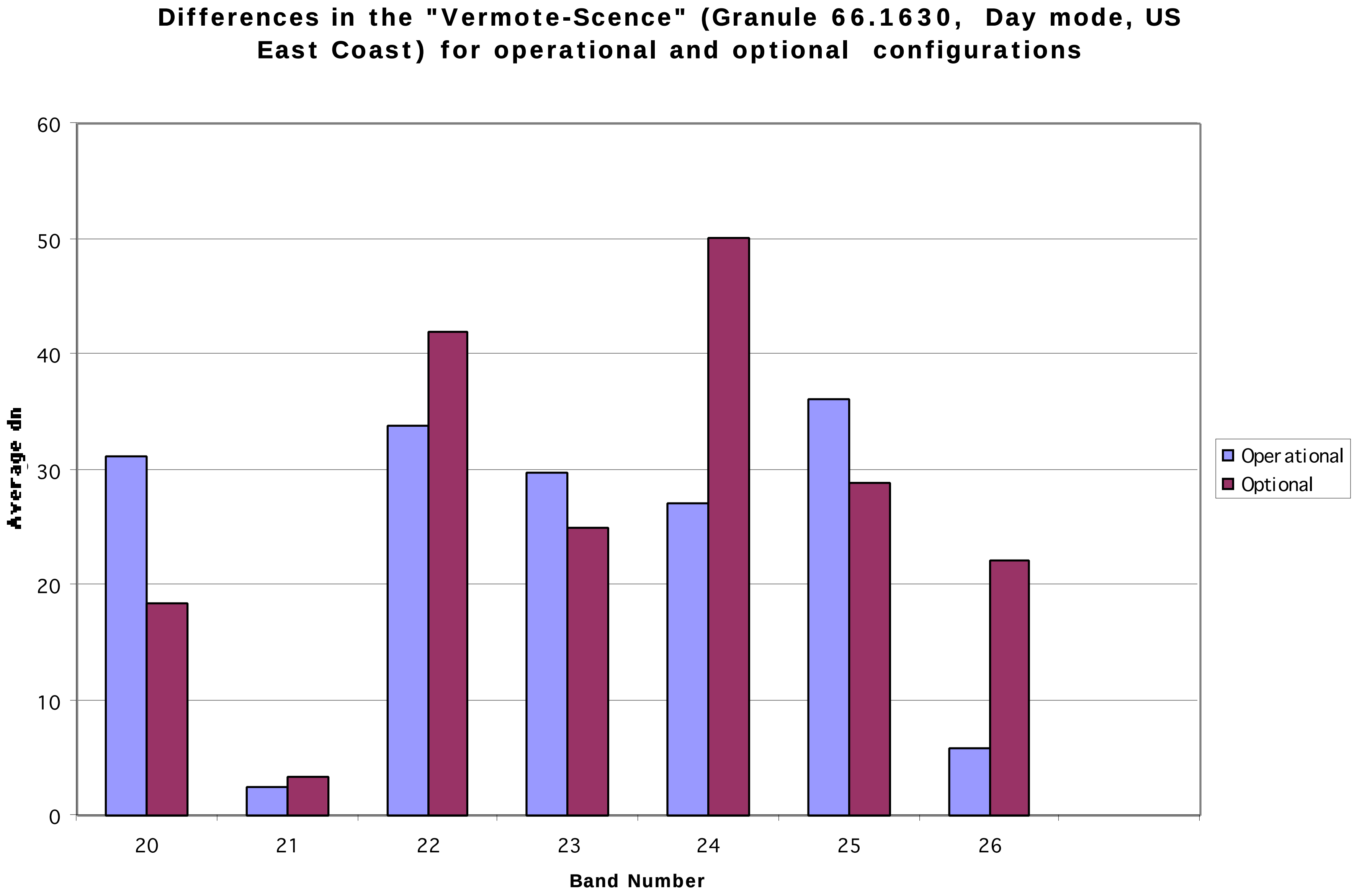
- Operationall Configuration
  - Itwl / Vdet = 110 / 226
  - Lunar observation at 84 20:20

Contamination due to cross-talk for the two lunar observations

- Calculate the sum, S1, of the observed dns for a given band
- Isolate the region where true dns dominate and evaluate the summation of the dns, S2
- The total cross-talk from other bands, S3 = S1 - S2
- The ratio of the cross-talk over signal, R = S3 / S2

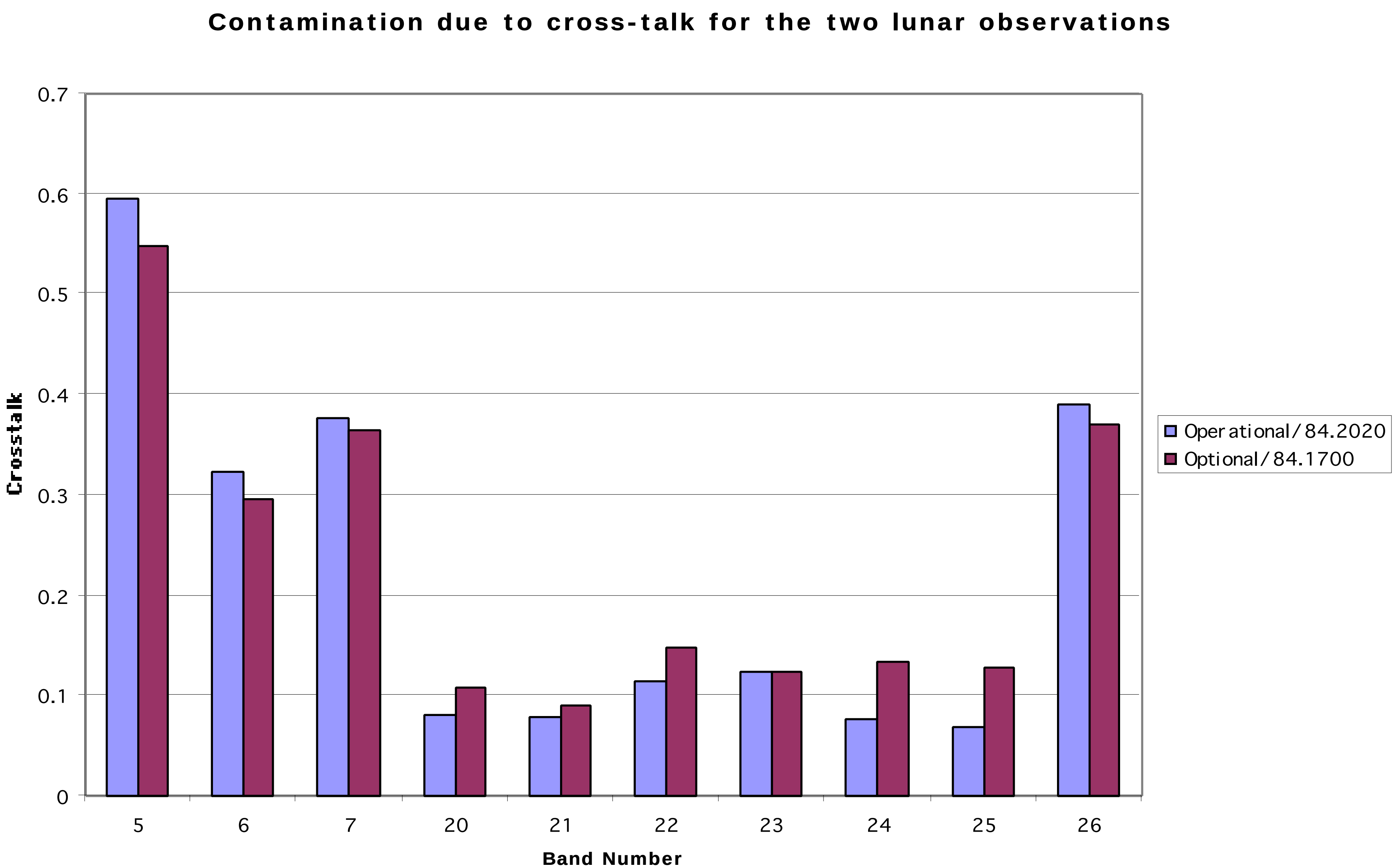
RSB & TEB Ltyp & dn@Ltyp

RSB Band	CWL (nm)	Ltyp ($W/m^2/sr/\mu m$)	dn @ Ltyp	TEB Band	CWL (μm)	Ltyp $W/m^2/sr/\mu m$)	dn @ Ltyp
1	646.5	21.8	111	20	3.788	0.45	966
2	856.7	24.7	315	21	3.992	2.38	150
3	465.6	35.3	163	22	3.972	0.67	1346
4	553.7	29.0	209	23	4.057	0.79	1372
5	1241.9	5.4	195	24	4.473	0.17	263
6	1629.1	7.3	389	25	4.545	0.59	876
7	2114.3	1.0	190	27	6.765	1.16	404
8	411.8	44.9	925	28	7.337	2.18	698
9	442.1	41.9	1201	29	8.524	9.58	2284
10	486.9	32.1	1189	30	9.730	3.69	681
11	529.7	27.9	1305	31	11.014	9.55	1301
12	546.8	21.0	1236	32	12.028	8.94	1448
13lo	665.6	9.5	1056	33	13.361	4.52	1324
14lo	676.7	8.7	1025	34	13.680	3.76	1029
15	746.4	10.2	1421	35	13.911	3.11	842
16	886.2	6.2	887	36	14.195	2.08	461
17	904.1	10.0	190				
18	935.3	3.6	51				
19	936.1	15.0	287				
26	1382.0	6.0	288				
13hi	665.6	9.5	1465				
14hi	676.7	8.7	1735				


Differences in the "Vermote-Scence" (Granule 66.1630, Day mode, US East Coast) for operational and optional configurations
Average dn
60
50
40
30
20
10
0
20
21
22
23
24
25
26
Band Number
Operational
Optional

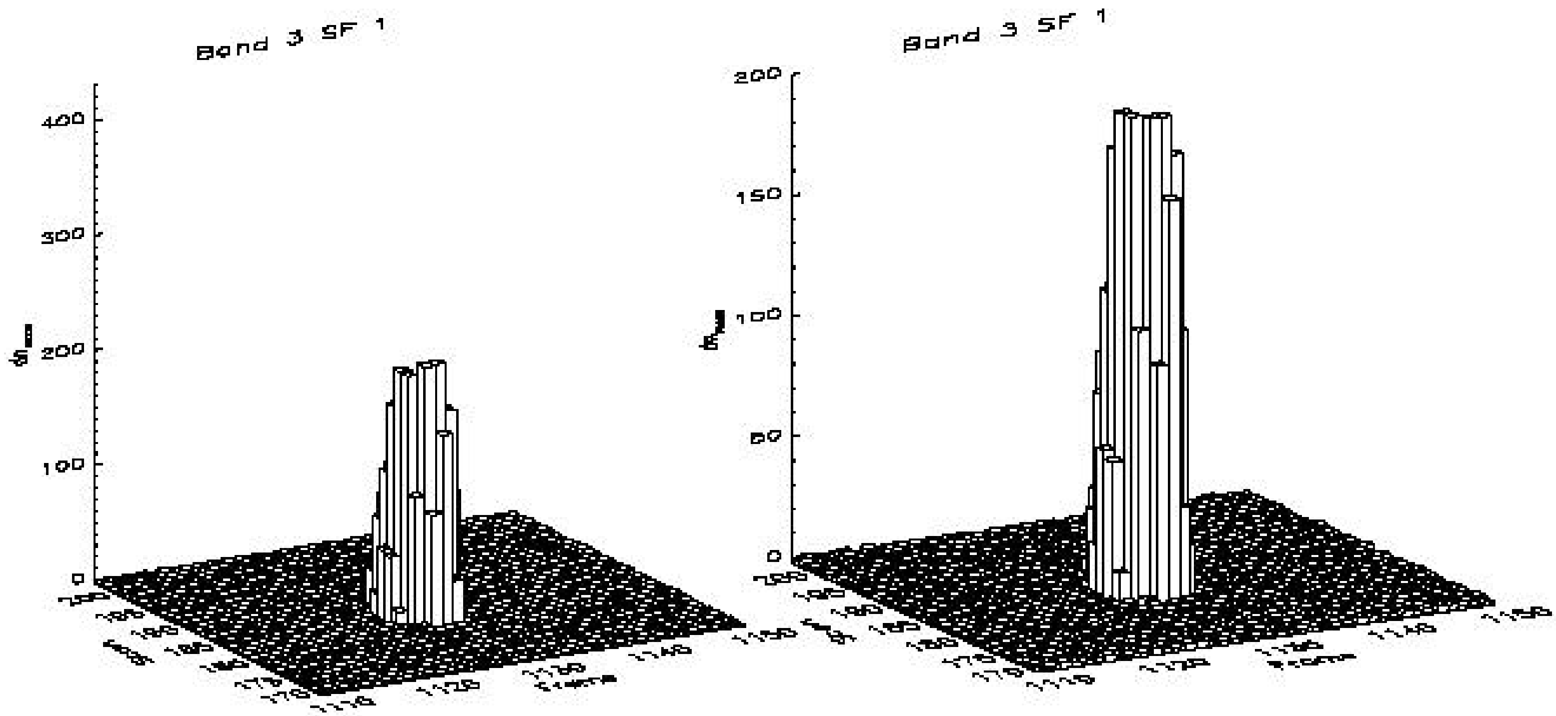
Differences in the “Vermote-Scence” for the operational & optional configurations

- Cross-talk coefficients are determined for the two configurations with a linear response assumption using the dns of the lunar views
- With each group of cross-talk coefficients, a correction can be calculated for each pixel
- The correction dns vary with detectors, scans, frames, and the cross-talk coefficients
- Average the correction dns over detectors, scans, frames for each band


Contamination due to cross-talk for the two lunar observations
Crosstalk
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
5
6
7
20
21
22
23
24
25
26
Band Number
Operational/84.2020
Optional/84.1700

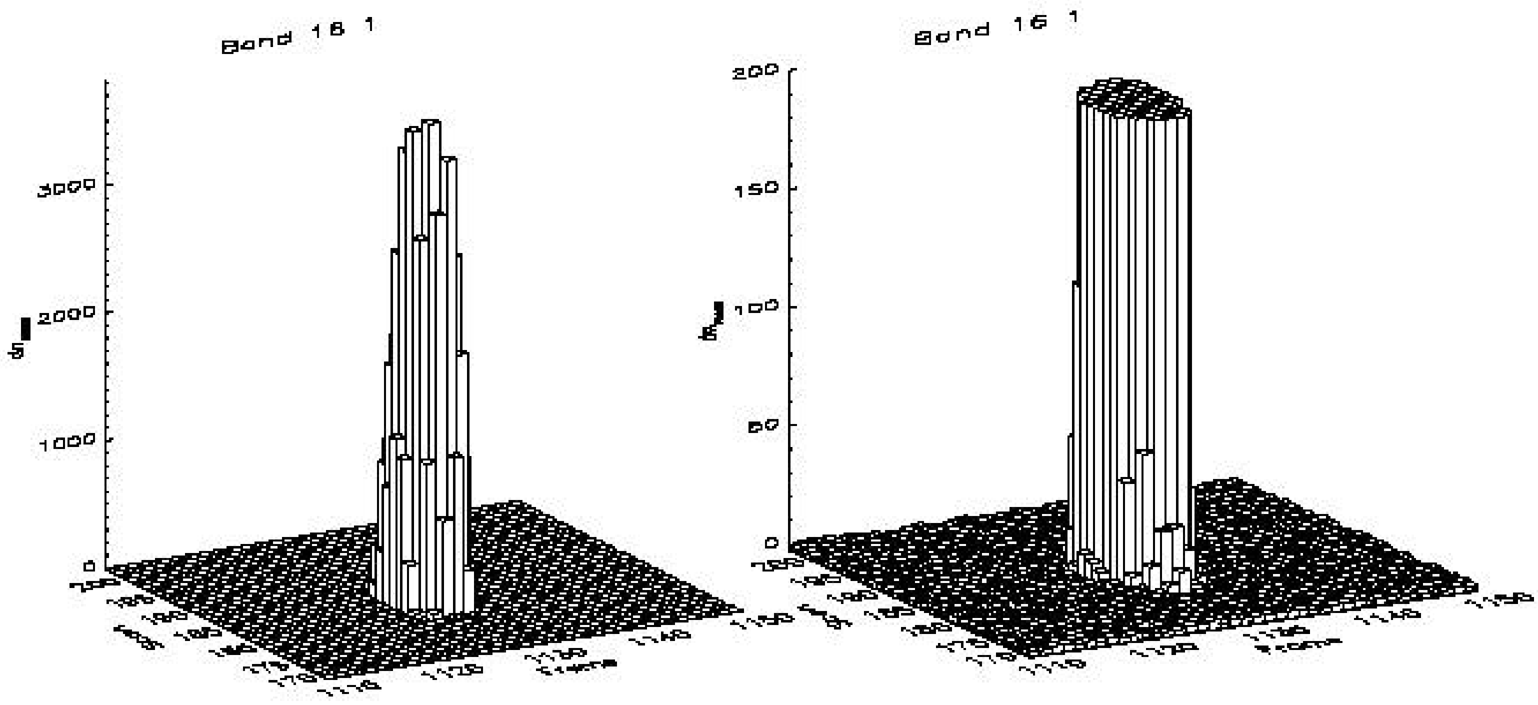
Moon-in-Space-View-Port Results

Band 3 (Channel 10) During 84/17:00 Moon View Event



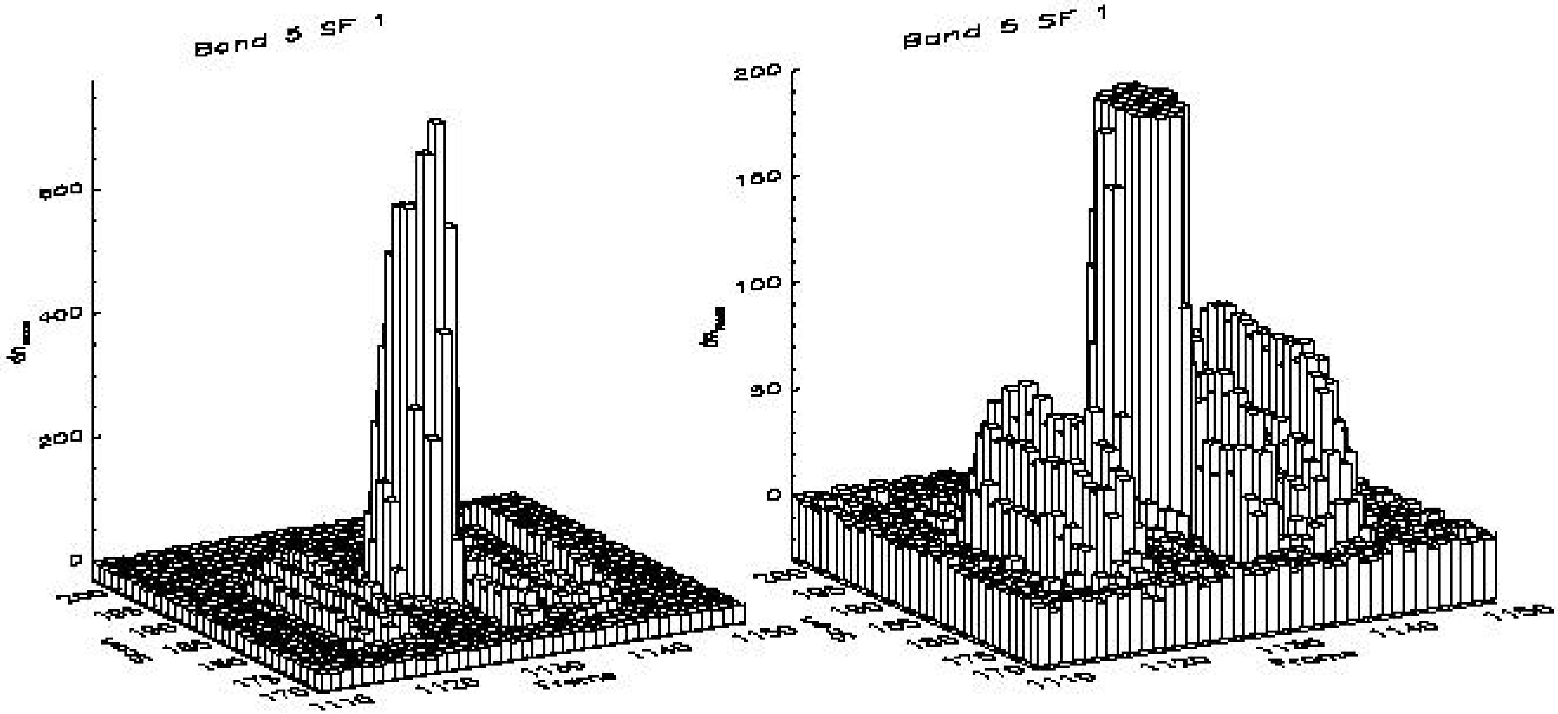
Moon-in-Space-View-Port Results

Band 16 (Channel 5) During 84/17:00 Moon View Event



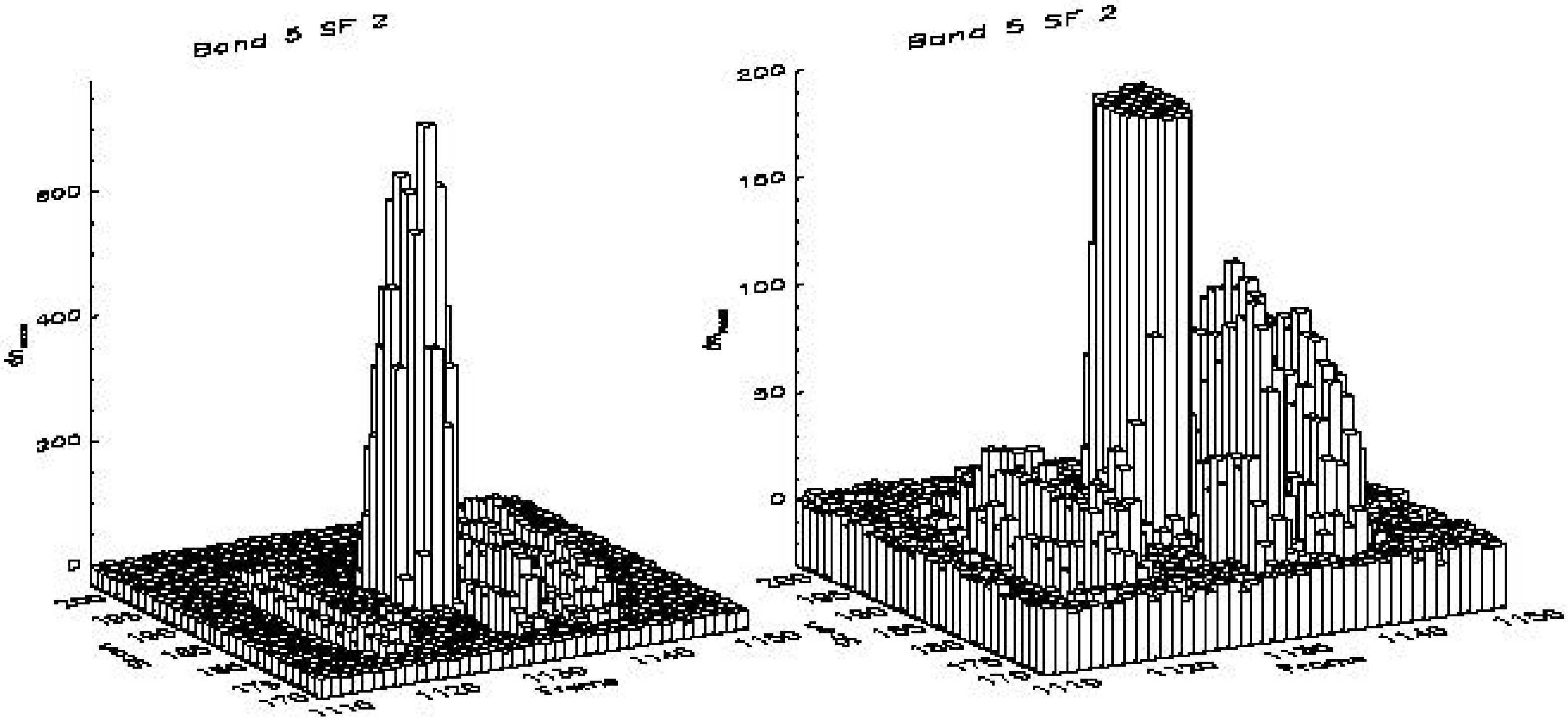
Moon-in-Space-View-Port Results

Band 5 (Channel 10) During 84/17:00 Moon View Event



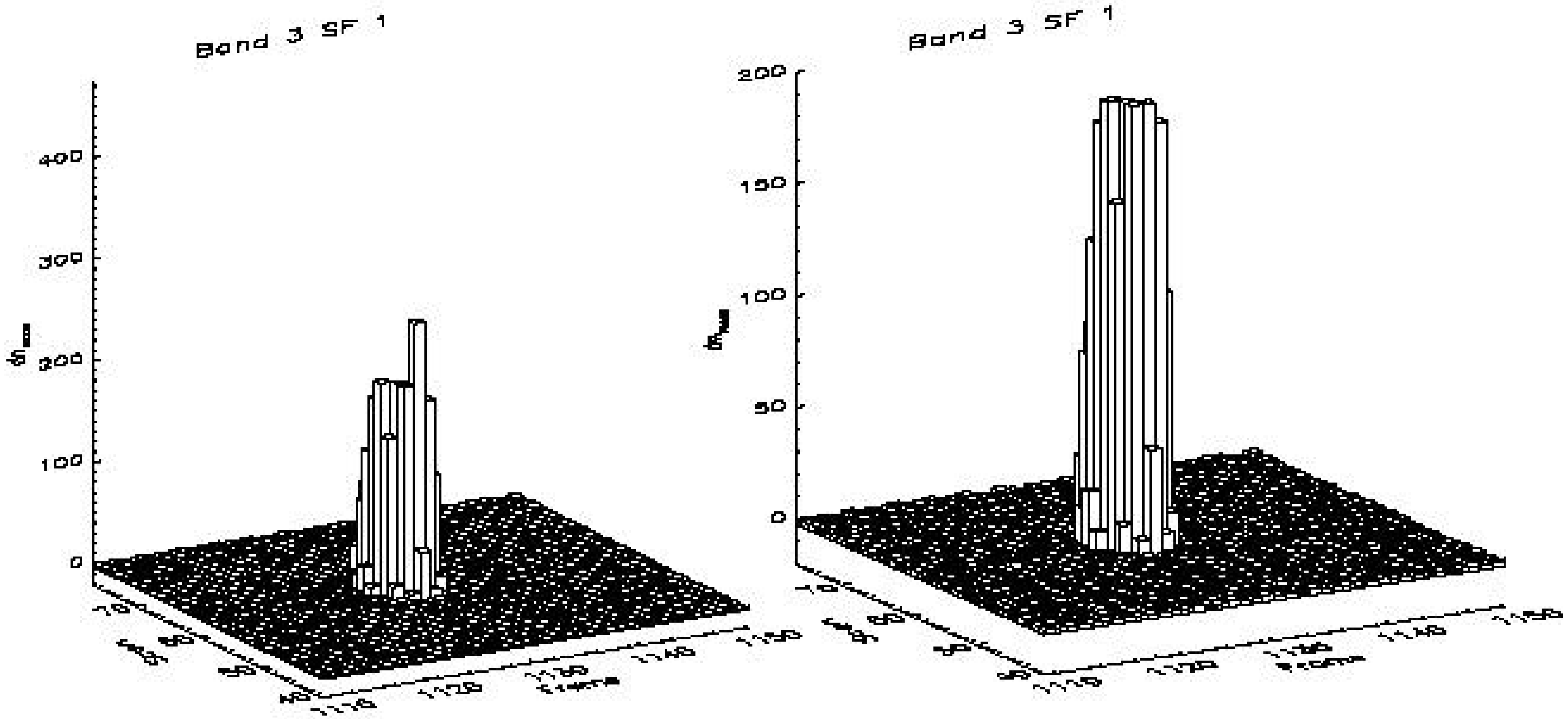
Moon-in-Space-View-Port Results

Band 5 (Channel 10) During 84/17:00 Moon View Event



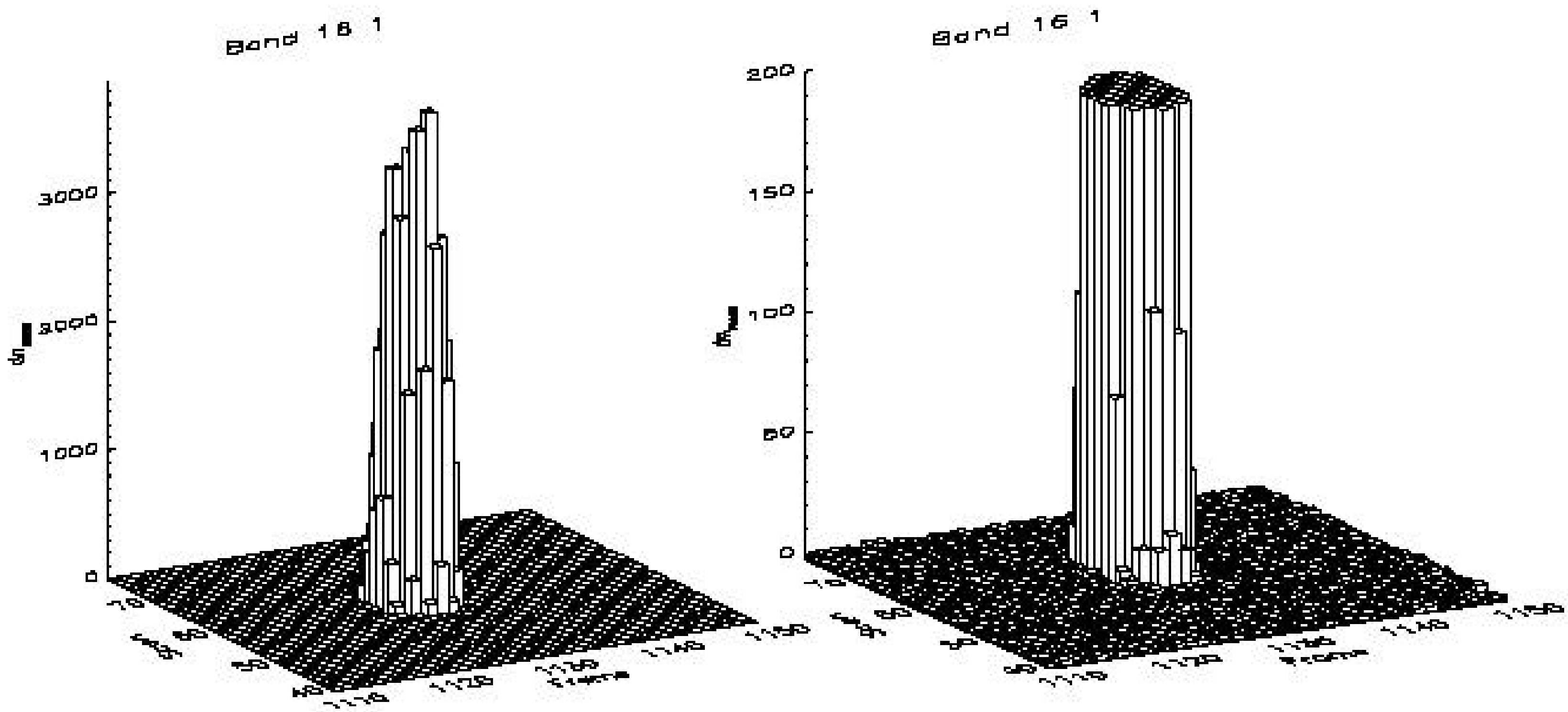
Moon-in-Space-View-Port Results

Band 3 (Channel 10) During 84/20:20 Moon View Event



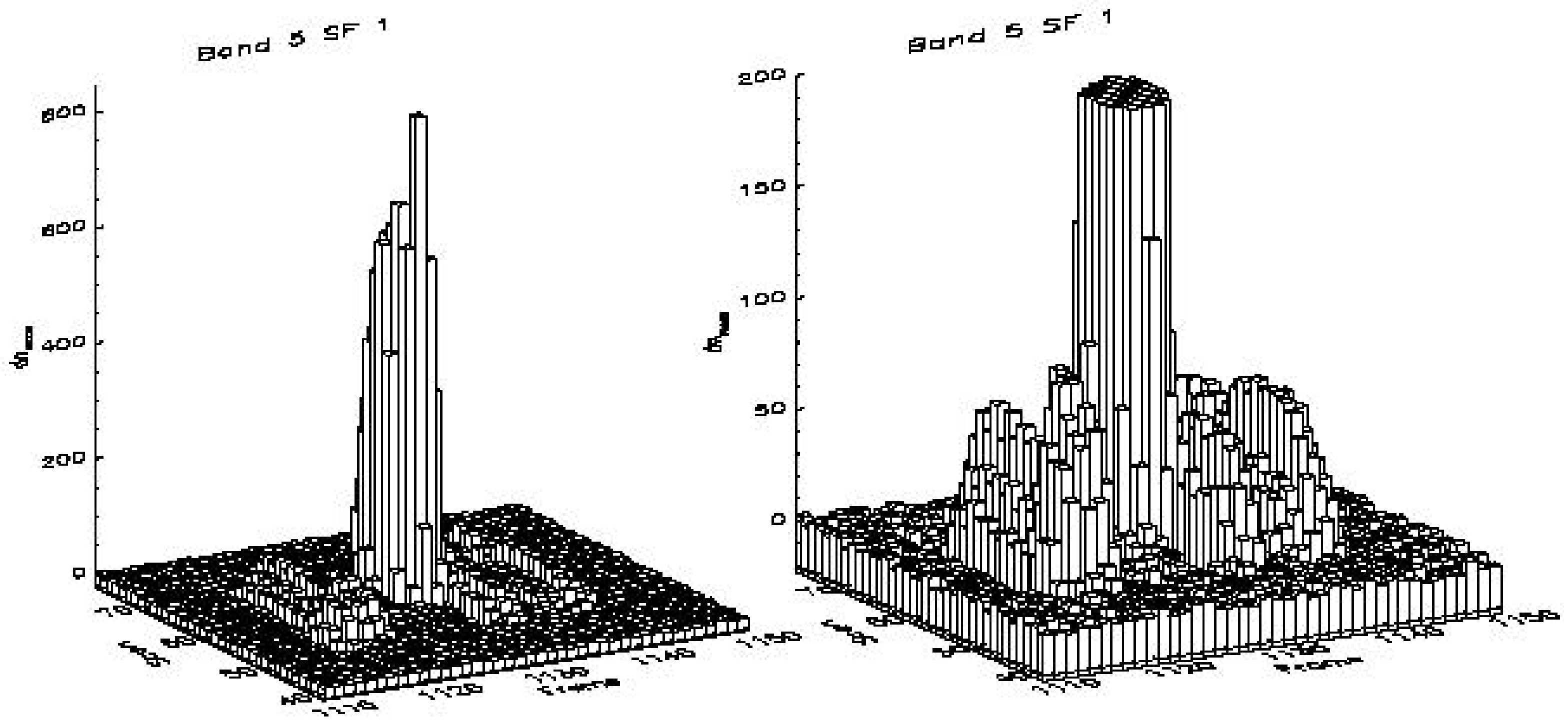
Moon-in-Space-View-Port Results

Band 16 (Channel 5) During 84/20:20 Moon View Event



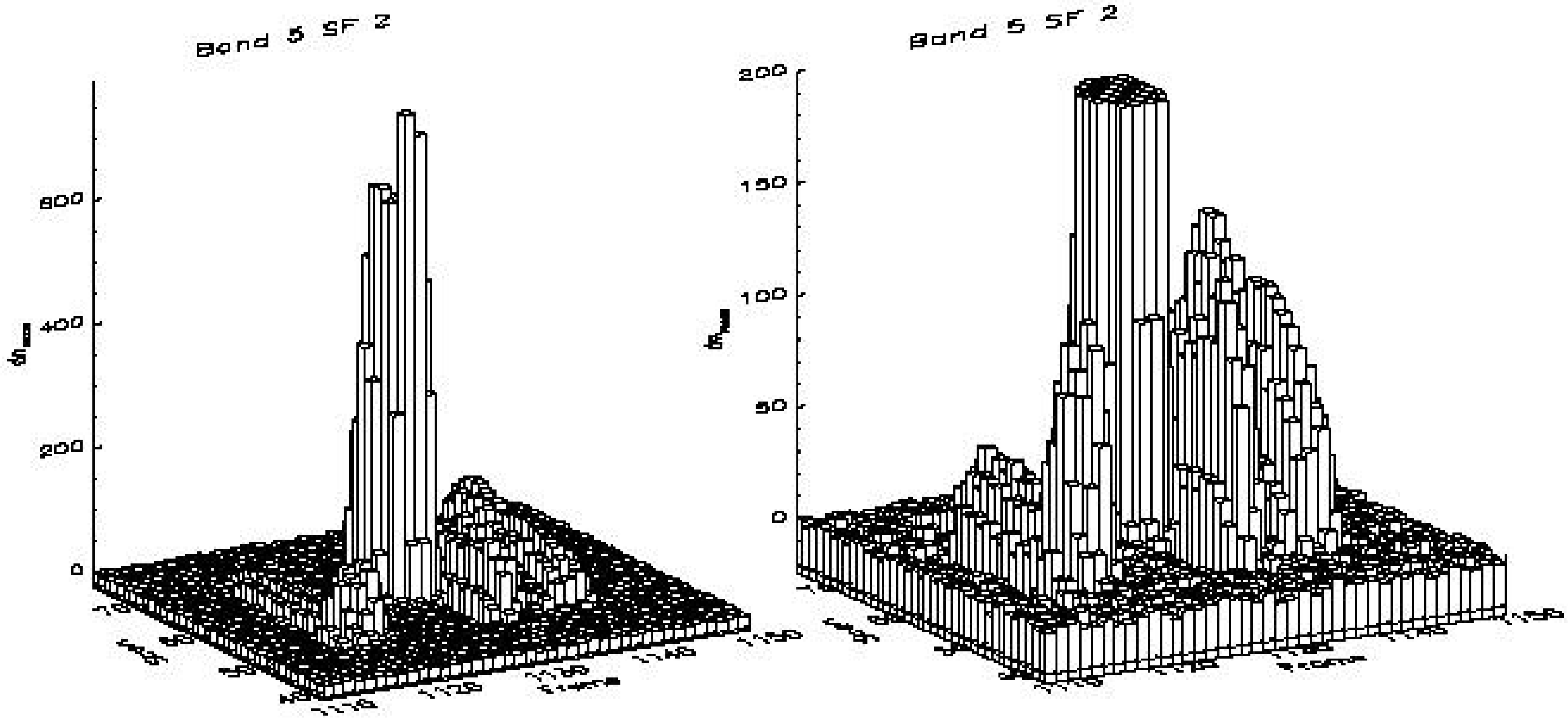
Moon-in-Space-View-Port Results

Band 5 10 (Channel 10) During 84/20:20 Moon View Event



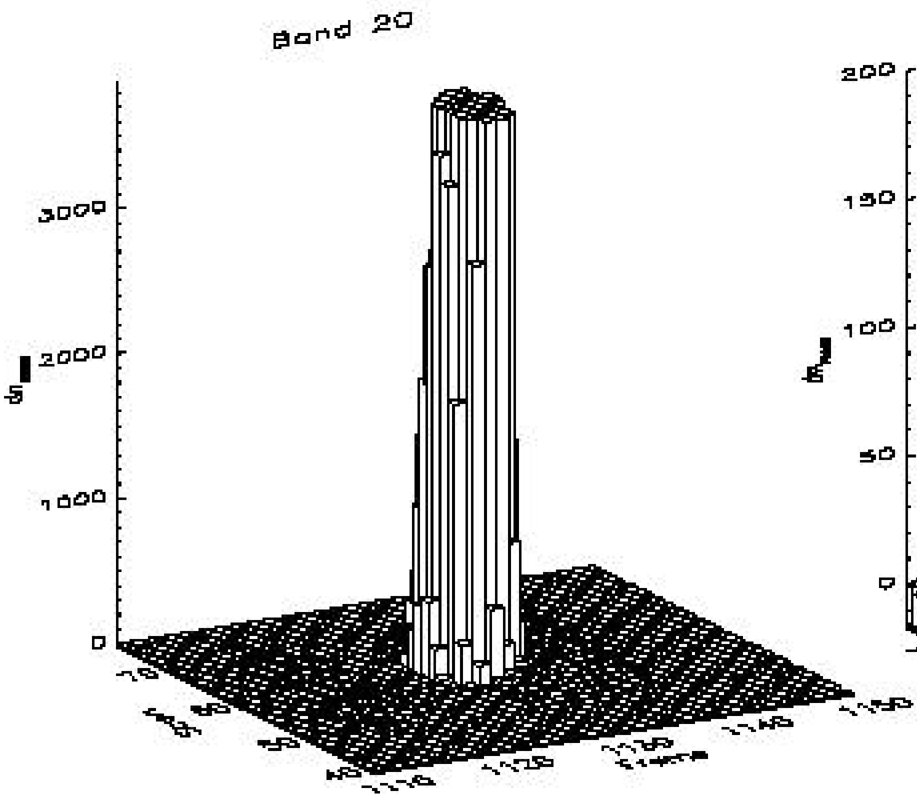
Moon-in-Space-View-Port Results

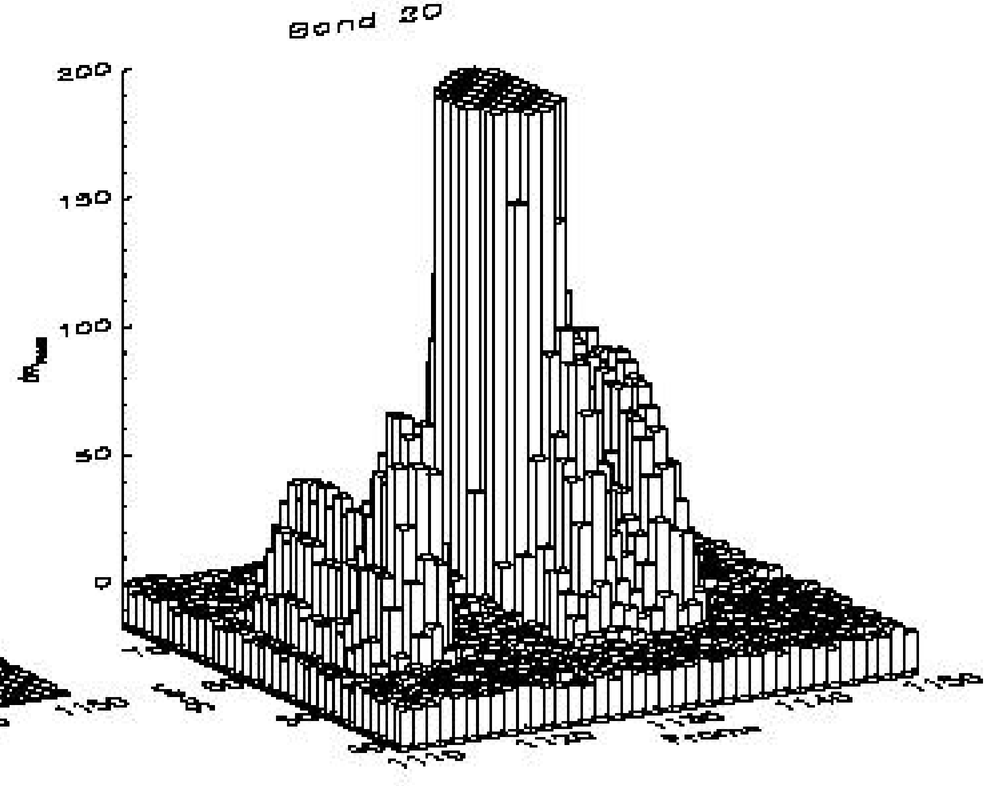
Band 5 10 (Channel 10) During 84/20:20 Moon View Event



Moon-in-Space-View-Port Results

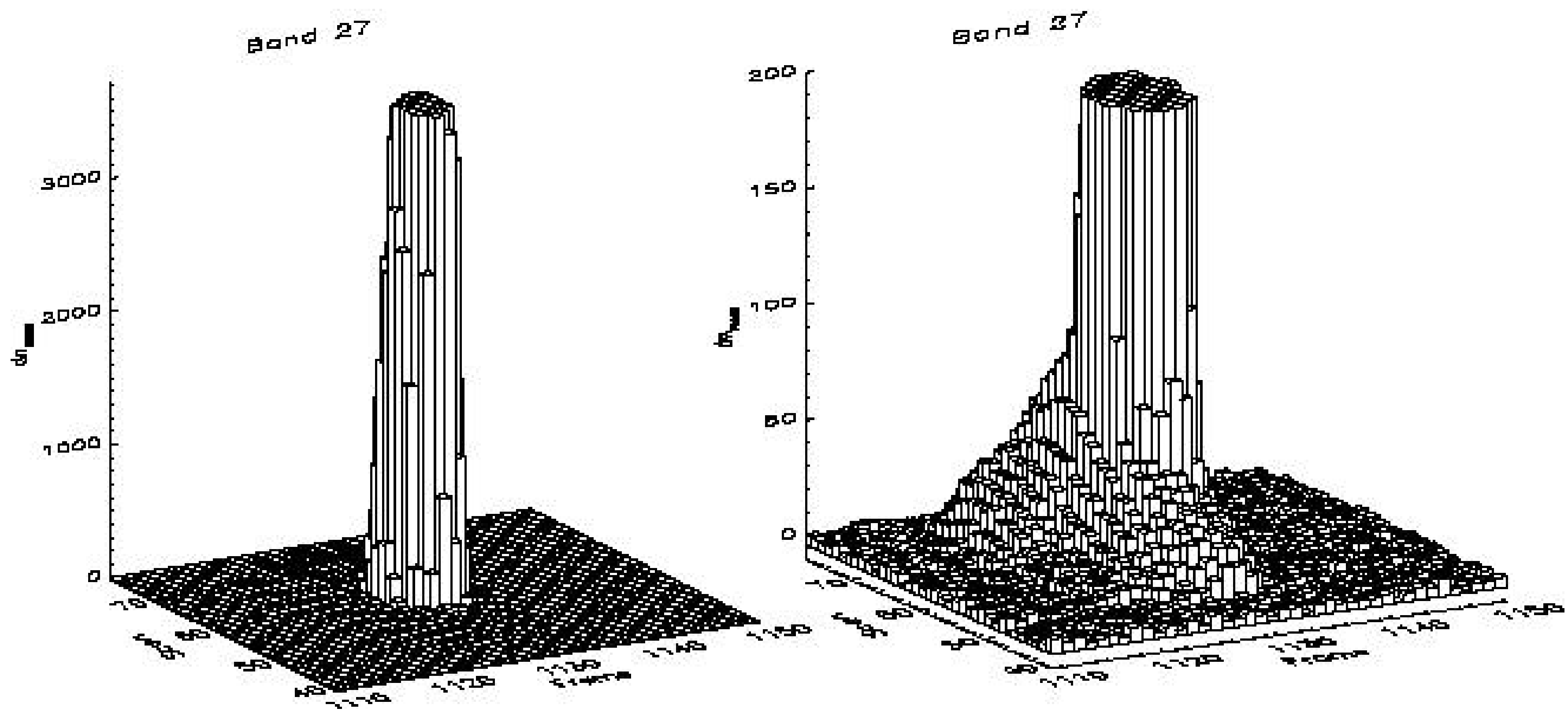
Band 20 (Channel 5) During 84/20:20 Moon View Event



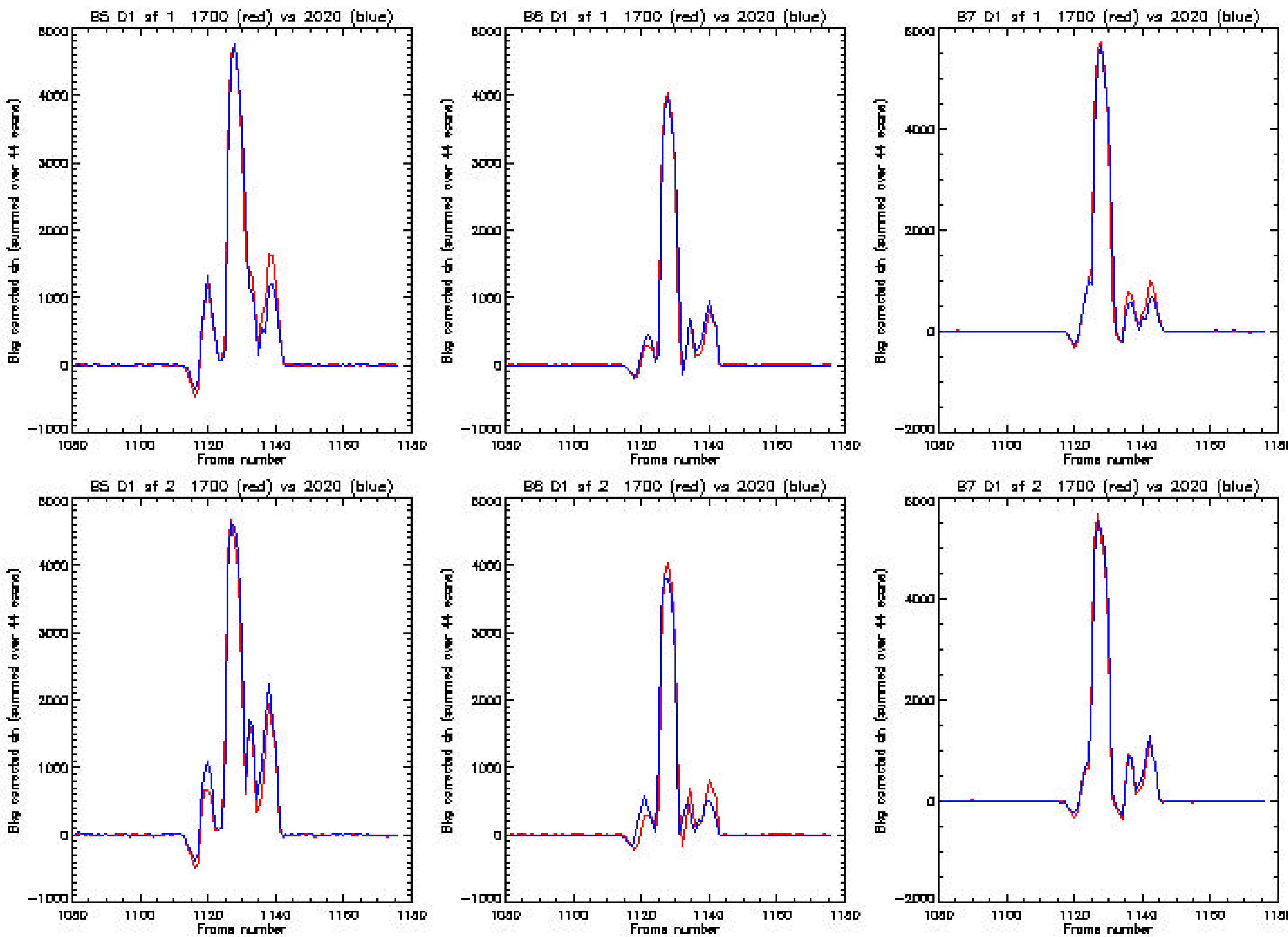


Moon-in-Space-View-Port Results

Band 27 (Channel 5) During 84/20:20 Moon View Event



Moon-in-Space-View-Port Results



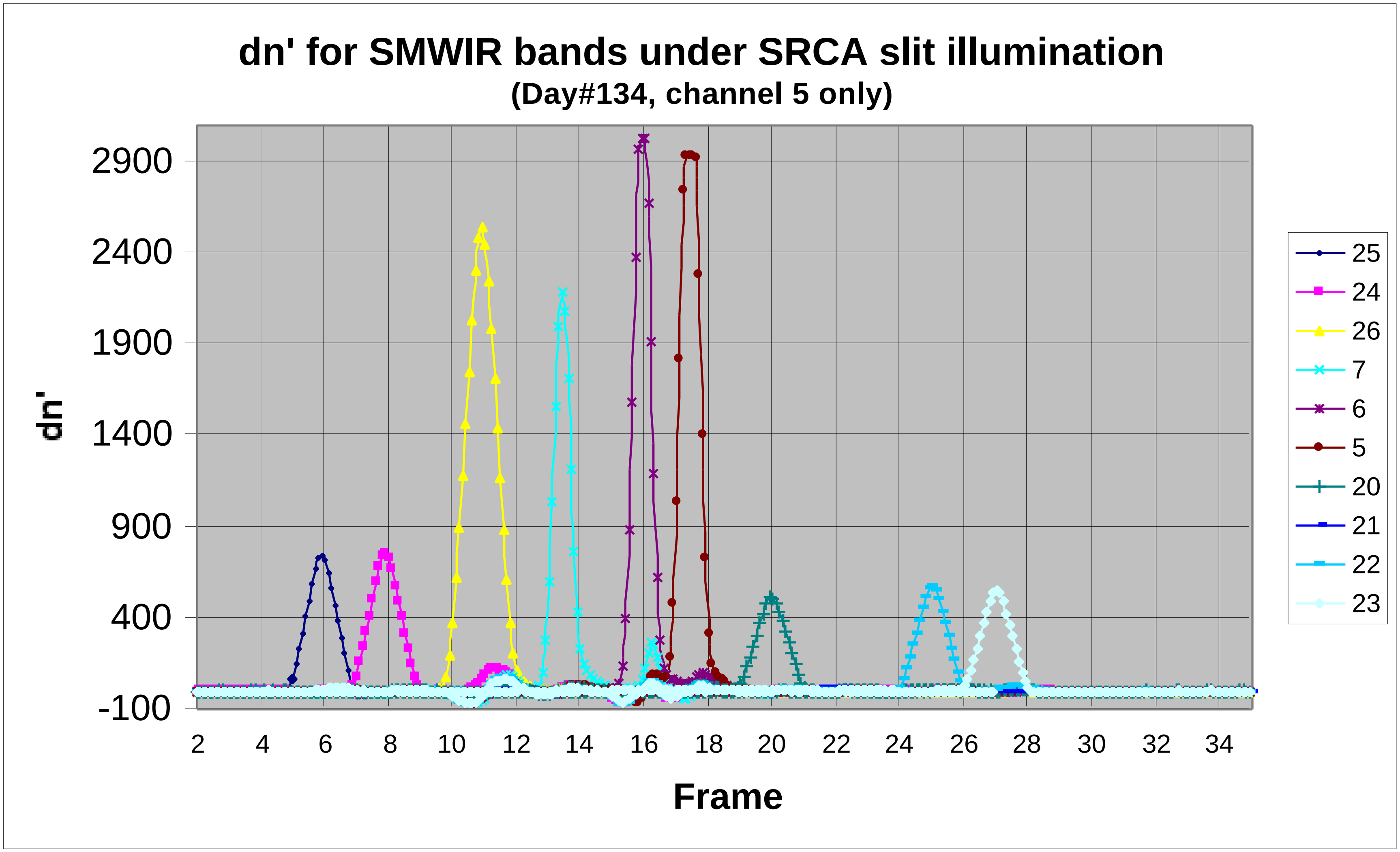
Moon-in-Space-View-Port Results

- Results to date:
  - Differences in electronic cross-talk less than had been expected from low-flux OBC-BB testing
  - Behavior looks complicated and non-linear

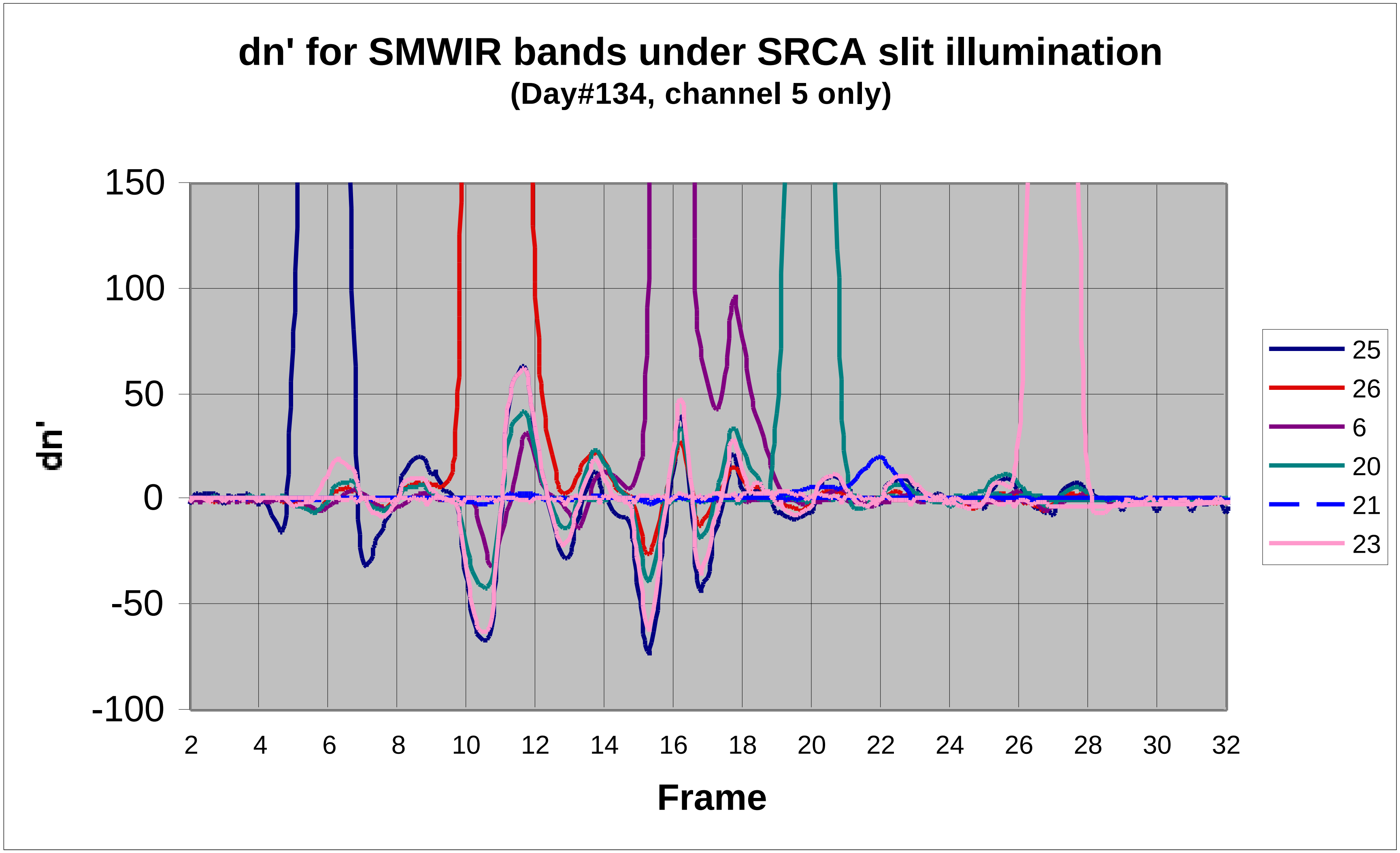
SRCA (Spatial) Results
Only Operational Configuration to Date

- On-orbit SRCA Spatial Test
  - Slit (1 by 10) illumination
  - Sector rotation - more frames
  - Itwk/Vdet = 110/226
- dn': dark background subtracted

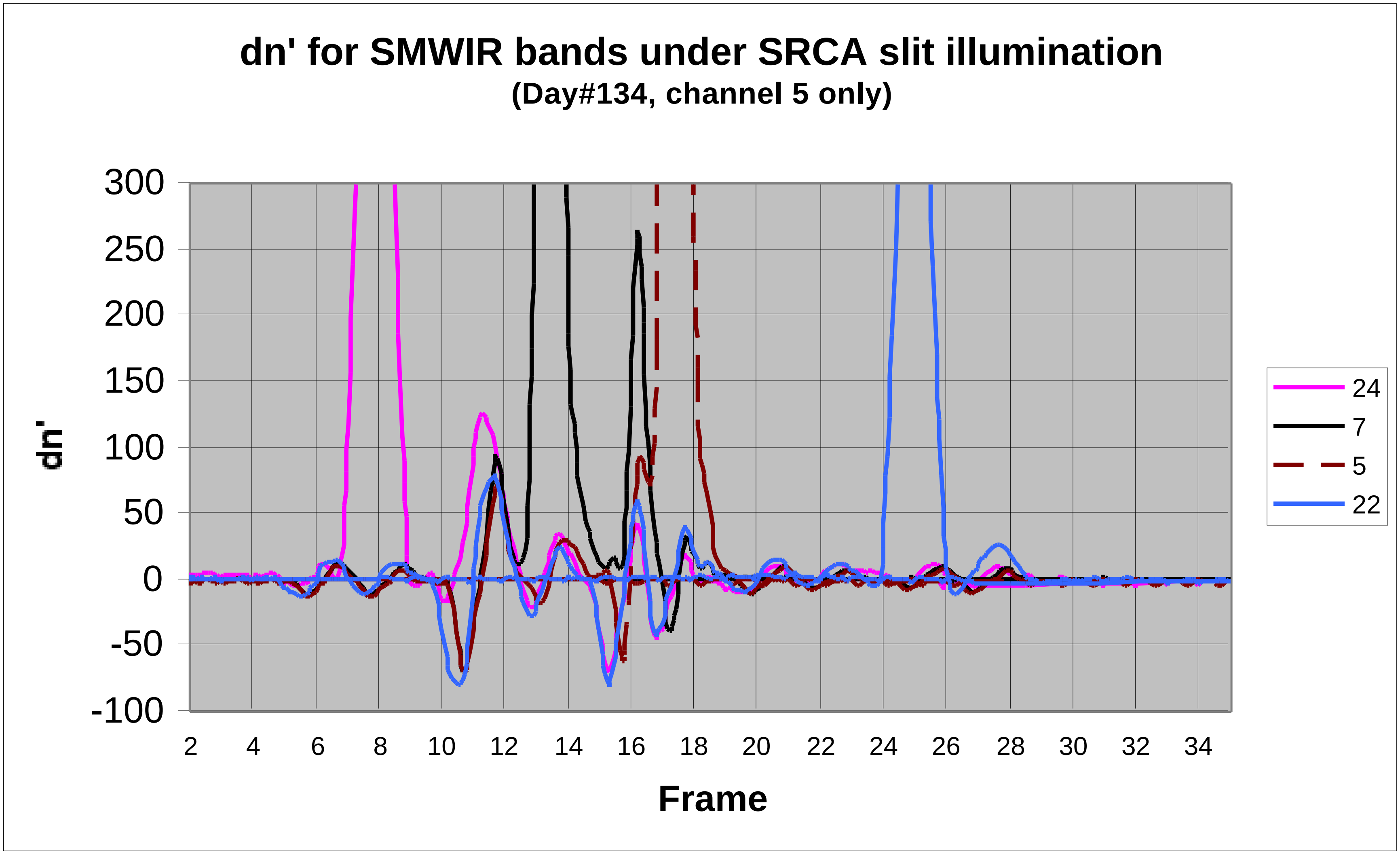
SRCA (Spatial) Results



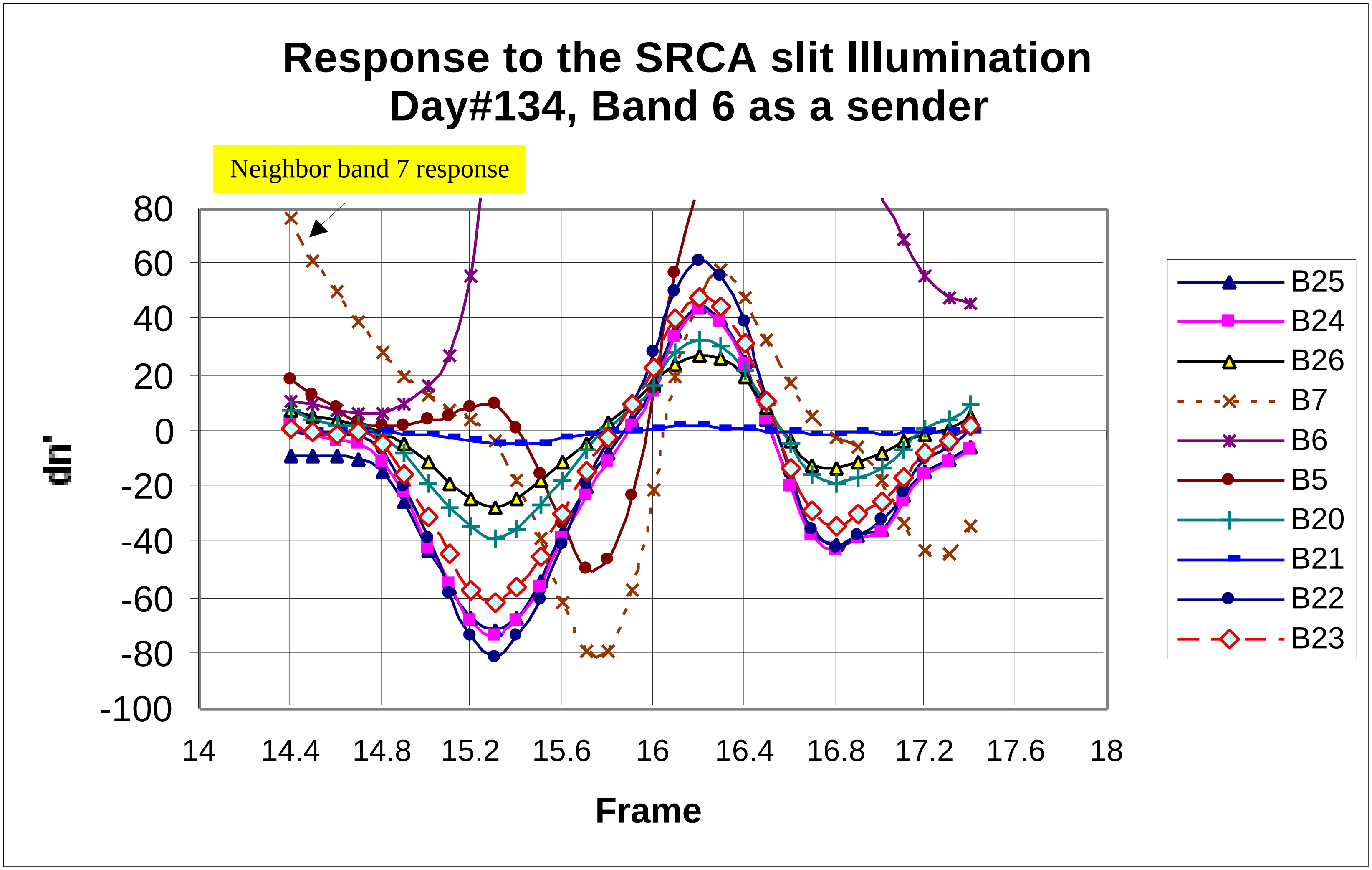
SRCA (Spatial) Results



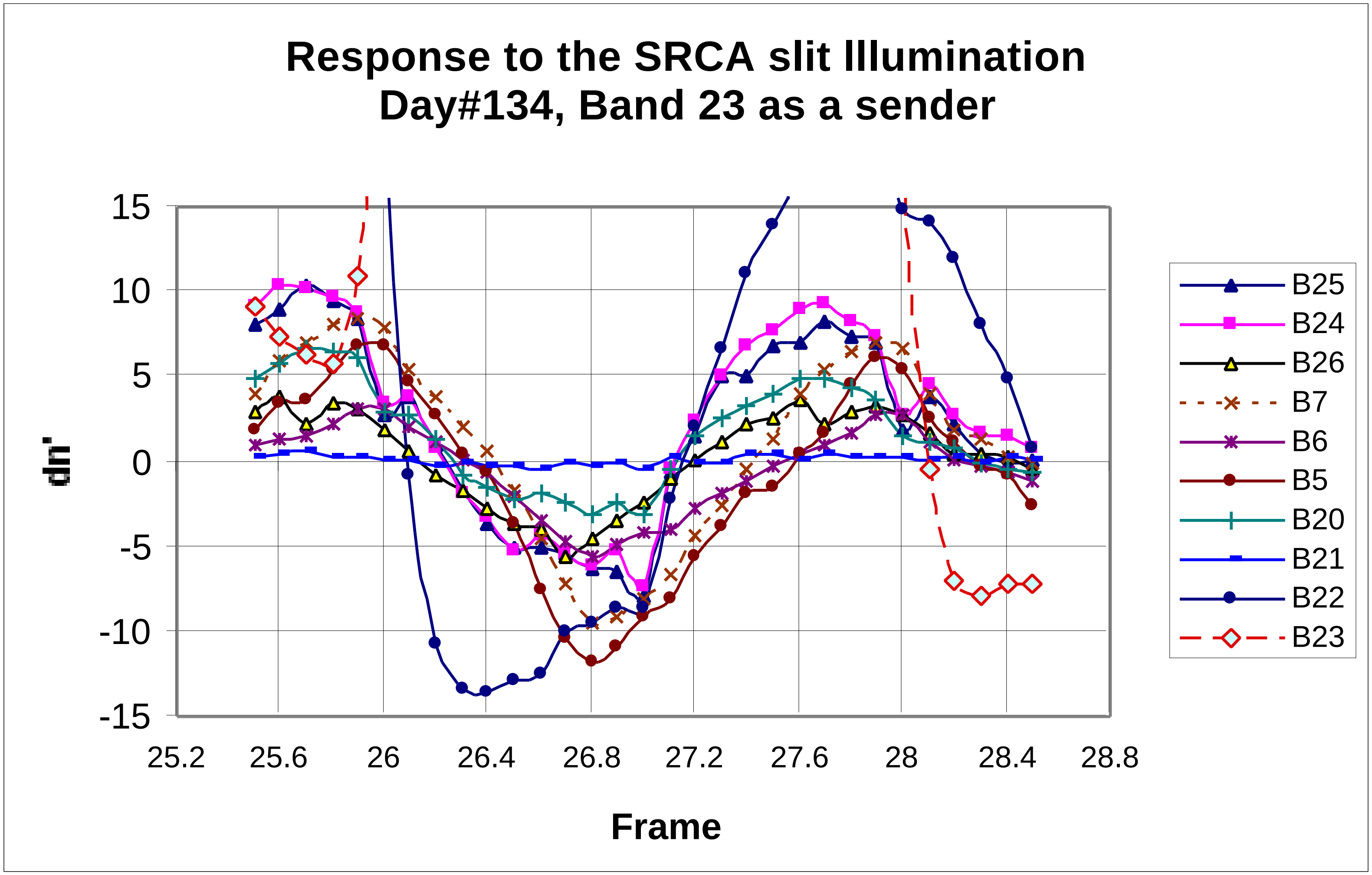
SRCA (Spatial) Results



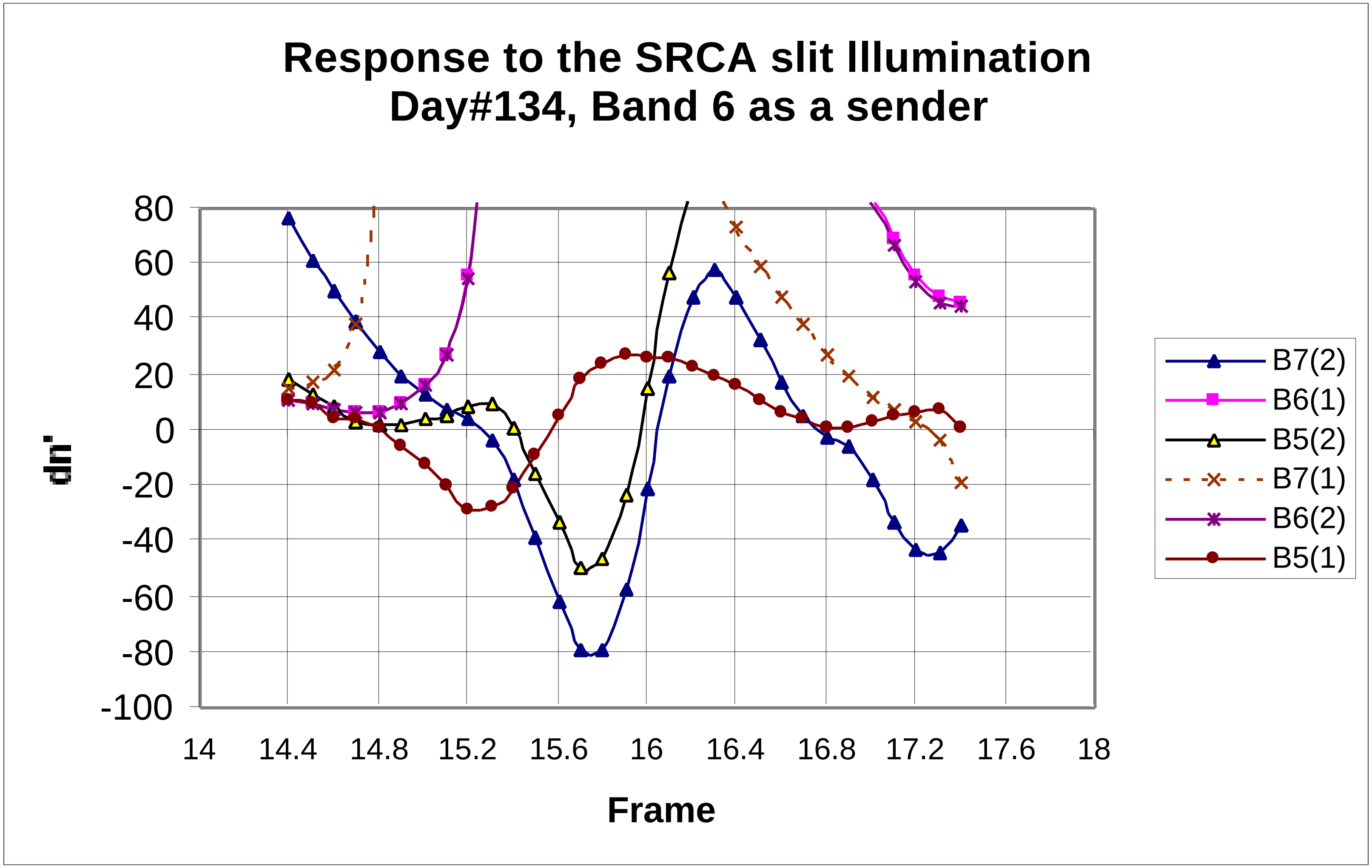
SRCA (Spatial) Results



SRCA (Spatial) Results



SRCA (Spatial) Results



SRCA (Spatial) Results

- Clearly different electronic cross-talk (receiver) for similar illumination levels in sender band
- Need perform careful comparison with other measures of this behavior
- Note: M-SV over-drives the focal plane in way not typical to how operate on orbit, but SRCA seems to illuminate TEB in way similar to earth scenes, but SWIR illumination not really typical

Summary of electronic cross-talk performance characterizations

	Feature			
Configuration	**Cross-talk**	**SWIR sub-frame difference, low flux levels**	**SWIR sub-frame difference, high flux level**	**Non-functional Detectors**
Launch 79/190	Presumed significant; will verify 21 June	Significant	Significant	None
Optional 100/218	Small, but larger than Operational	Small (all bands)	Small	3 SWIR channels
Operational 110/226	Small	Negligible	Negligible (small Band 7)	3 SWIR channels 3 MWIR channels

What Still Needs To Be Done

- MCST recommendations that Science Team not rely on any correction algorithms in selecting operating configuration
- Will repeat M-SV on 21 June, for 3 configurations
- Will get SRCA observations for all 3 configurations
- What about the B-side
- Reassess after measuring 3 configurations for SRCA and M-SV in June
- Land Team evaluating early data for at-launch configuration

Changes in configuration changes gains

Preliminary Conclusions

- Electronic Cross-talk (based on M-SV data set)

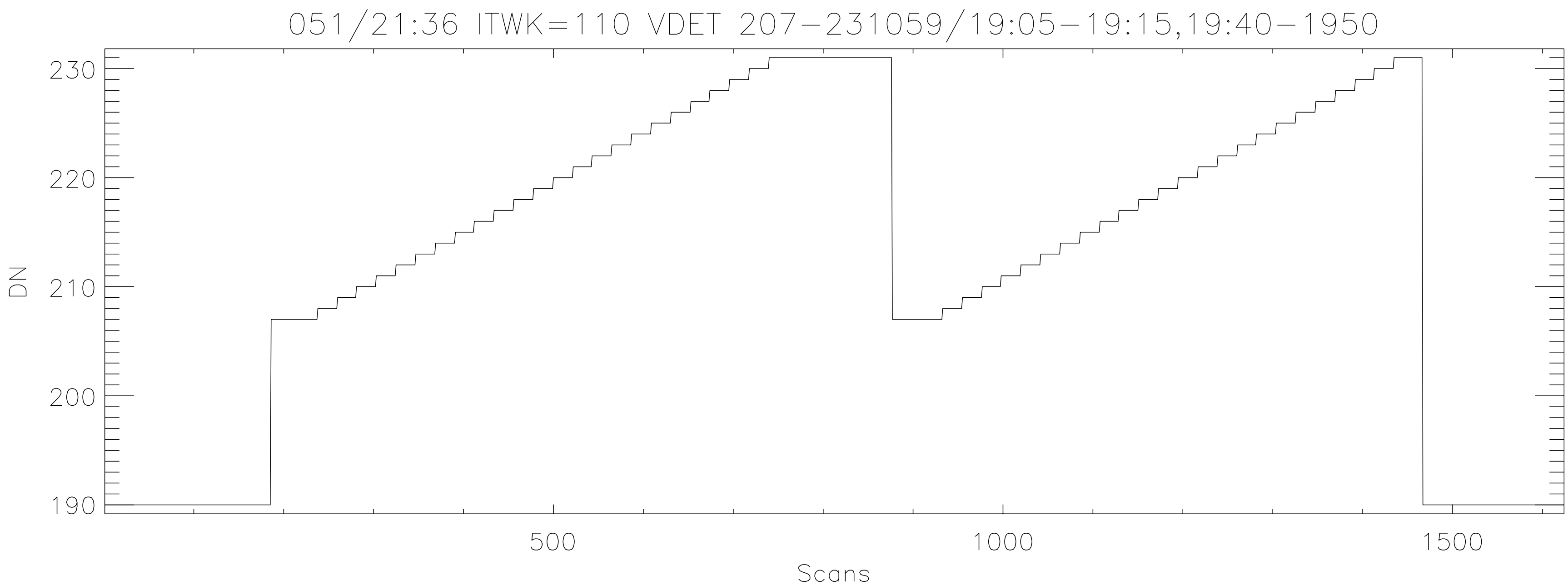
  At Operational Configuration (110/226)

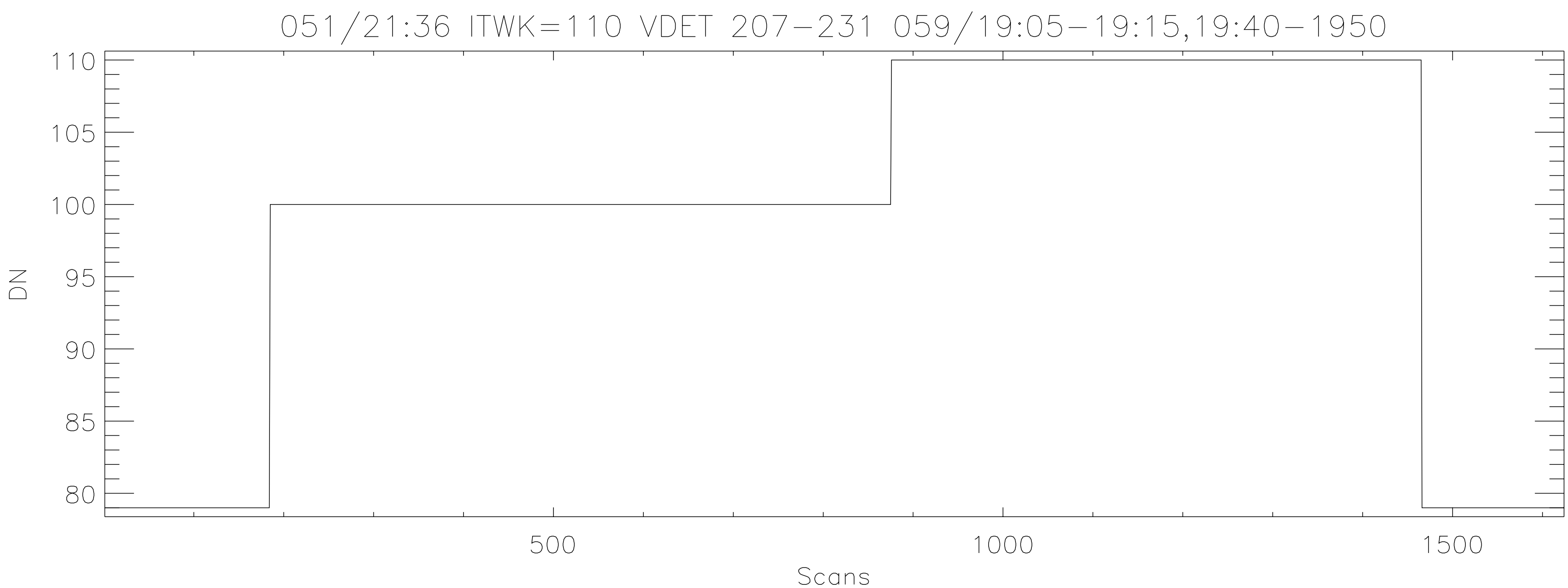
  – MWIR effects seem to be about 3%
    - Bias may be function of scene temperature
    - Effect "incorporated" into calibration coefficient determination

  – SWIR effects may be typically 1 - 3%
    - Must be very careful for scenes with low dn signals in a SWIR band
    - Need verify DN_{SV} not contaminated

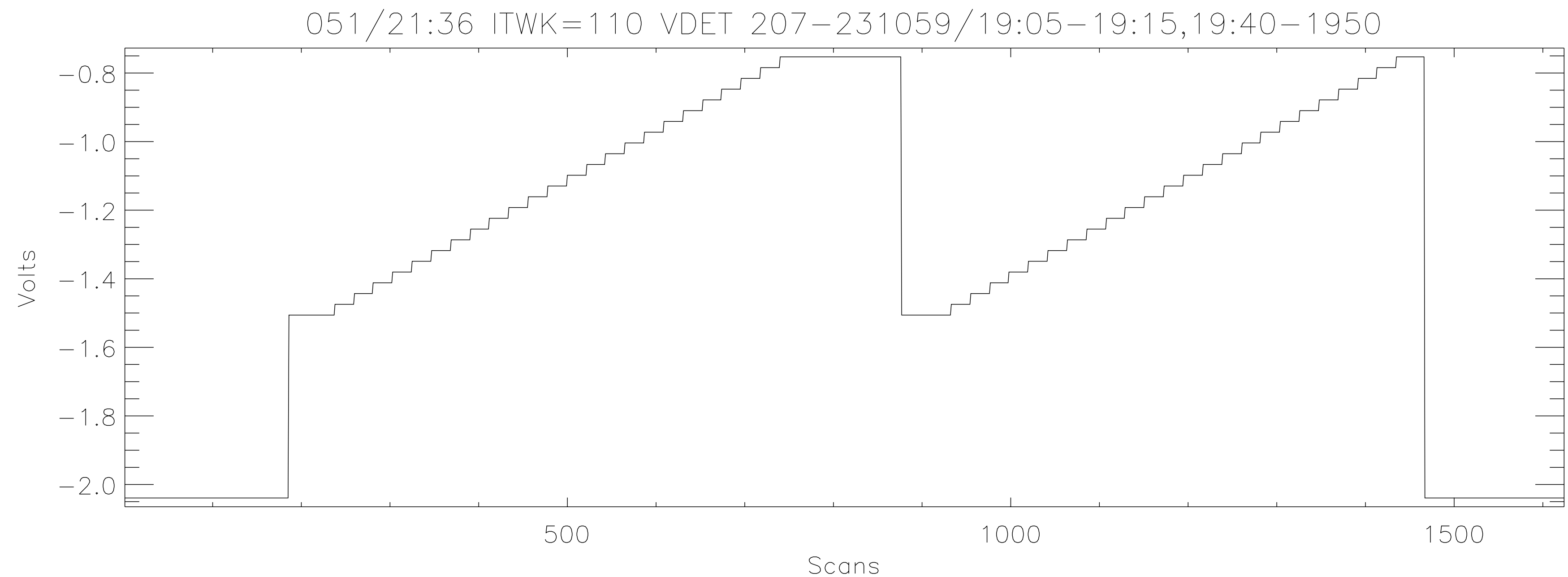
  – PV LWIR effect gone

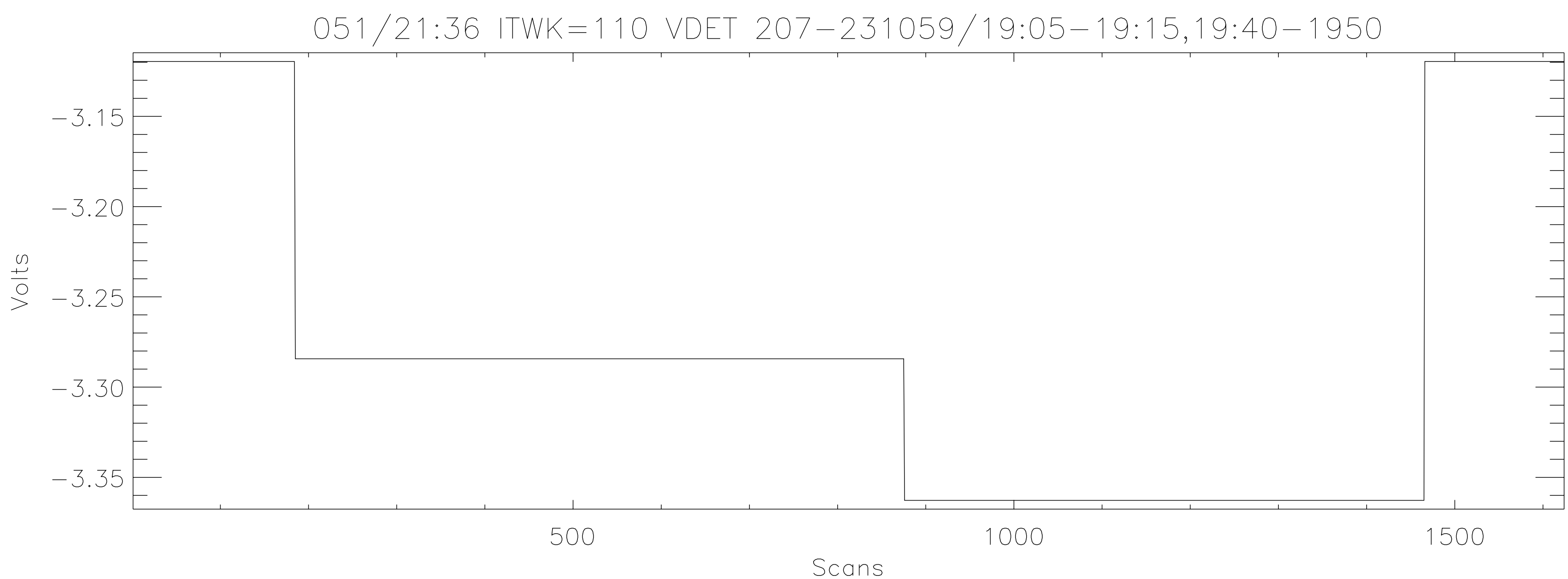
Need review results from June M-SV data & provide recommendation for final operating configuration to Team Leader


051/21:36 ITWK=110 VDET 207-231059/19:05-19:15,19:40-1950
DN
230
220
210
200
190
500
1000
1500
Scans


051/21:36 ITWK=110 VDET 207-231 059/19:05-19:15,19:40-1950
DN
110
105
100
95
90
85
80
500
1000
1500
Scans

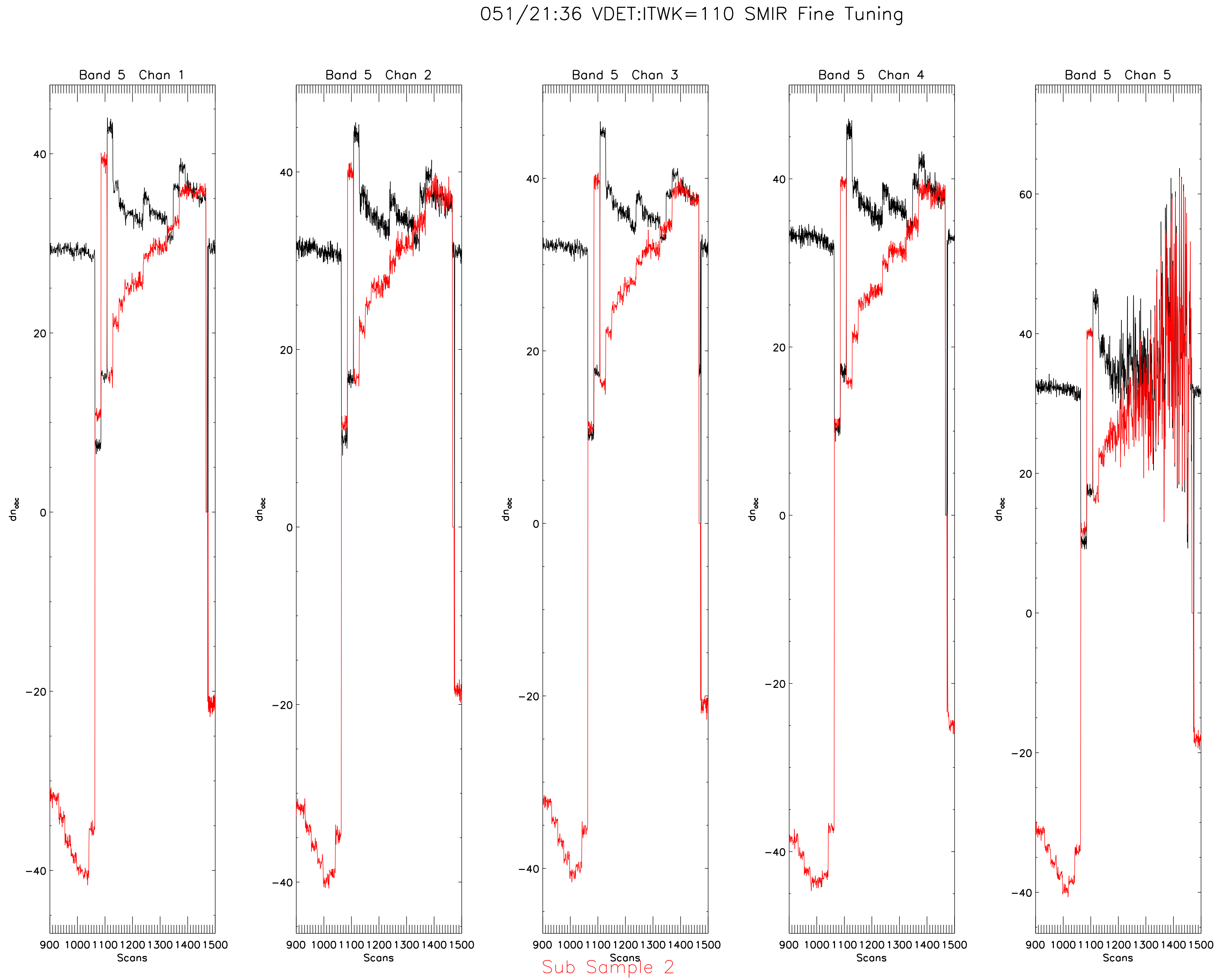
EXTK-A1





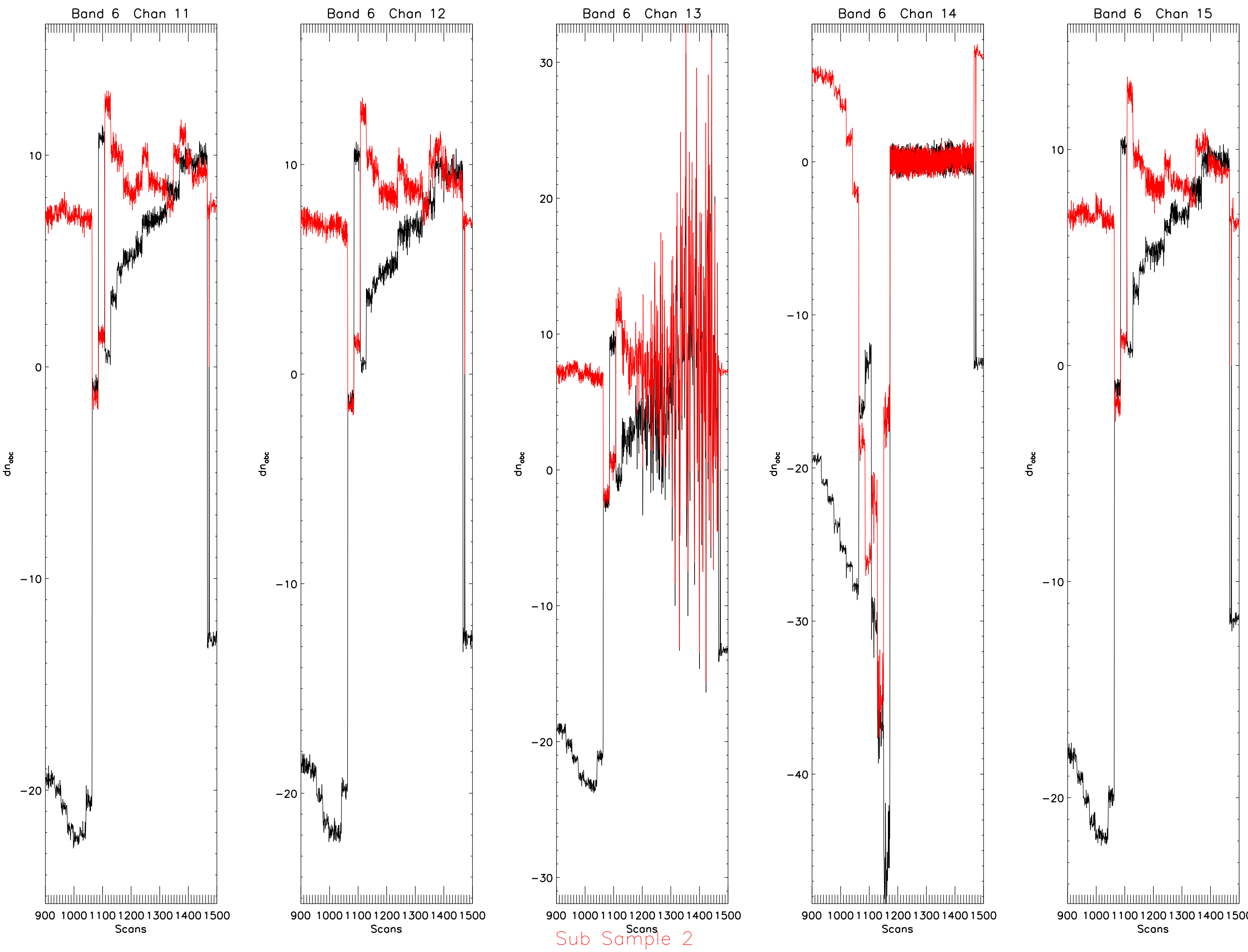
Voltages converted using Command and Telemetry coefficients

EXTK-A2

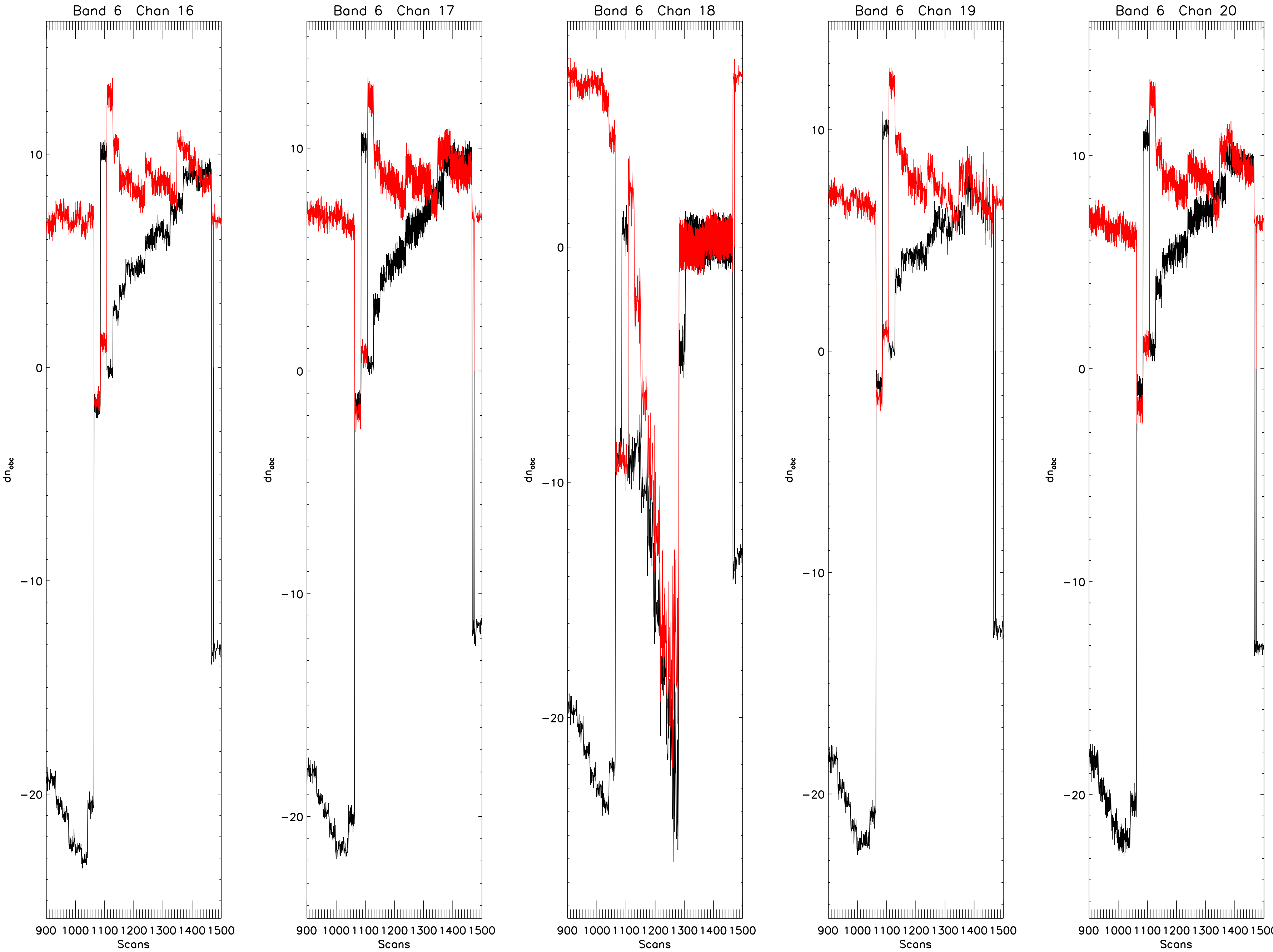

051/21:36 VDET:ITWK=110 SMIR Fine Tuning
Band 5 Chan 1
Band 5 Chan 2
Band 5 Chan 3
Band 5 Chan 4
Band 5 Chan 5
dn_{obc}
Scans
Sub Sample 2

EXTK-A3

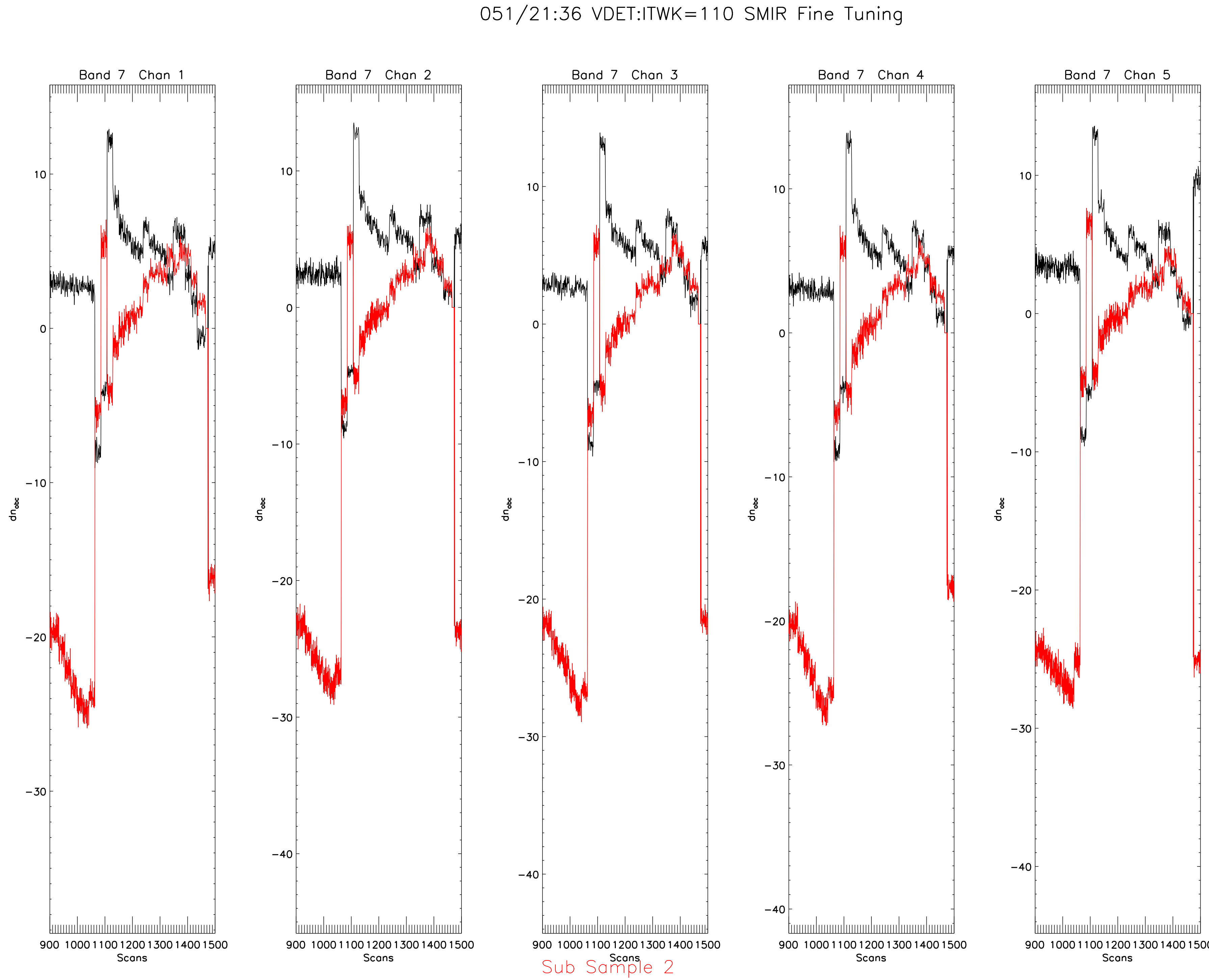
051/21:36 VDET:ITWK=110 SMIR Fine Tuning



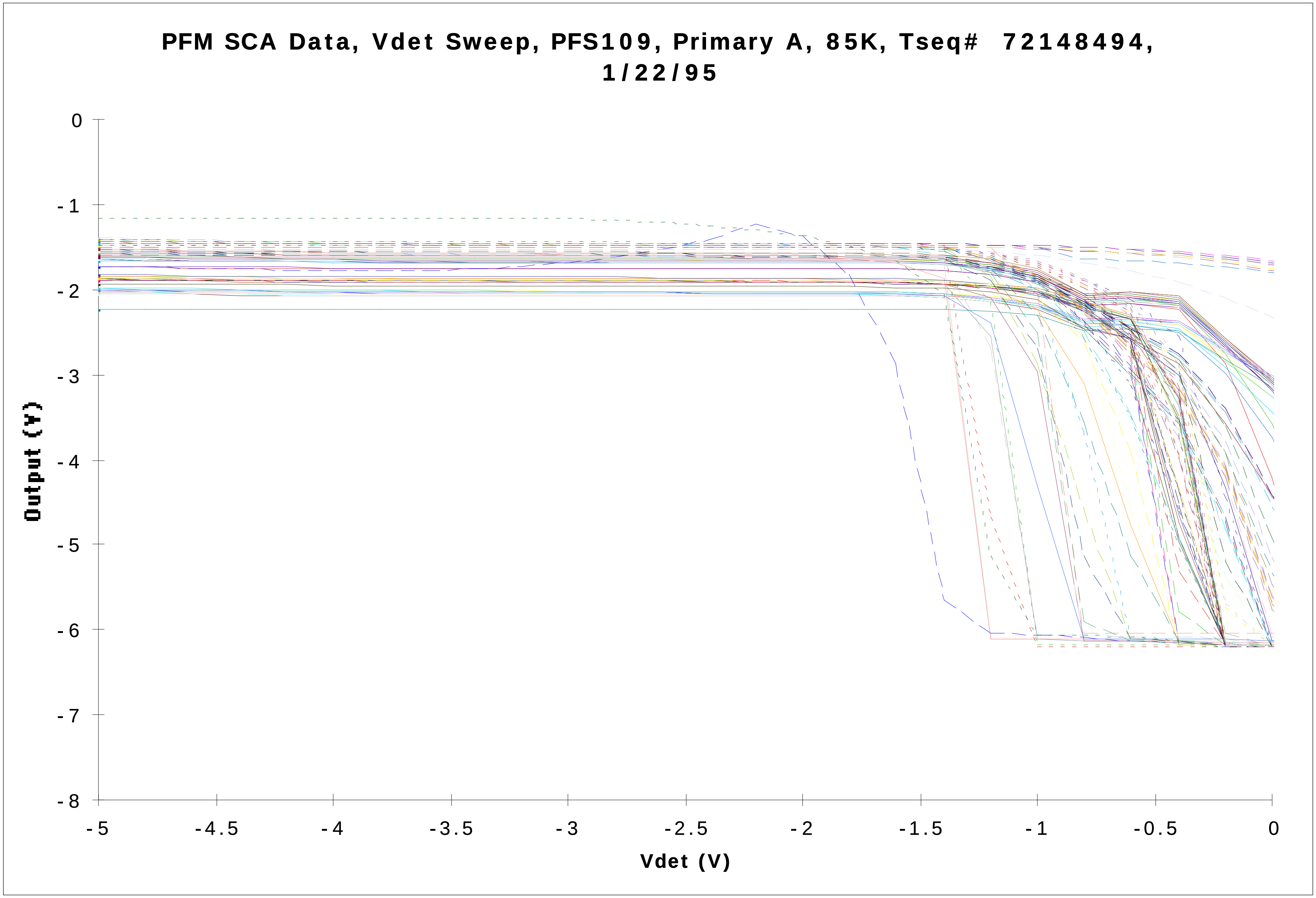
EXTK-A4


Band 6 Chan 16
Band 6 Chan 17
Band 6 Chan 18
Band 6 Chan 19
Band 6 Chan 20
dn_{obc}
Scans
900 1000 1100 1200 1300 1400 1500
10
0
−10
−20

EXTK-A5

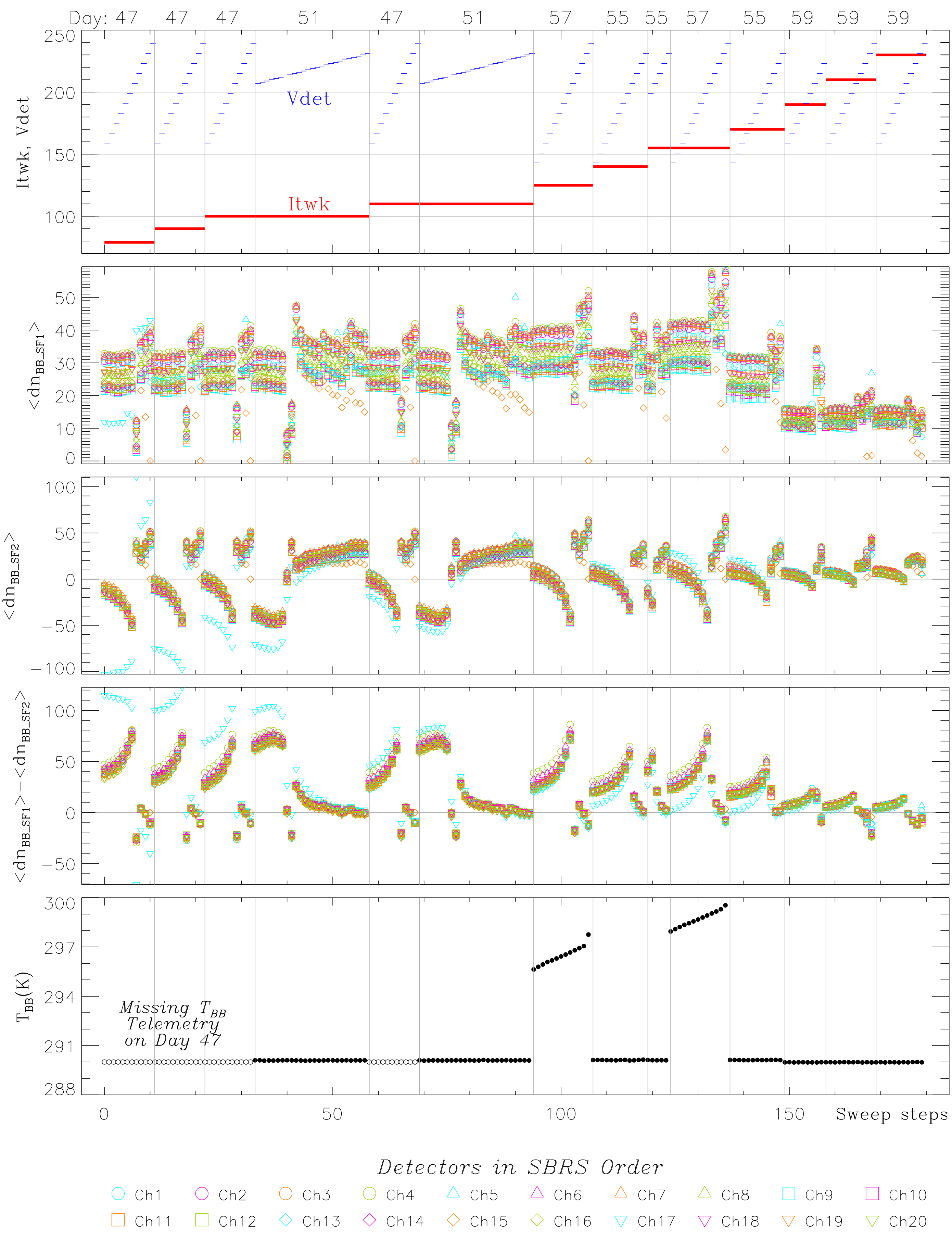

051/21:36 VDET:ITWK=110 SMIR Fine Tuning
Band 7 Chan 1
Band 7 Chan 2
Band 7 Chan 3
Band 7 Chan 4
Band 7 Chan 5
dn_obc
Scans
Sub Sample 2

EXTK-A6


PFM SCA Data, Vdet Sweep, PFS109, Primary A, 85K, Tseq# 72148494, 1/22/95
Output (V)
0
-1
-2
-3
-4
-5
-6
-7
-8
-5
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
Vdet (V)

EXTK-A7

Figure 1. Band 5 dn_{BB} of SMIR–A Itwk/Vdet Sweeps



EXTK-A8

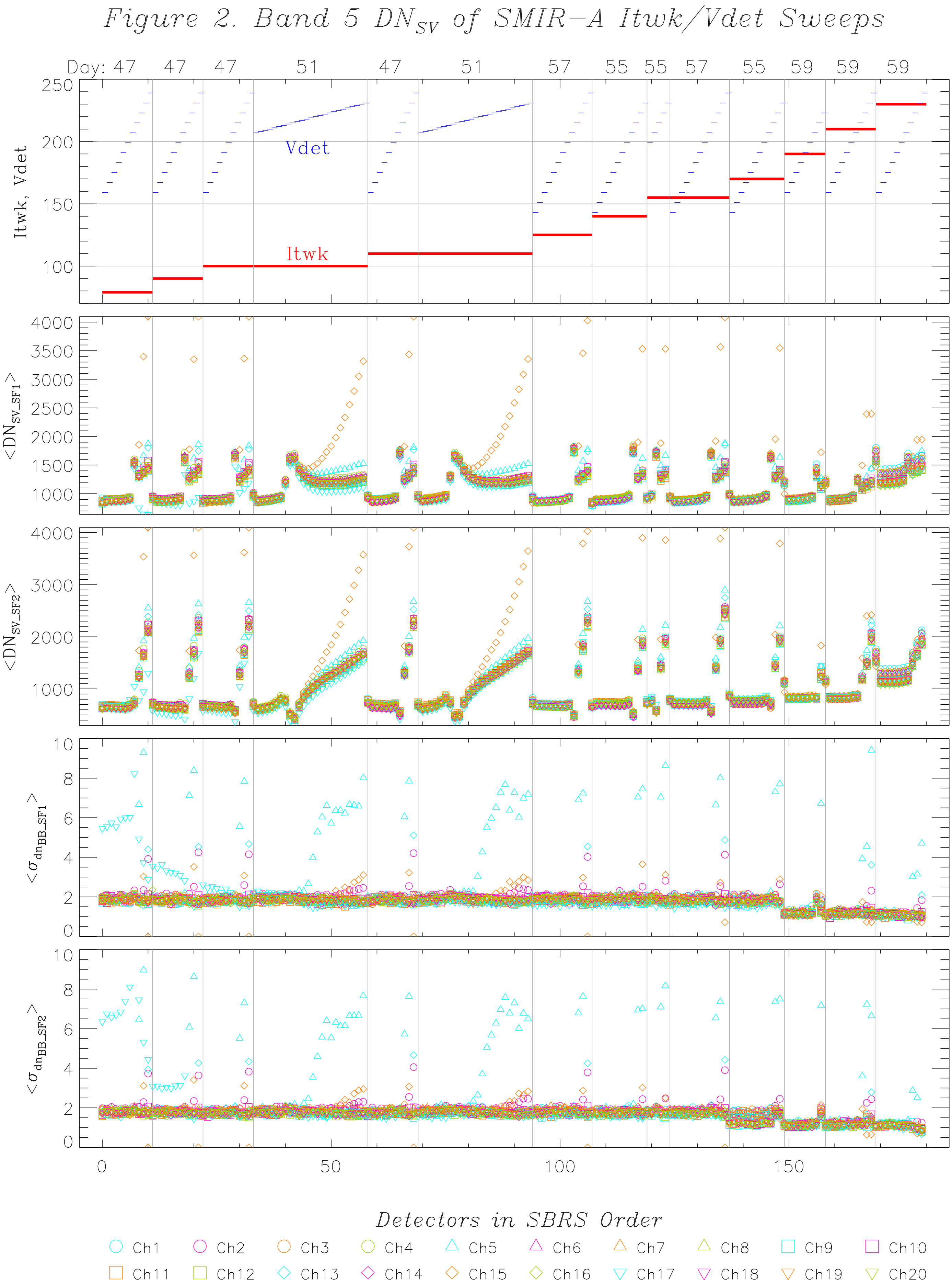


Figure 2. Band 5 DN$_{SV}$ of SMIR-A Itwk/Vdet Sweeps
Day: 47 47 47 51 47 51 57 55 55 57 55 59 59 59
Itwk, Vdet
Vdet
Itwk
<DN$_{SV_SF1}$>
<DN$_{SV_SF2}$>
<$\sigma_{dn_{BB\_SF1}}$>
<$\sigma_{dn_{BB\_SF2}}$>
Detectors in SBRS Order
Ch1 Ch2 Ch3 Ch4 Ch5 Ch6 Ch7 Ch8 Ch9 Ch10
Ch11 Ch12 Ch13 Ch14 Ch15 Ch16 Ch17 Ch18 Ch19 Ch20

Figure 3. Band 6 dn_{BB} of SMIR–A Itwk/Vdet Sweeps

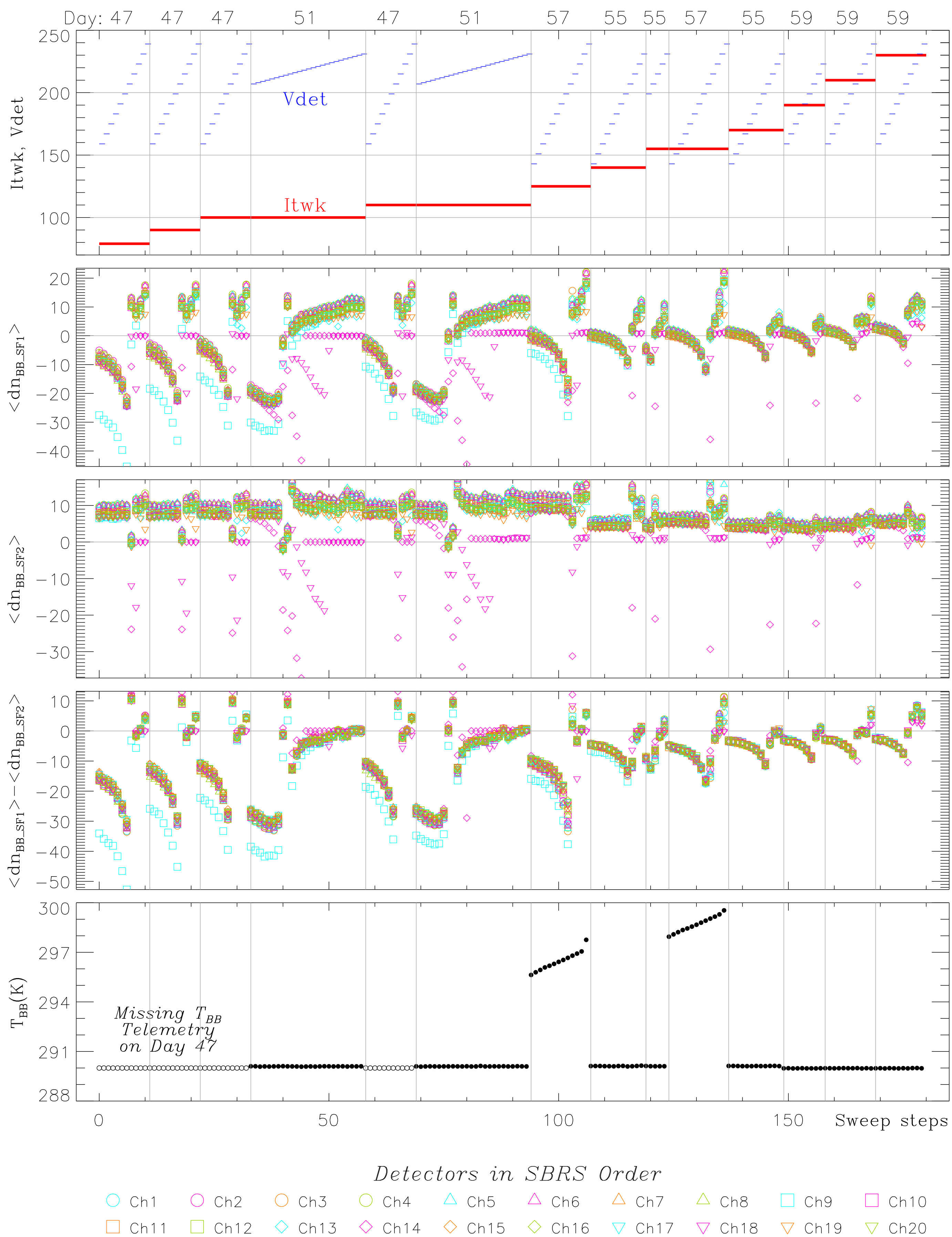


Figure 4. Band 6 DN_{SV} of SMIR–A Itwk/Vdet Sweeps

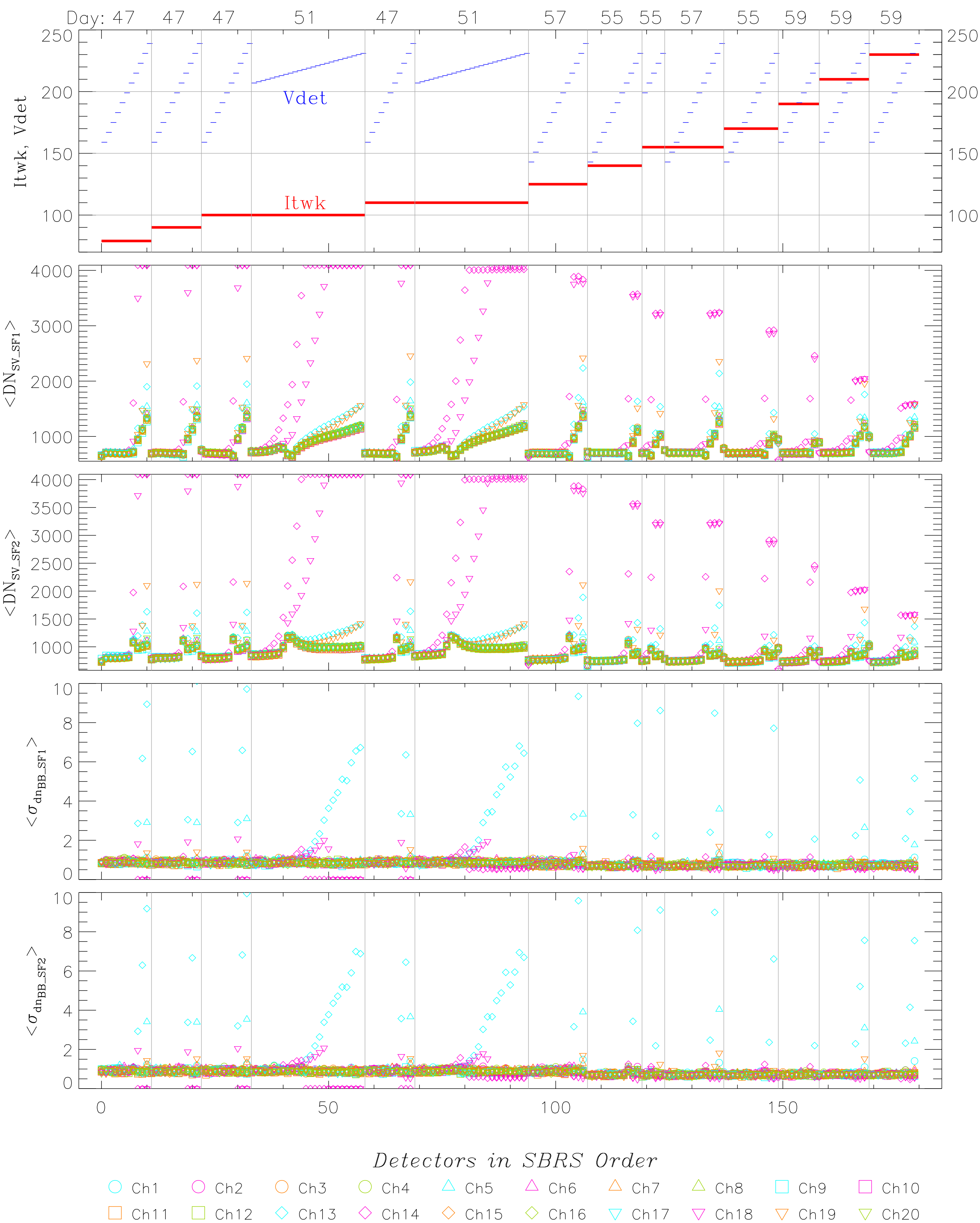


Figure 5. Band 7 dn_{BB} of SMIR–A Itwk/Vdet Sweeps

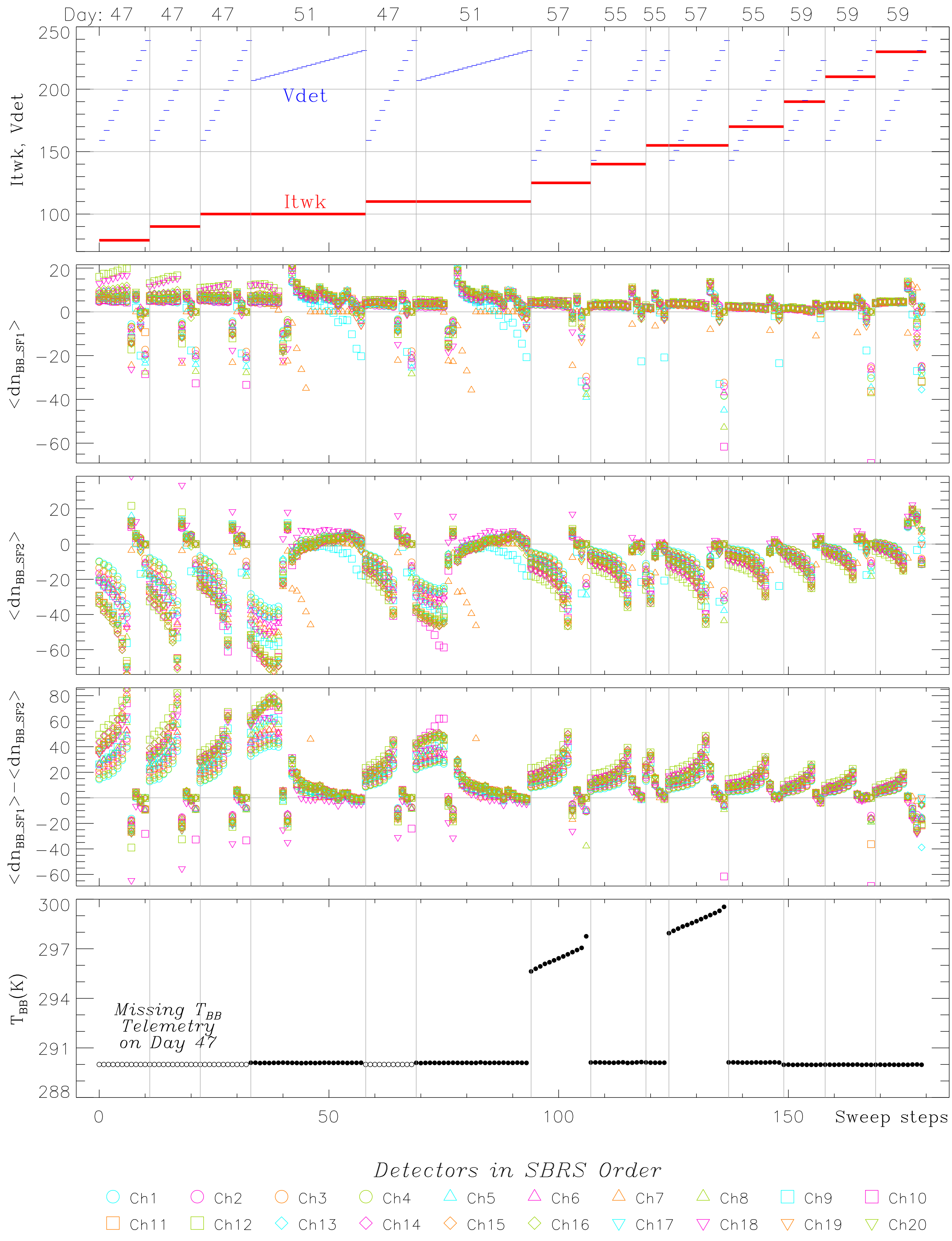


Figure 6. Band 7 DN_{SV} of SMIR–A Itwk/Vdet Sweeps

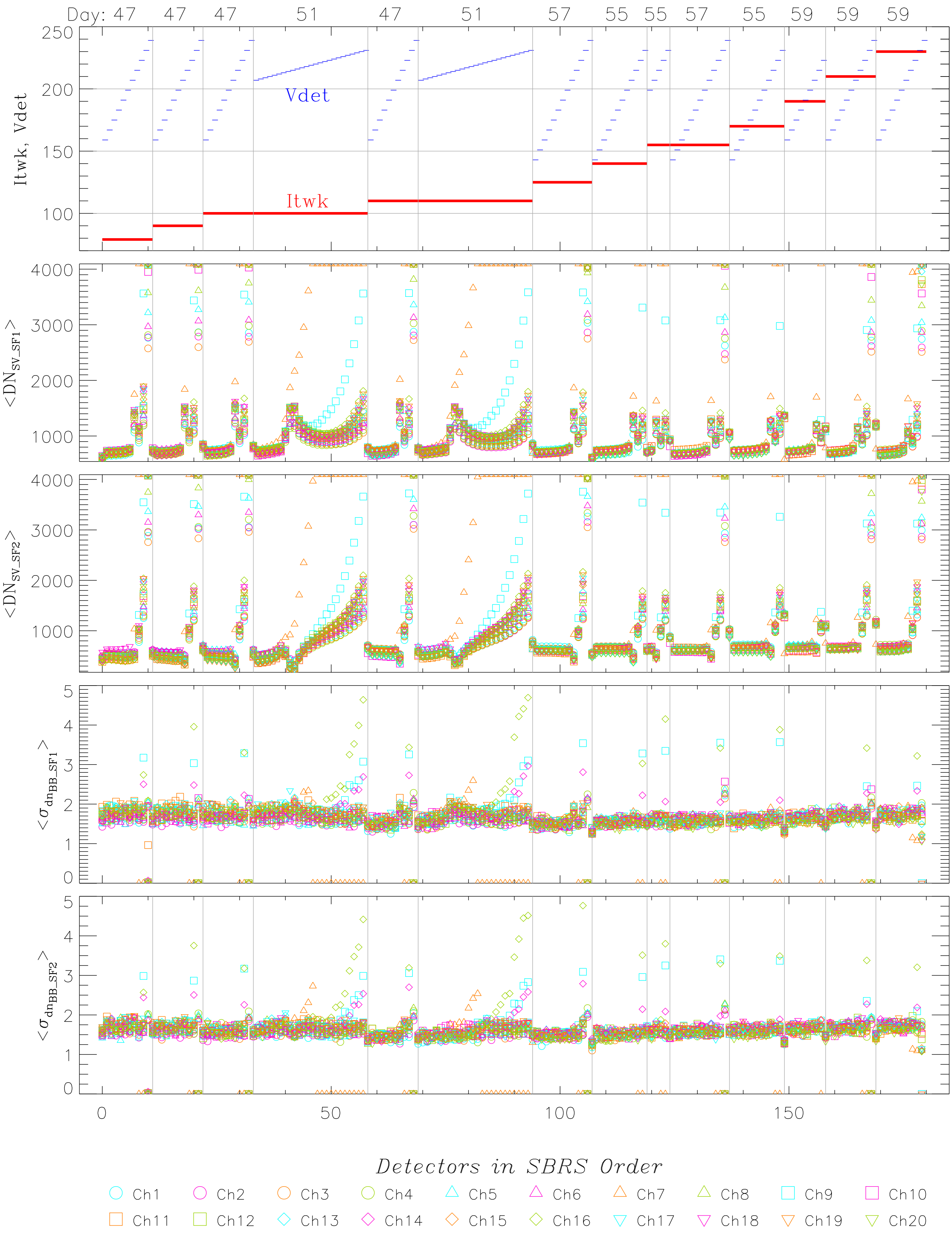


Figure 1. PFM B5 <dn_{BB}> of Sub-frame 1, 2, and their Difference

OBC Data Sets Selected during OA-26 (Day 45-47)
(Blackbody Warm-up/Cool-down Activity; Itwk:79/Vdet:190)

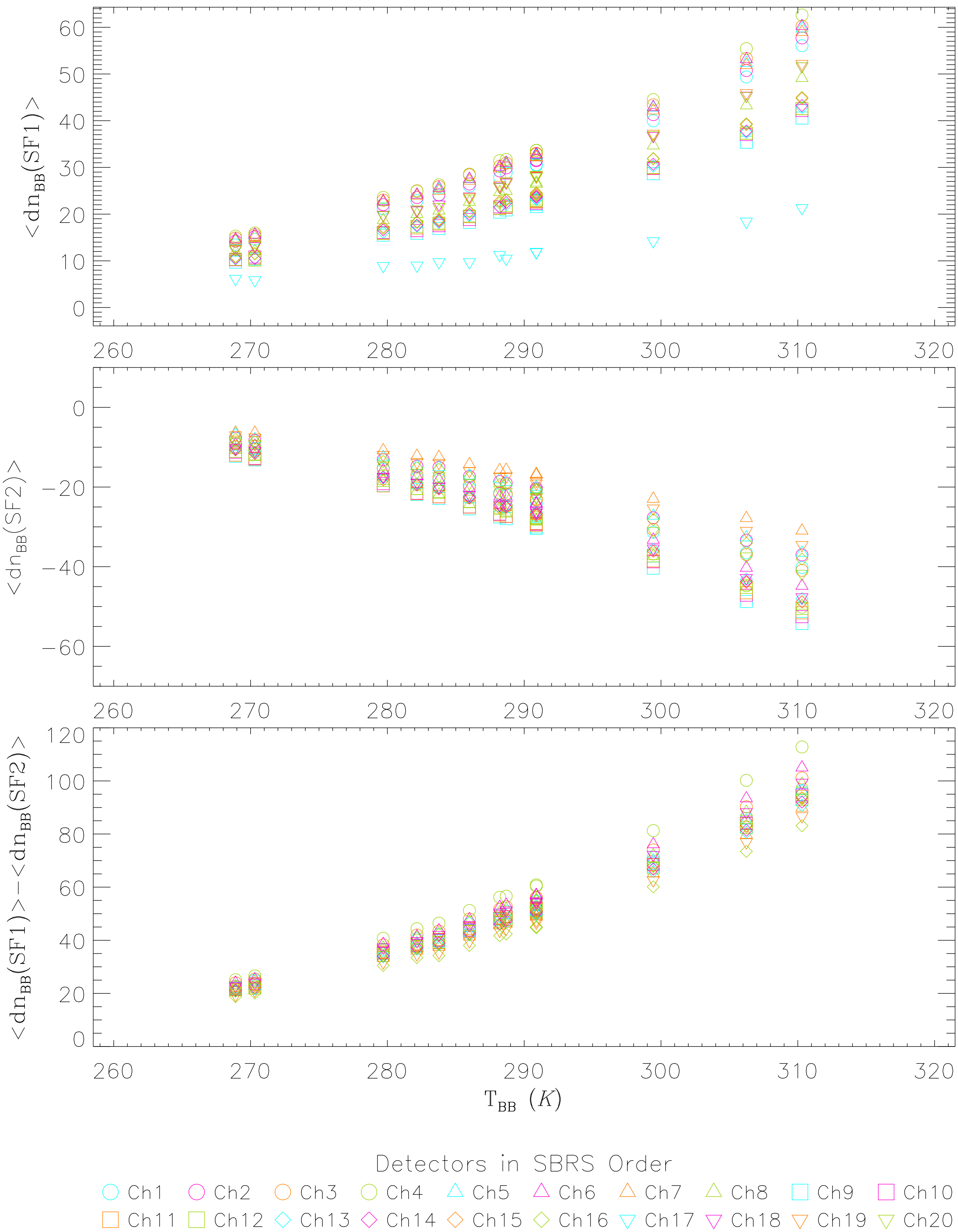


Figure 2. PFM B6 $<dn_{BB}>$ of Sub-frame 1, 2, and their Difference

OBC Data Sets Selected during OA-26 (Day 45-47)
(Blackbody Warm-up/Cool-down Activity; Itwk:79/Vdet:190)

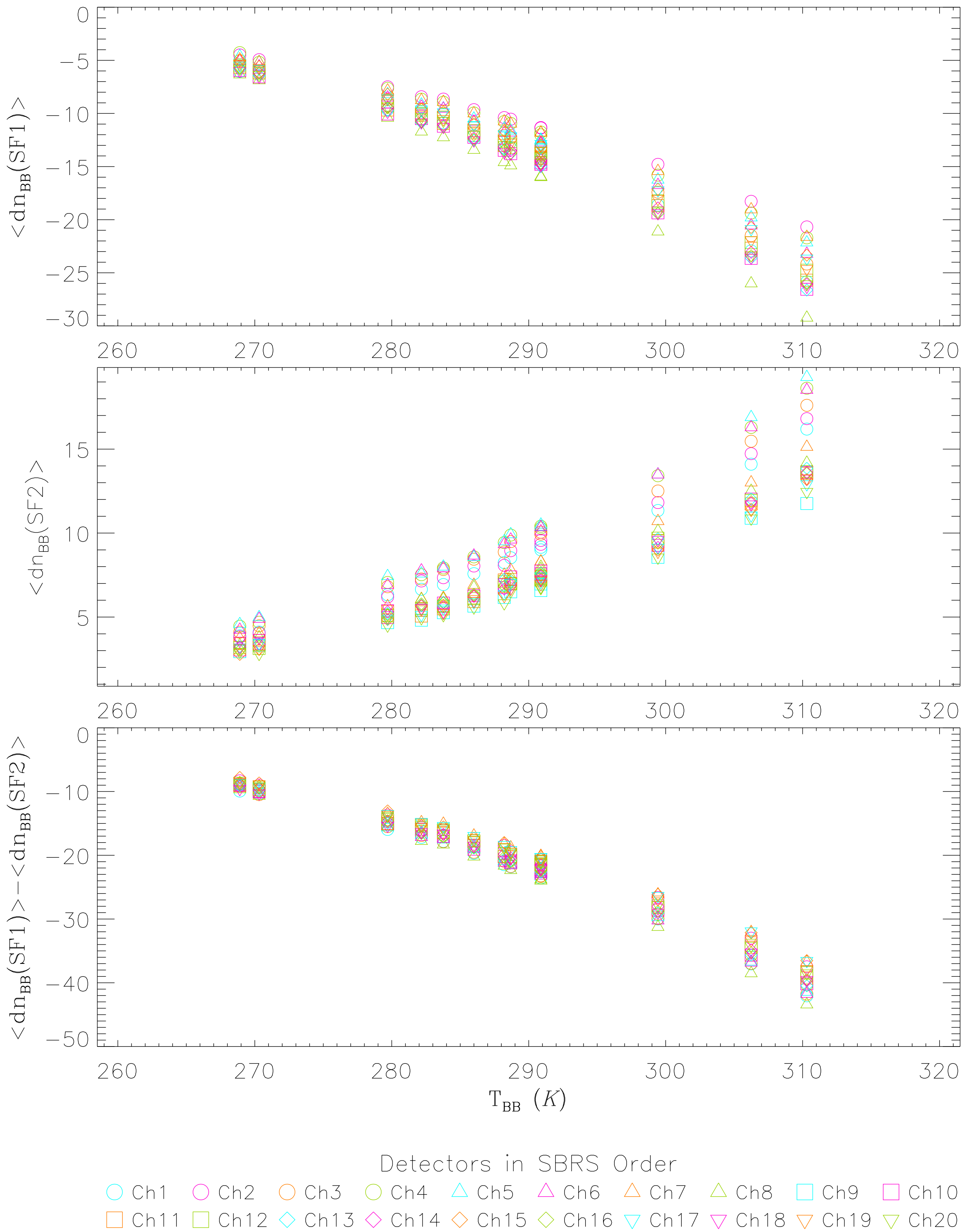


Figure 3. PFM B7 <dn_{BB}> of Sub-frame 1, 2, and their Difference

OBC Data Sets Selected during OA-26 (Day 45-47)
(Blackbody Warm-up/Cool-down Activity; Itwk:79/Vdet:190)

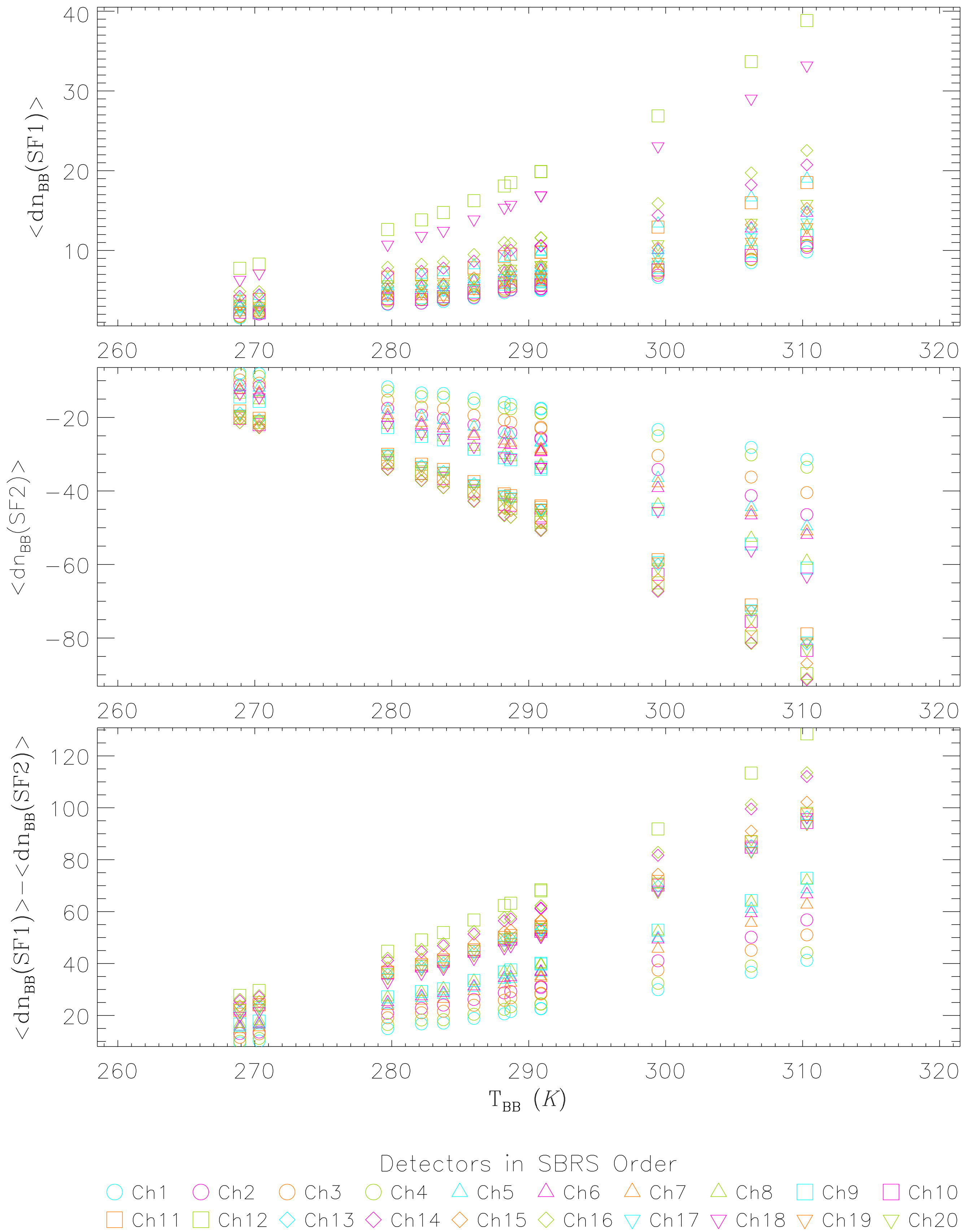
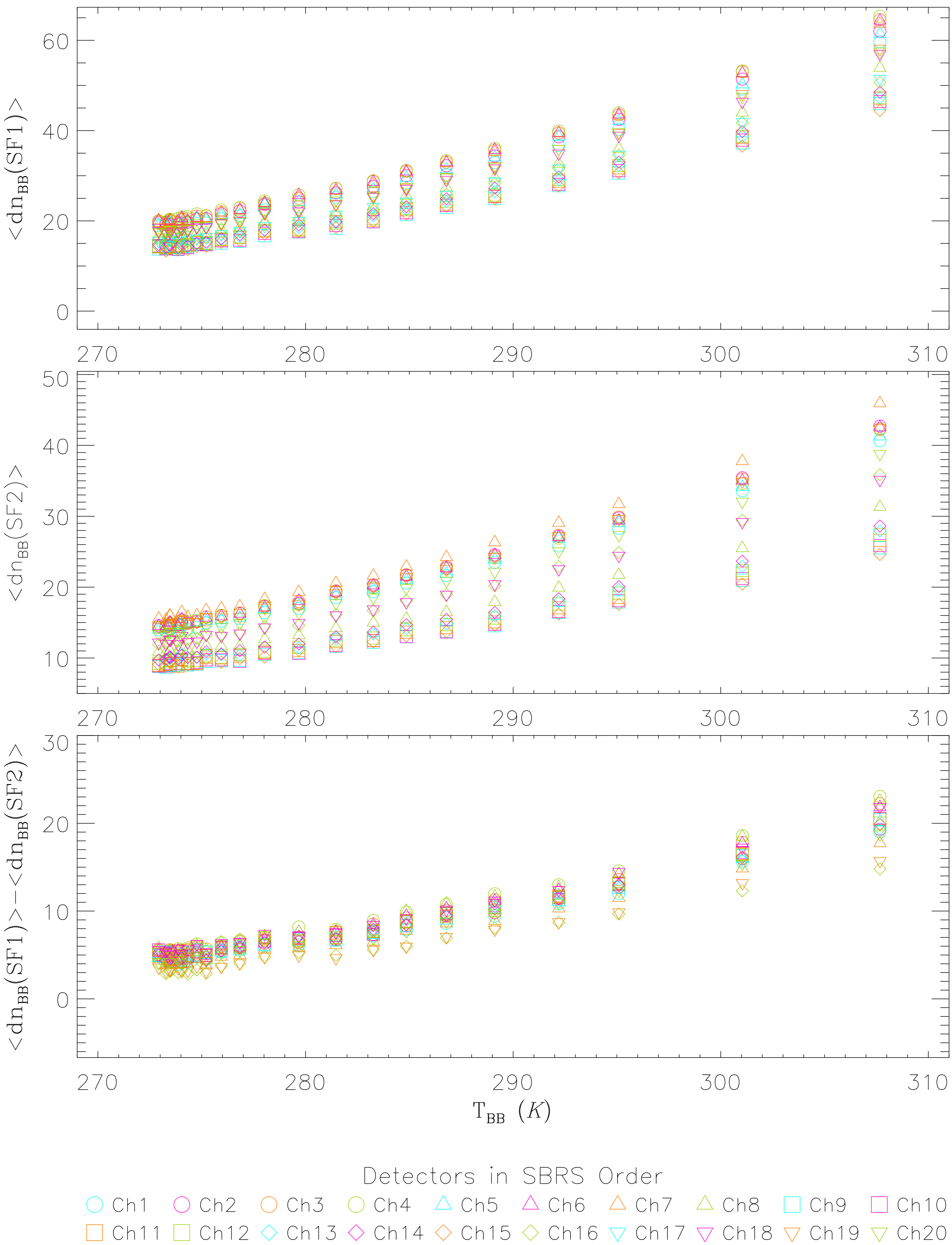


Figure 1. PFM B5 <dn_{BB}> of Sub-frame 1, 2, and their Difference

OBC Data Sets Selected during OA-26 (Day 83-84)
(Blackbody Cool-down Activity; Itwk:100/Vdet:218)



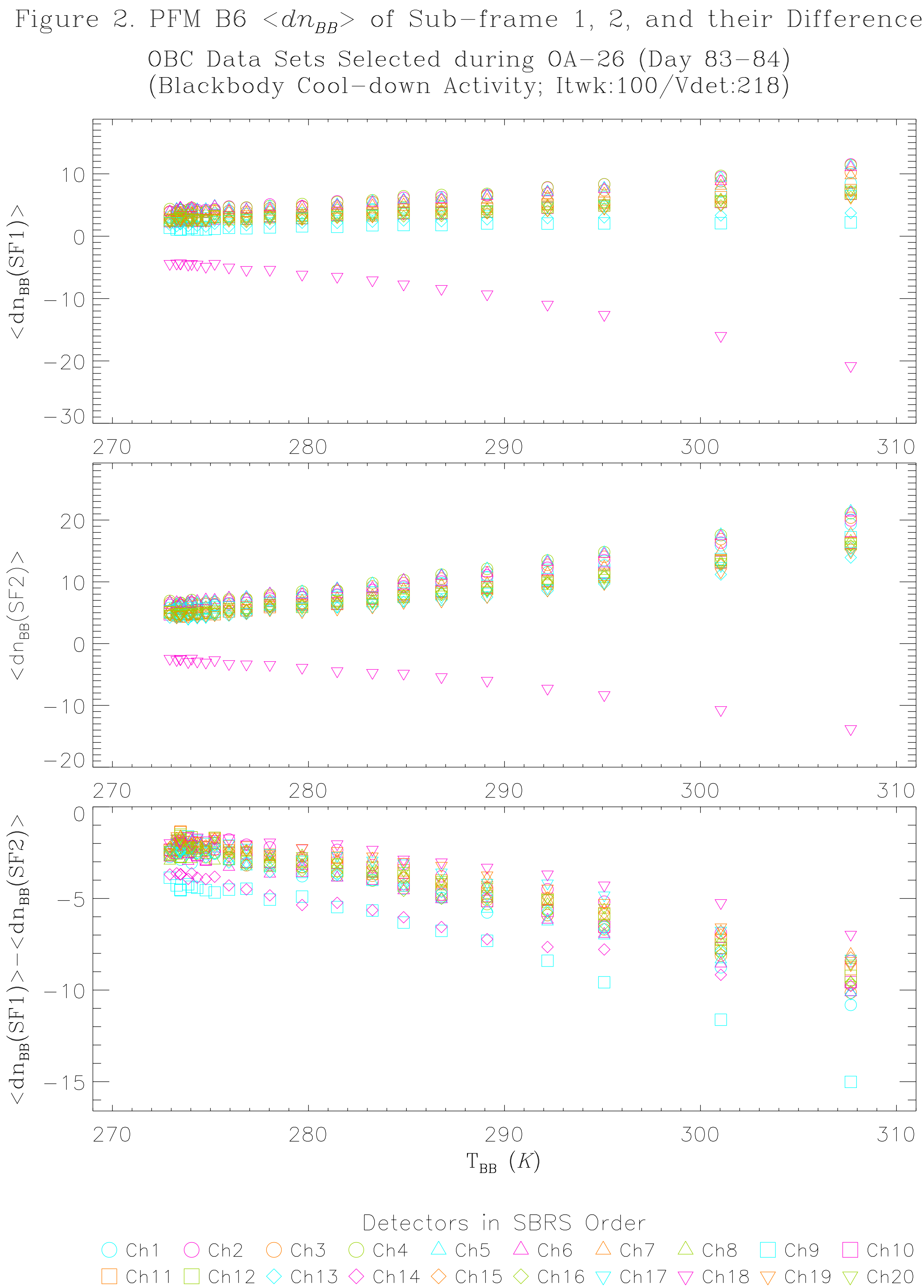
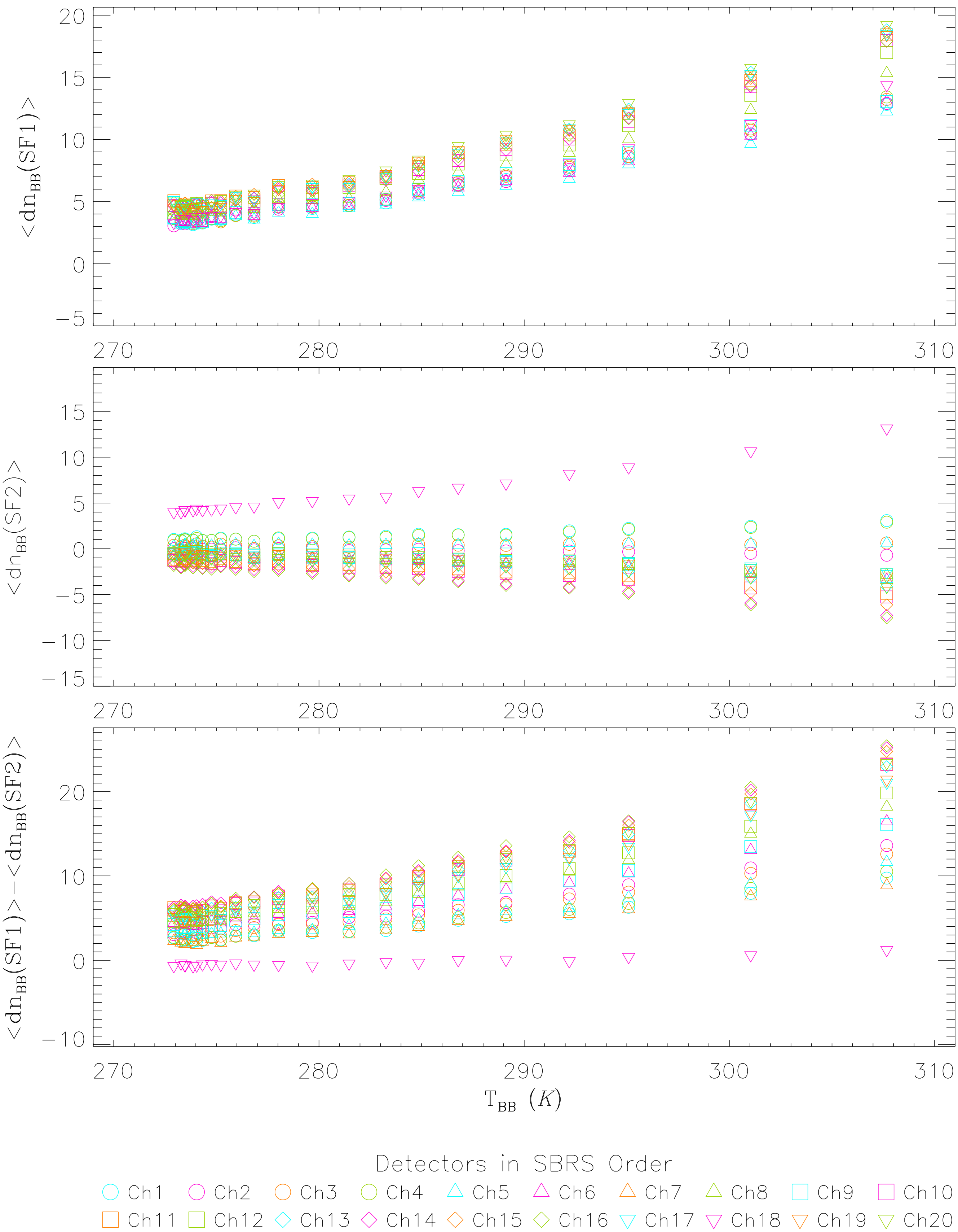


Figure 2. PFM B6 <dn_BB> of Sub-frame 1, 2, and their Difference
OBC Data Sets Selected during OA-26 (Day 83-84)
(Blackbody Cool-down Activity; Itwk:100/Vdet:218)
<dn_BB(SF1)>
<dn_BB(SF2)>
<dn_BB(SF1)>-<dn_BB(SF2)>
T_BB (K)
Detectors in SBRS Order
Ch1 Ch2 Ch3 Ch4 Ch5 Ch6 Ch7 Ch8 Ch9 Ch10
Ch11 Ch12 Ch13 Ch14 Ch15 Ch16 Ch17 Ch18 Ch19 Ch20

Figure 3. PFM B7 $<dn_{BB}>$ of Sub-frame 1, 2, and their Difference

OBC Data Sets Selected during OA-26 (Day 83-84)
(Blackbody Cool-down Activity; Itwk:100/Vdet:218)



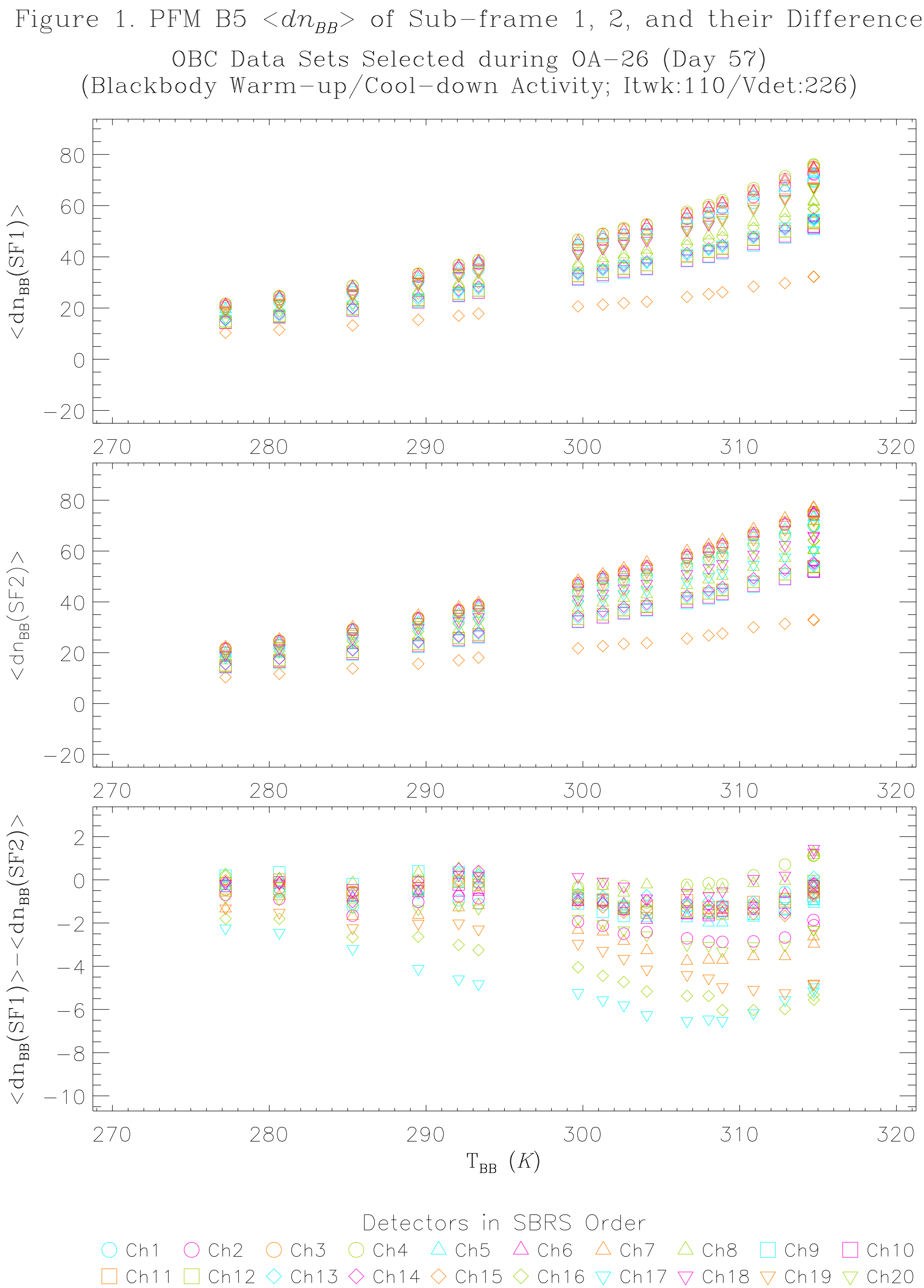
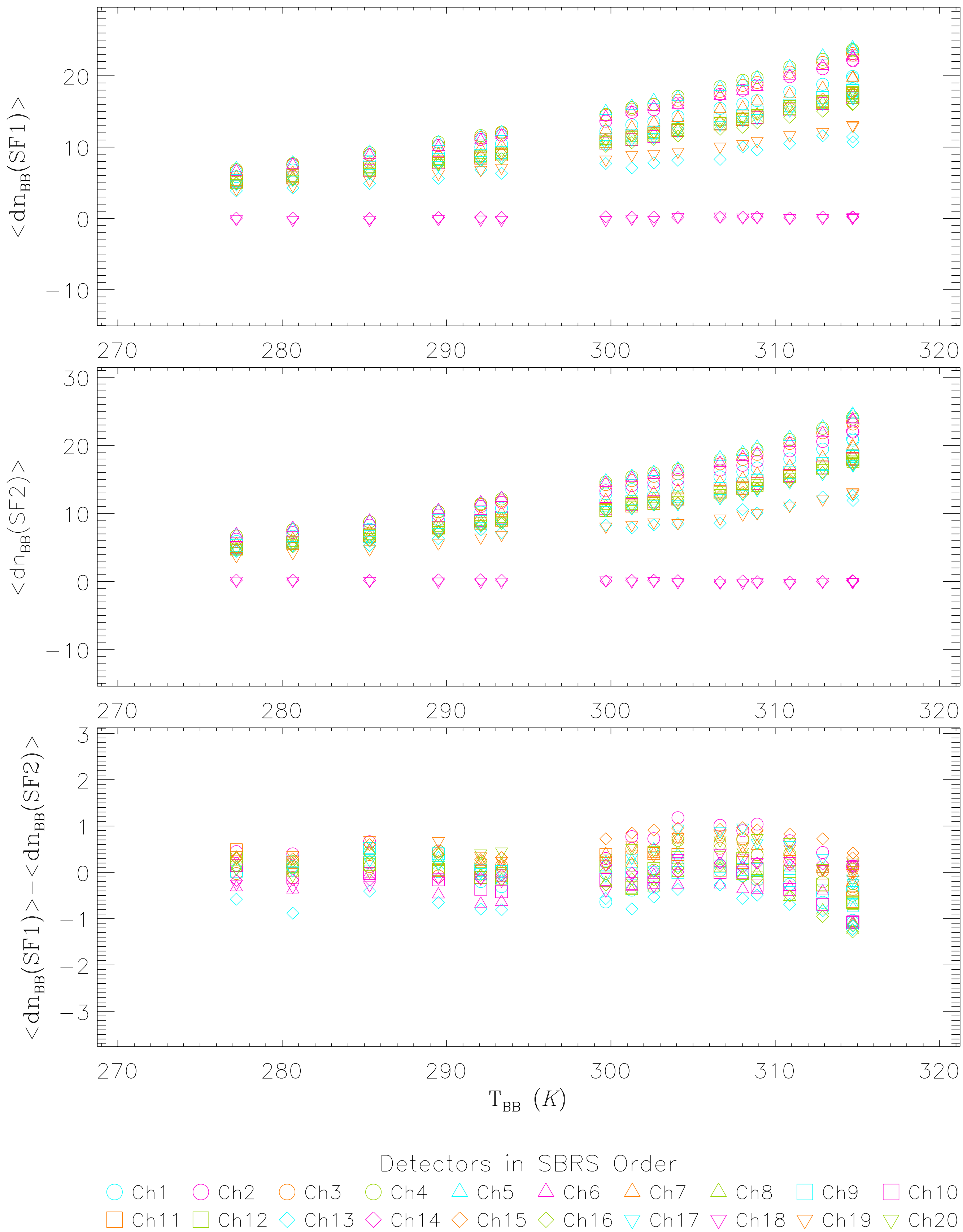


Figure 1. PFM B5 <dn_BB> of Sub-frame 1, 2, and their Difference
OBC Data Sets Selected during OA-26 (Day 57)
(Blackbody Warm-up/Cool-down Activity; Itwk:110/Vdet:226)
<dn_BB(SF1)>
<dn_BB(SF2)>
<dn_BB(SF1)>-<dn_BB(SF2)>
T_BB (K)
80
60
40
20
0
−20
2
0
−2
−4
−6
−8
−10
270
280
290
300
310
320
Detectors in SBRS Order
Ch1
Ch2
Ch3
Ch4
Ch5
Ch6
Ch7
Ch8
Ch9
Ch10
Ch11
Ch12
Ch13
Ch14
Ch15
Ch16
Ch17
Ch18
Ch19
Ch20

Figure 2. PFM B6 <dn_{BB}> of Sub-frame 1, 2, and their Difference

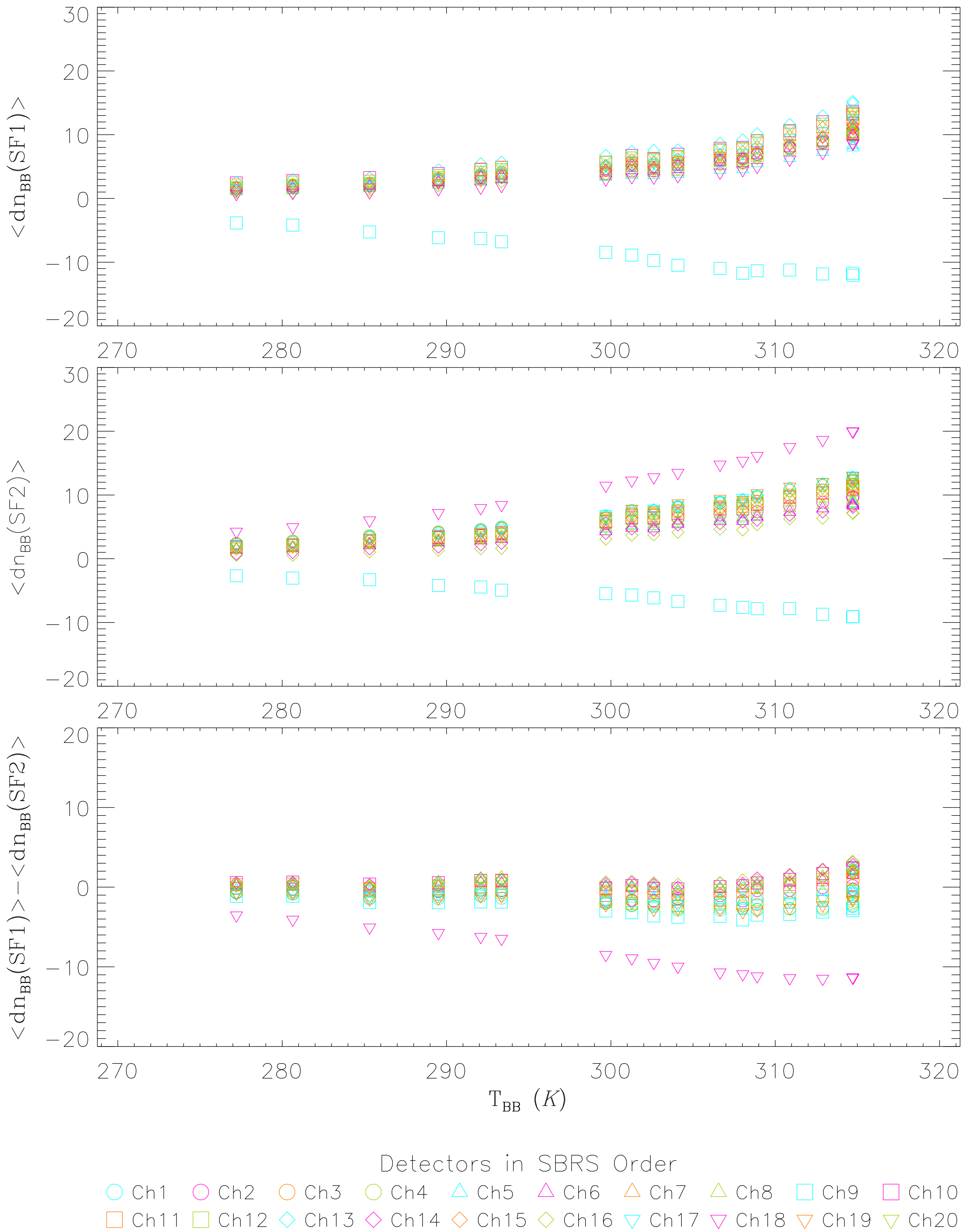
OBC Data Sets Selected during OA-26 (Day 57)
(Blackbody Warm-up/Cool-down Activity; Itwk:110/Vdet:226)



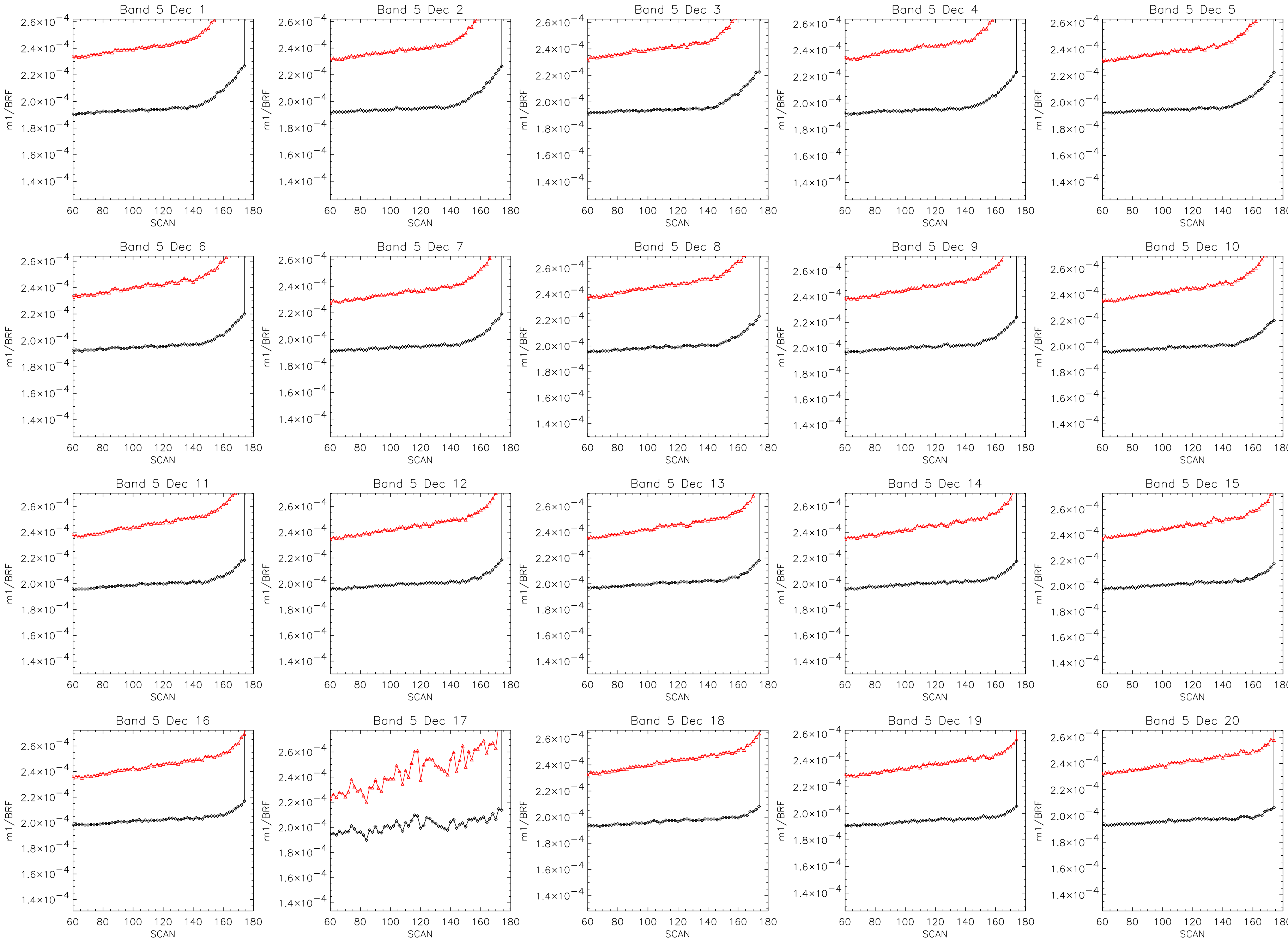
EXTK-A21

Figure 3. PFM B7 $\langle dn_{BB} \rangle$ of Sub-frame 1, 2, and their Difference

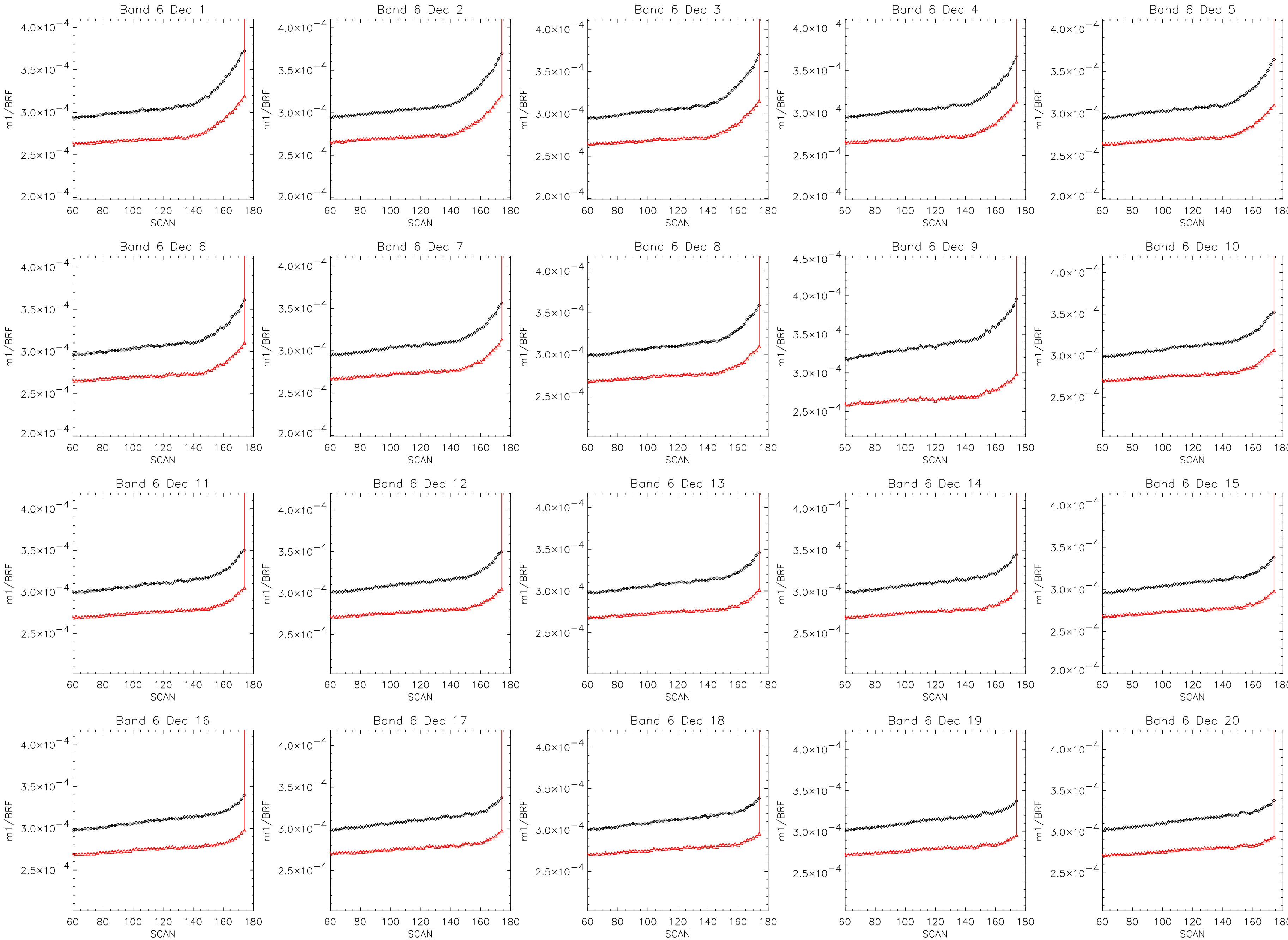
OBC Data Sets Selected during OA-26 (Day 57)
(Blackbody Warm-up/Cool-down Activity; Itwk:110/Vdet:226)



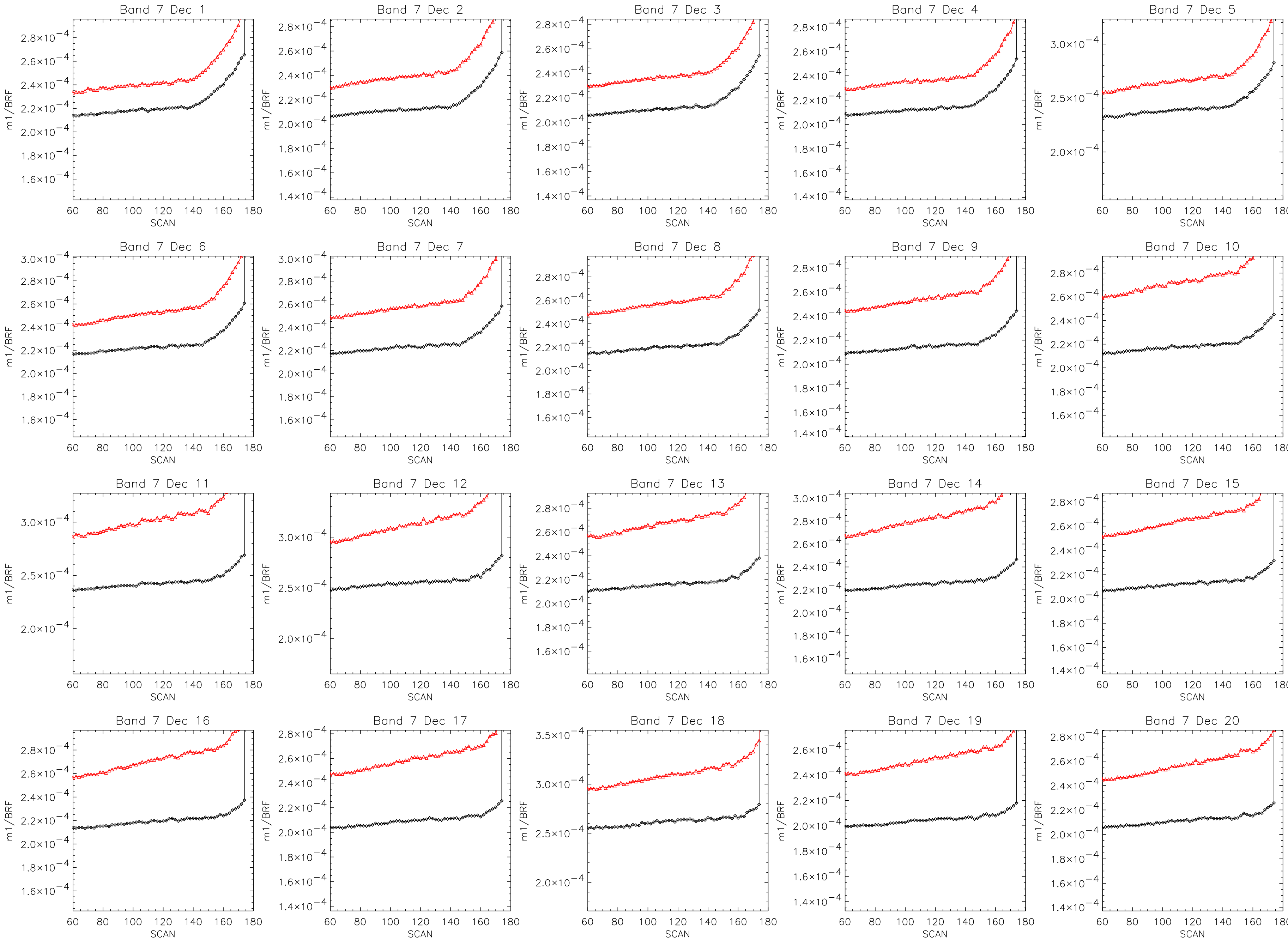
BAND: 5 side1, m1/BRF vs Scan, 2000_056_2350 VDEC/ITWK 79/190'



BAND: 6 side1, m1/BRF vs Scan, 2000_056_2350 VDEC/ITWK 79/190'

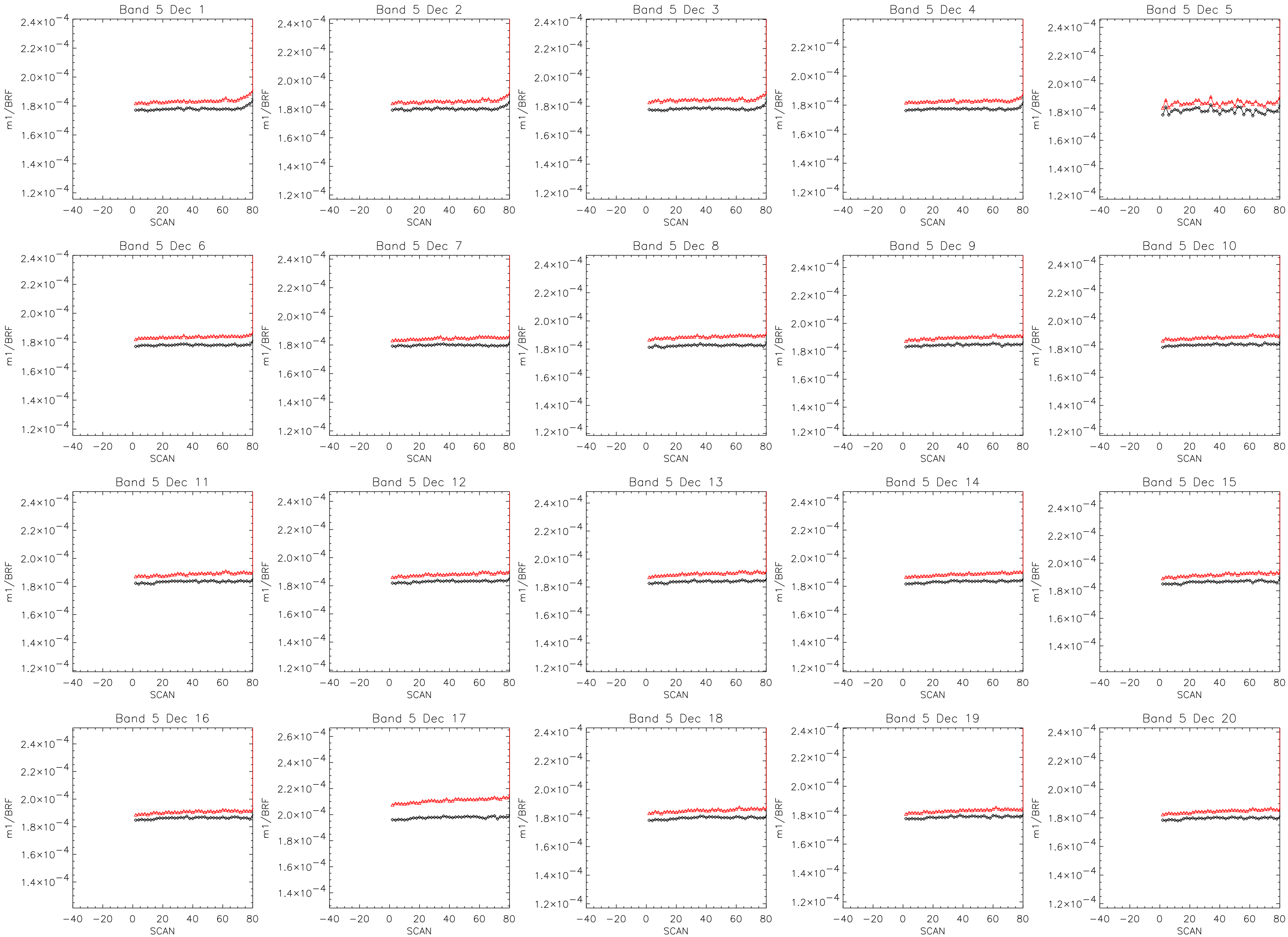


BAND: 7 side1, m1/BRF vs Scan, 2000_056_2350 VDEC/ITWK 79/190'

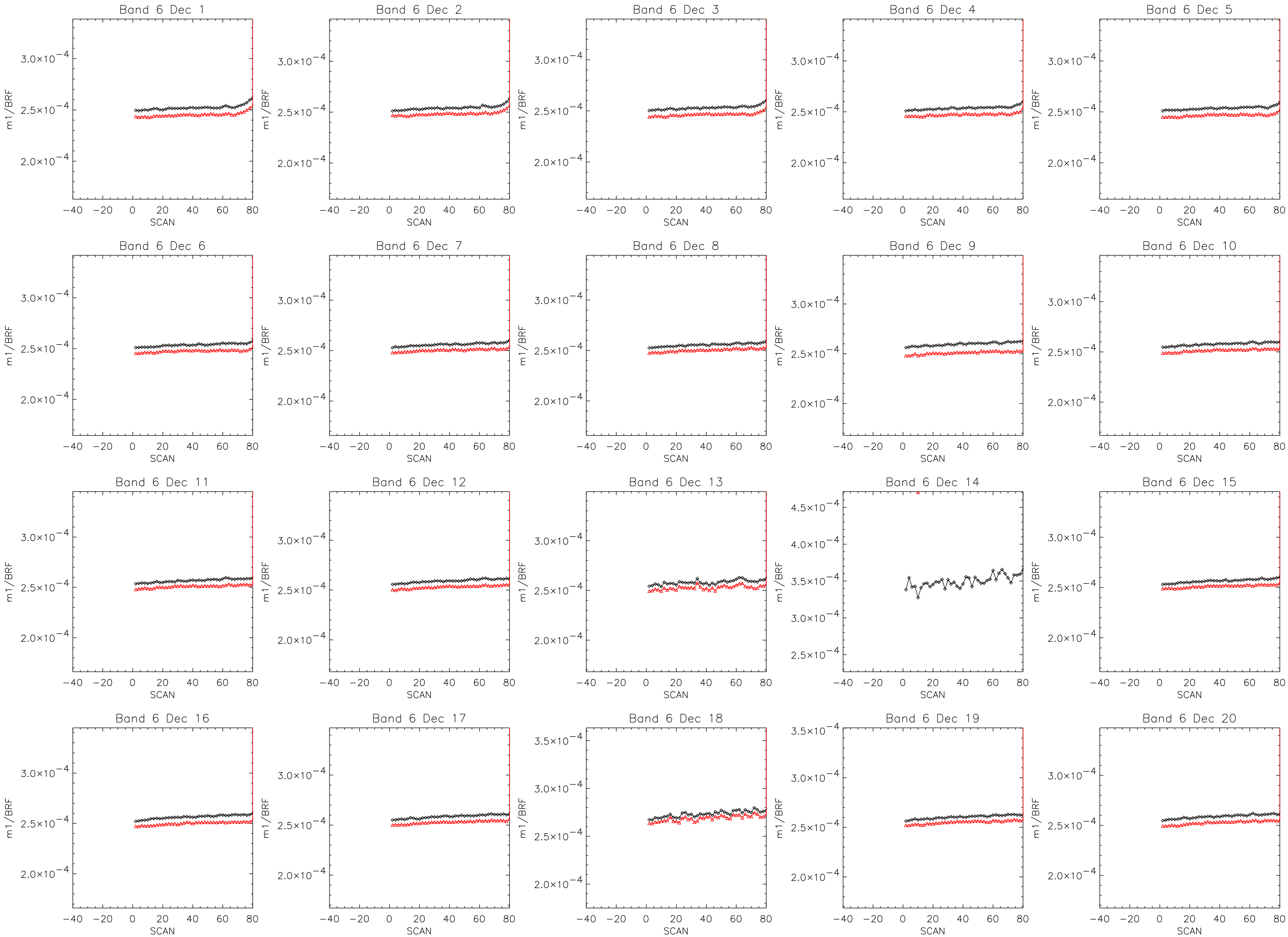


EXTK-A25

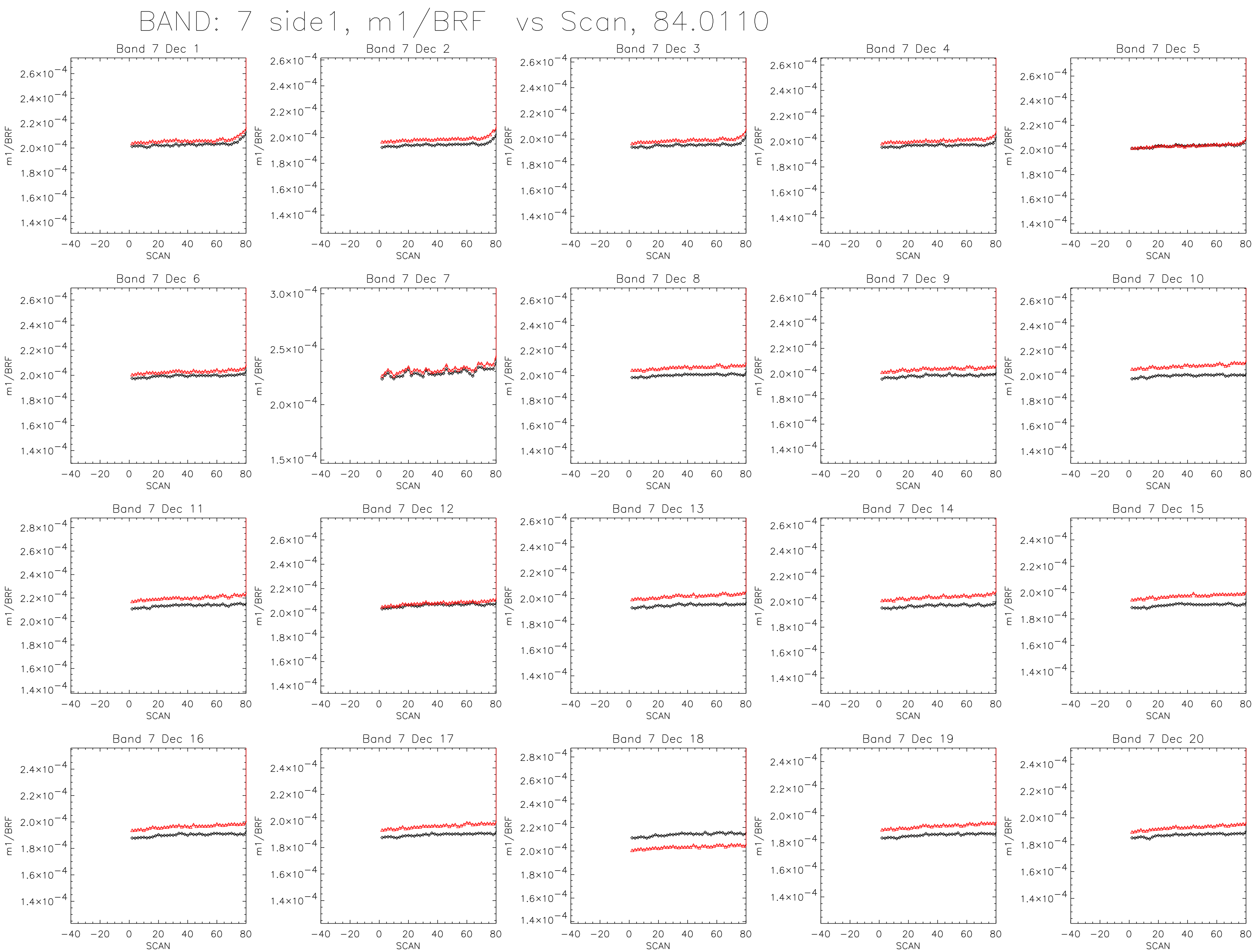
BAND: 5 side1, m1/BRF vs Scan, 84.0110



BAND: 6 side1, m1/BRF vs Scan, 84.0110

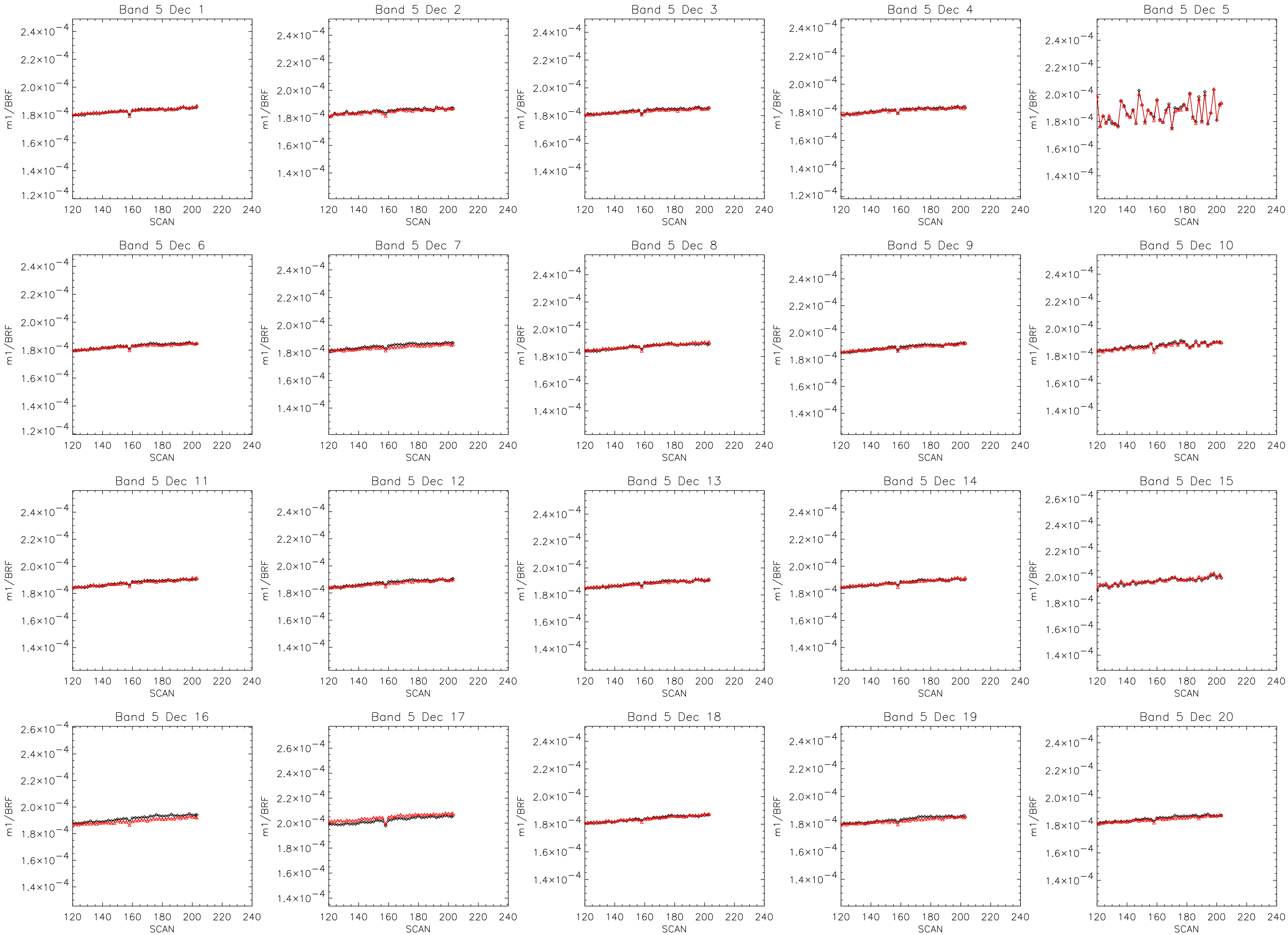


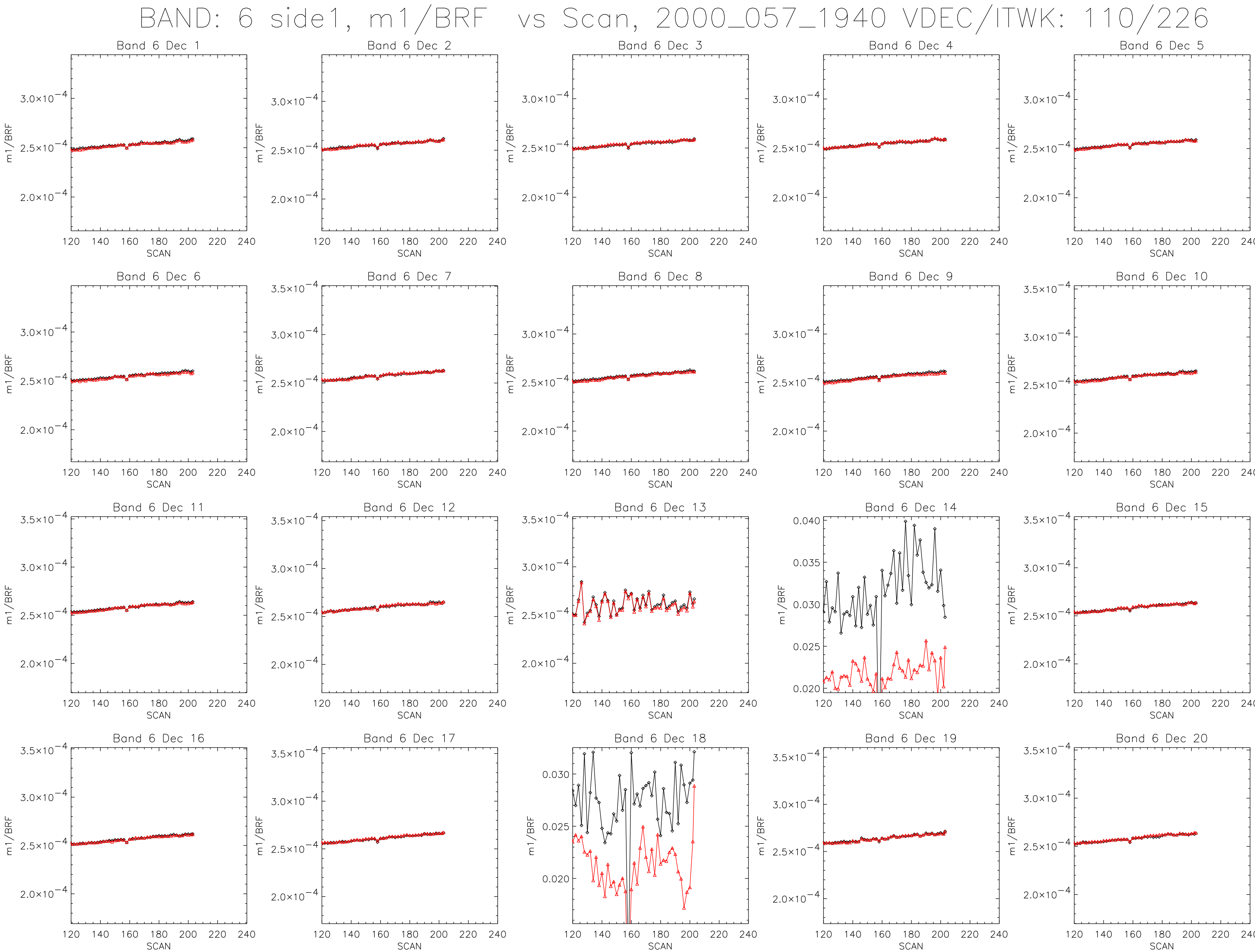
EXTK-A27


BAND: 7 side1, m1/BRF vs Scan, 84.0110
Band 7 Dec 1
Band 7 Dec 2
Band 7 Dec 3
Band 7 Dec 4
Band 7 Dec 5
Band 7 Dec 6
Band 7 Dec 7
Band 7 Dec 8
Band 7 Dec 9
Band 7 Dec 10
Band 7 Dec 11
Band 7 Dec 12
Band 7 Dec 13
Band 7 Dec 14
Band 7 Dec 15
Band 7 Dec 16
Band 7 Dec 17
Band 7 Dec 18
Band 7 Dec 19
Band 7 Dec 20
m1/BRF
SCAN

EXTK-A28

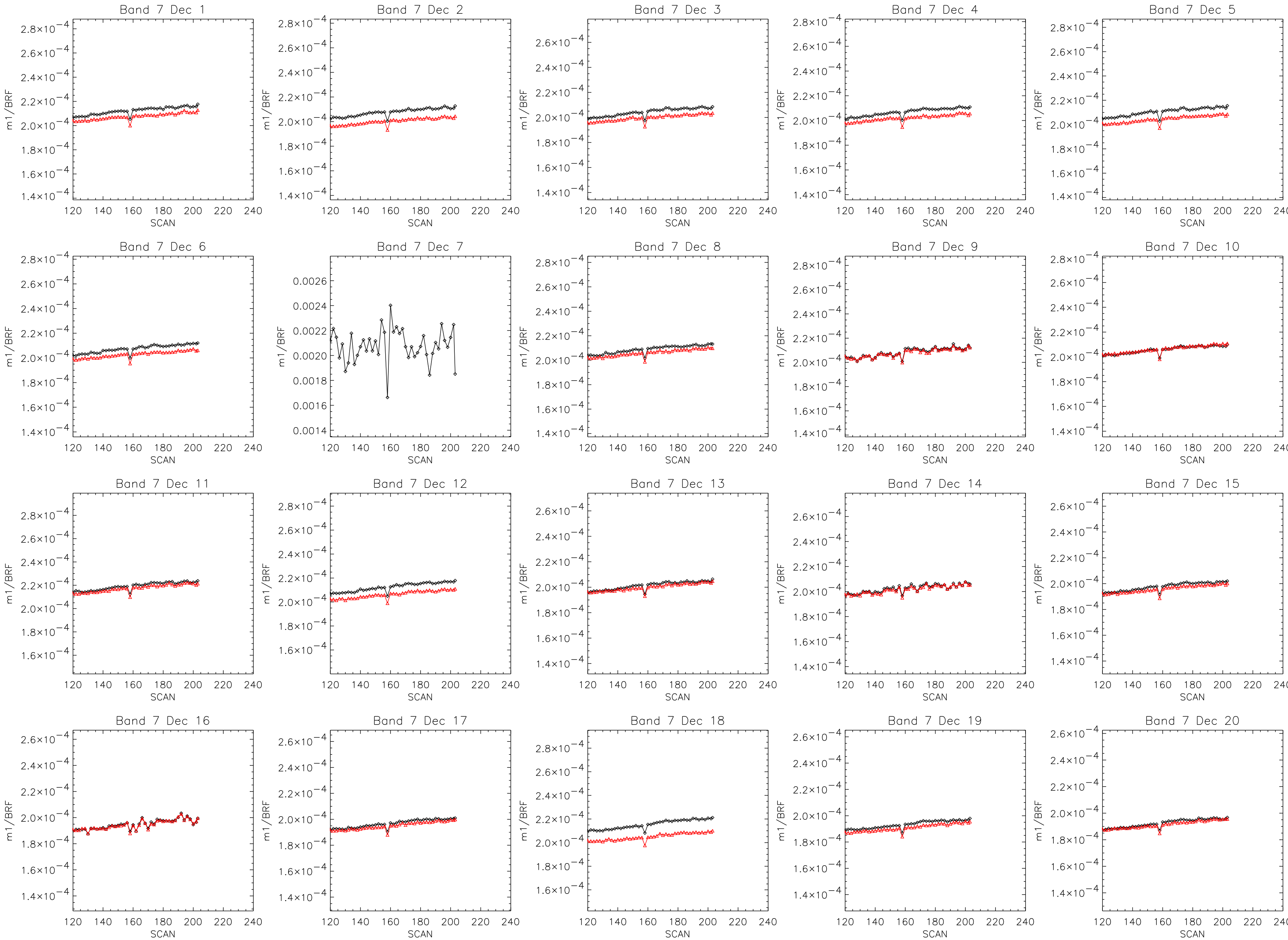
BAND: 5 side1, m1/BRF vs Scan, 2000_057_1940 VDEC/ITWK: 110/226



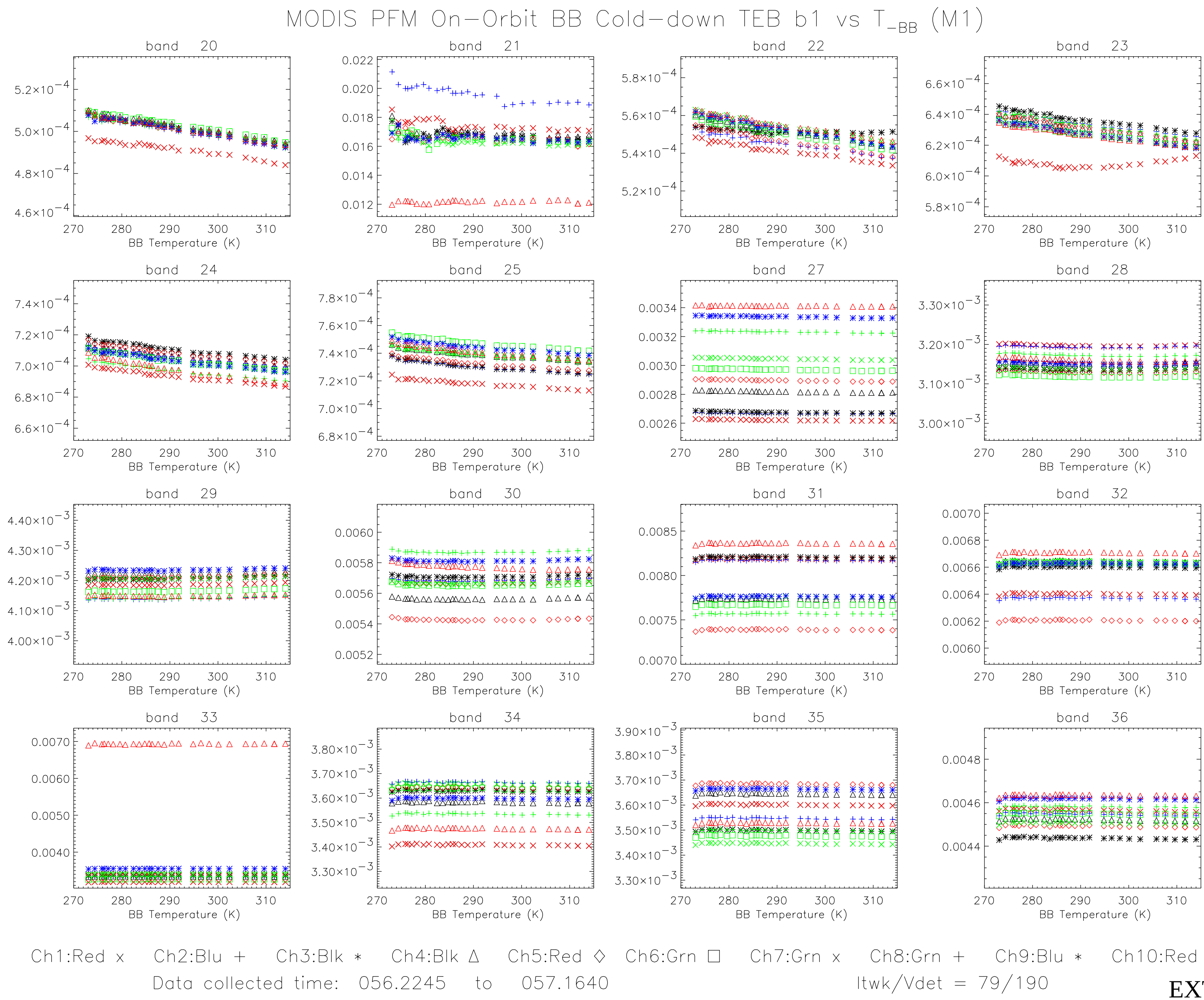

BAND: 6 side1, m1/BRF vs Scan, 2000_057_1940 VDEC/ITWK: 110/226
Band 6 Dec 1
Band 6 Dec 2
Band 6 Dec 3
Band 6 Dec 4
Band 6 Dec 5
Band 6 Dec 6
Band 6 Dec 7
Band 6 Dec 8
Band 6 Dec 9
Band 6 Dec 10
Band 6 Dec 11
Band 6 Dec 12
Band 6 Dec 13
Band 6 Dec 14
Band 6 Dec 15
Band 6 Dec 16
Band 6 Dec 17
Band 6 Dec 18
Band 6 Dec 19
Band 6 Dec 20
m1/BRF
SCAN

EXTK-A30

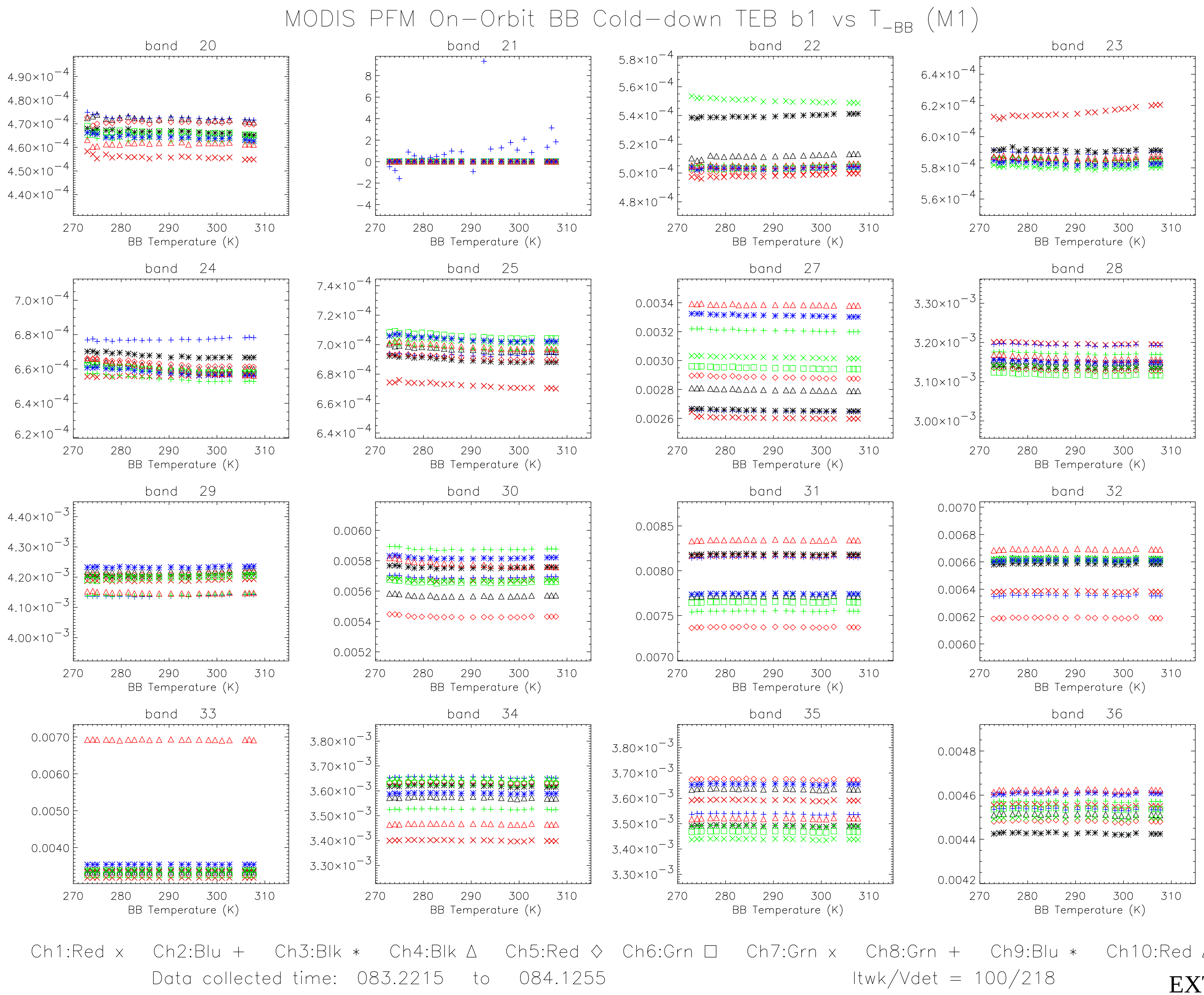
BAND: 7 side1, m1/BRF vs Scan, 2000_057_1940 VDEC/ITWK: 110/226



EXTK-A31

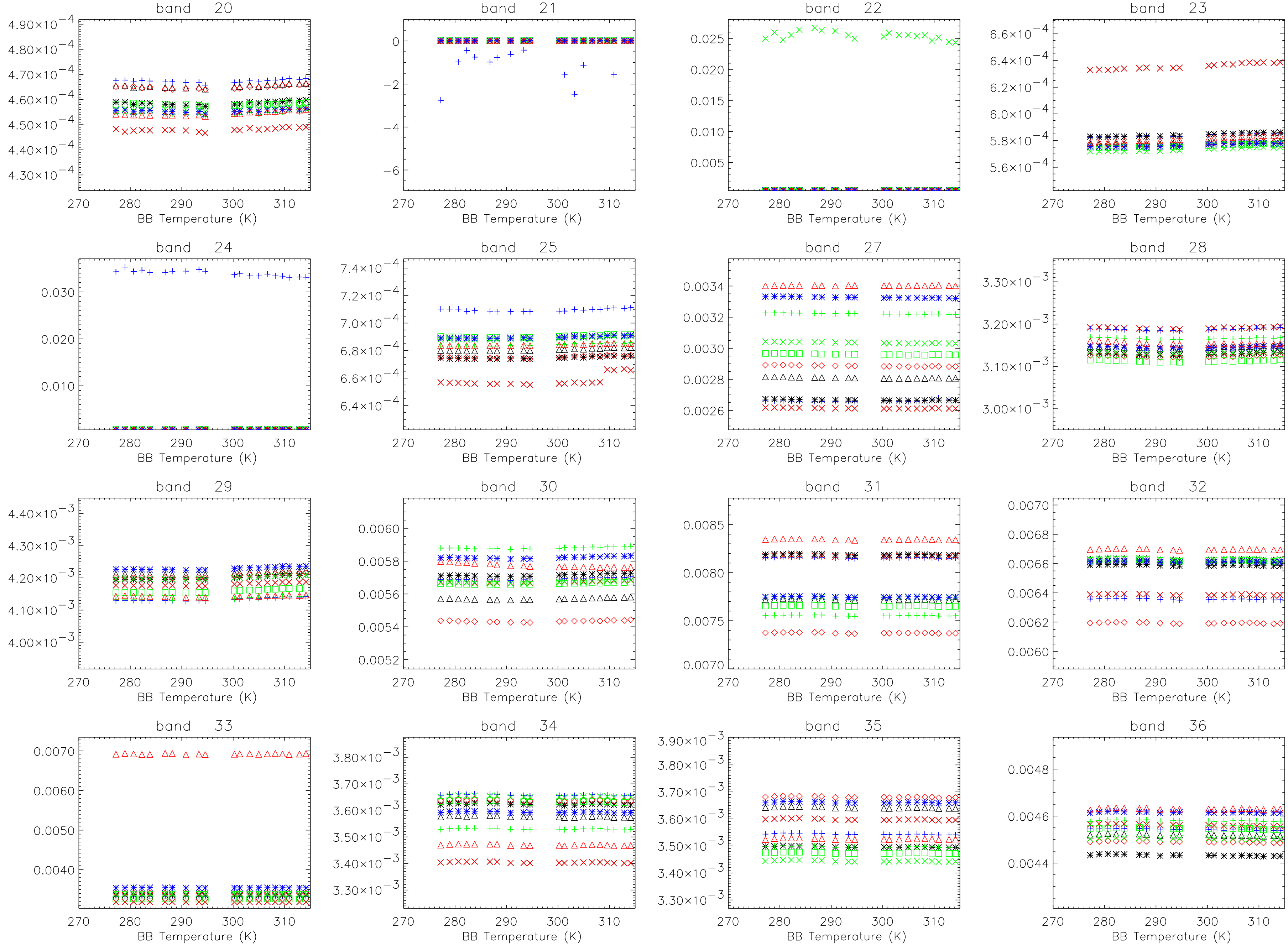

MODIS PFM On-Orbit BB Cold-down TEB b1 vs T_BB (M1)
band 20
band 21
band 22
band 23
band 24
band 25
band 27
band 28
band 29
band 30
band 31
band 32
band 33
band 34
band 35
band 36
BB Temperature (K)
Ch1:Red x Ch2:Blu + Ch3:Blk * Ch4:Blk Δ Ch5:Red ◇ Ch6:Grn □ Ch7:Grn x Ch8:Grn + Ch9:Blu * Ch10:Red Δ
Data collected time: 056.2245 to 057.1640
Itwk/Vdet = 79/190

EXTK-A32


MODIS PFM On-Orbit BB Cold-down TEB b1 vs T_BB (M1)
band 20
band 21
band 22
band 23
band 24
band 25
band 27
band 28
band 29
band 30
band 31
band 32
band 33
band 34
band 35
band 36
BB Temperature (K)
Ch1:Red x Ch2:Blu + Ch3:Blk * Ch4:Blk Δ Ch5:Red ◇ Ch6:Grn □ Ch7:Grn x Ch8:Grn + Ch9:Blu * Ch10:Red Δ
Data collected time: 083.2215 to 084.1255
Itwk/Vdet = 100/218

EXTK-A33

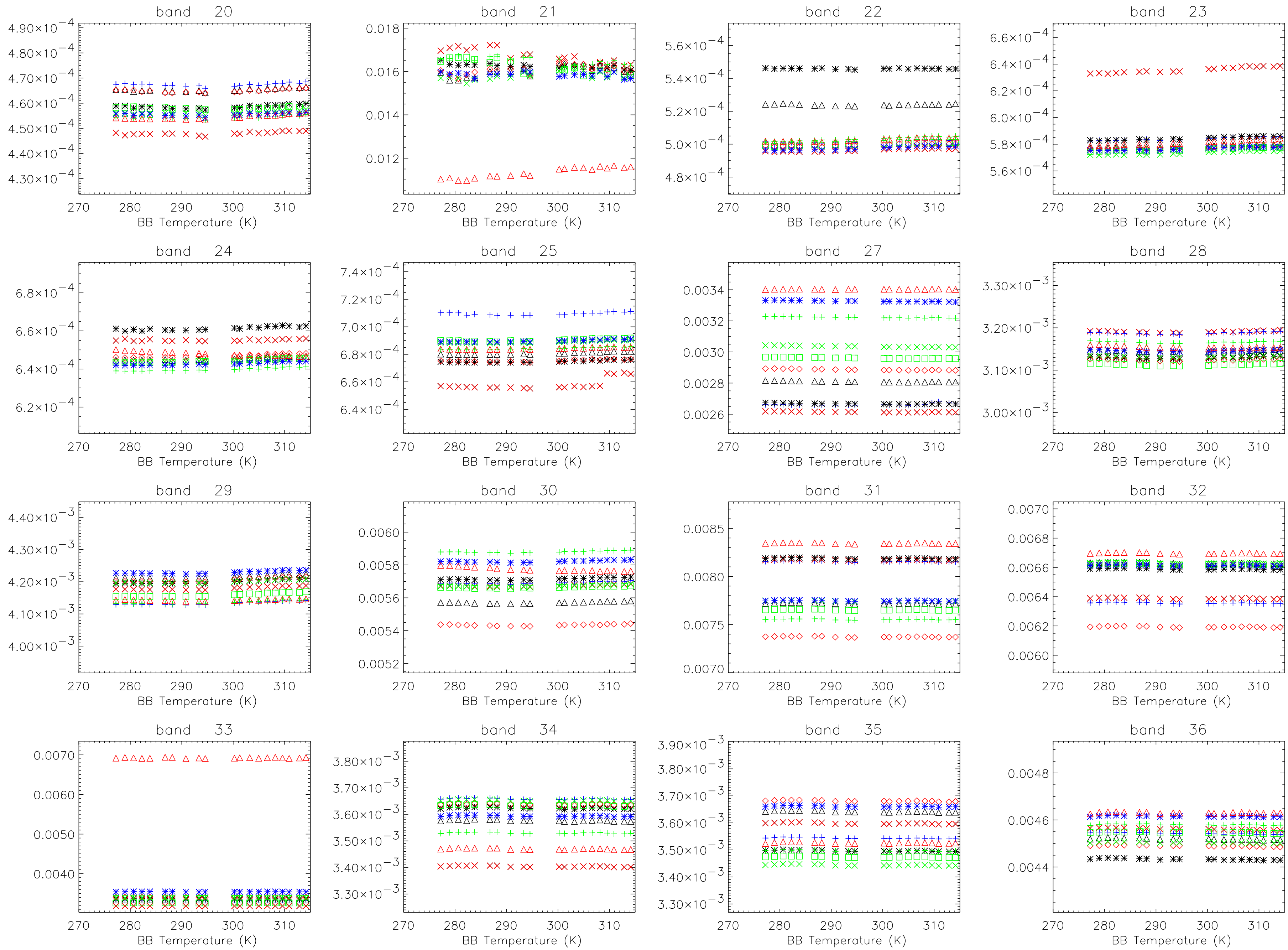
MODIS PFM On-Orbit BB Warm-up TEB b1 vs T_{-BB} (M1)



Ch1:Red x Ch2:Blu + Ch3:Blk * Ch4:Blk Δ Ch5:Red ◇ Ch6:Grn □ Ch7:Grn x Ch8:Grn + Ch9:Blu * Ch10:Red Δ

Data collected time: 057.1715 to 057.2010 Itwk/Vdet = 110/226

MODIS PFM On-Orbit BB Warm-up TEB b1 vs T_{-BB} (M1)



Ch1:Red × Ch2:Blu + Ch3:Blk ∗ Ch4:Blk △ Ch5:Red ◇ Ch6:Grn □ Ch7:Grn × Ch8:Grn + Ch9:Blu ∗ Ch10:Red △

Data collected time: 057.1715 to 057.2010 Itwk/Vdet = 110/226

EXTK-A35

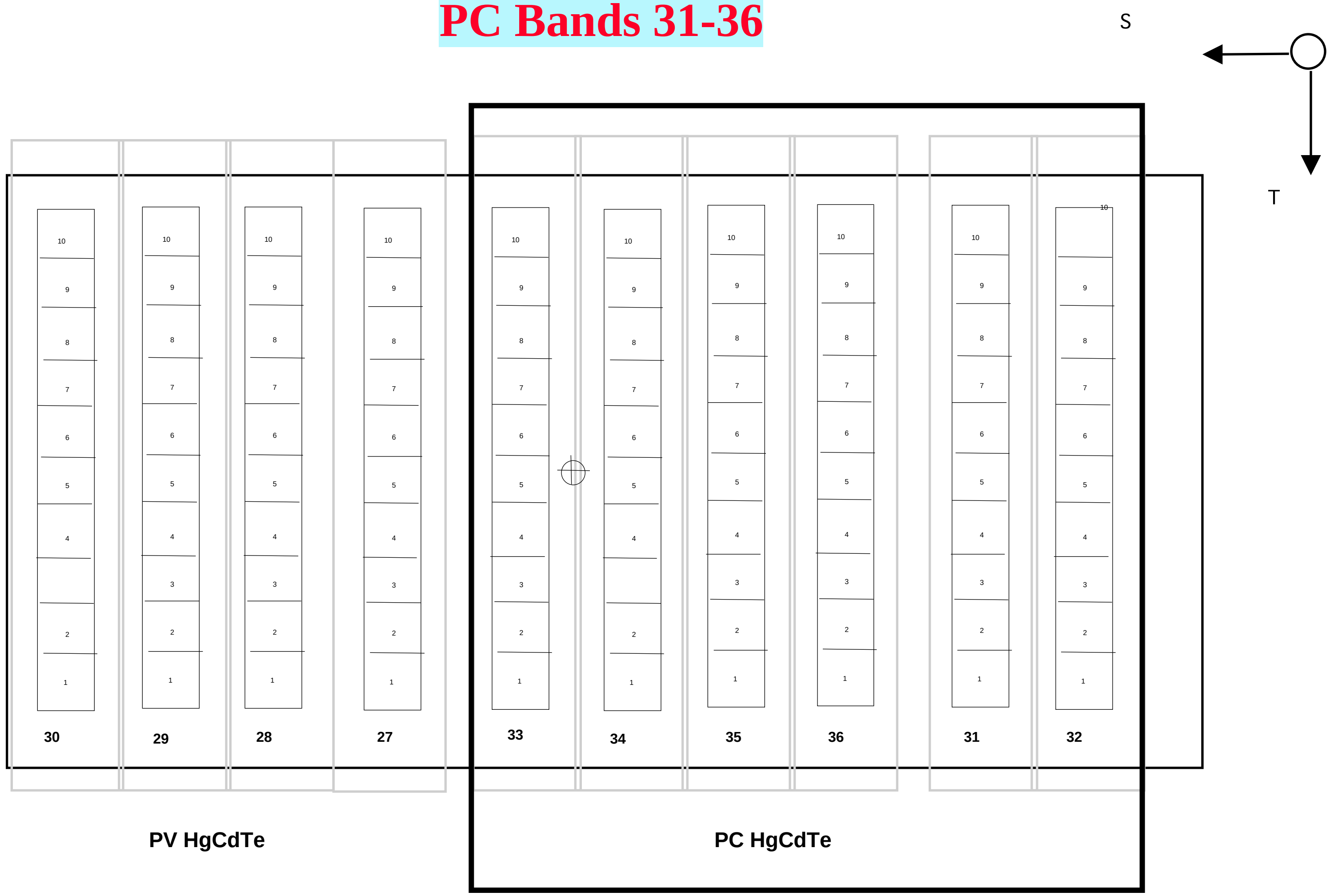
PC Bands Optical Crosstalk Study

- **Pre-launch** Analysis Review
  - Crosstalk observations
  - Correction algorithm
  - Coefficients determination

- **On-orbit** Analysis Results
  - Moon in Space View Port (SVP)
  - New coefficients
  - Scene applications

LWIR FPA

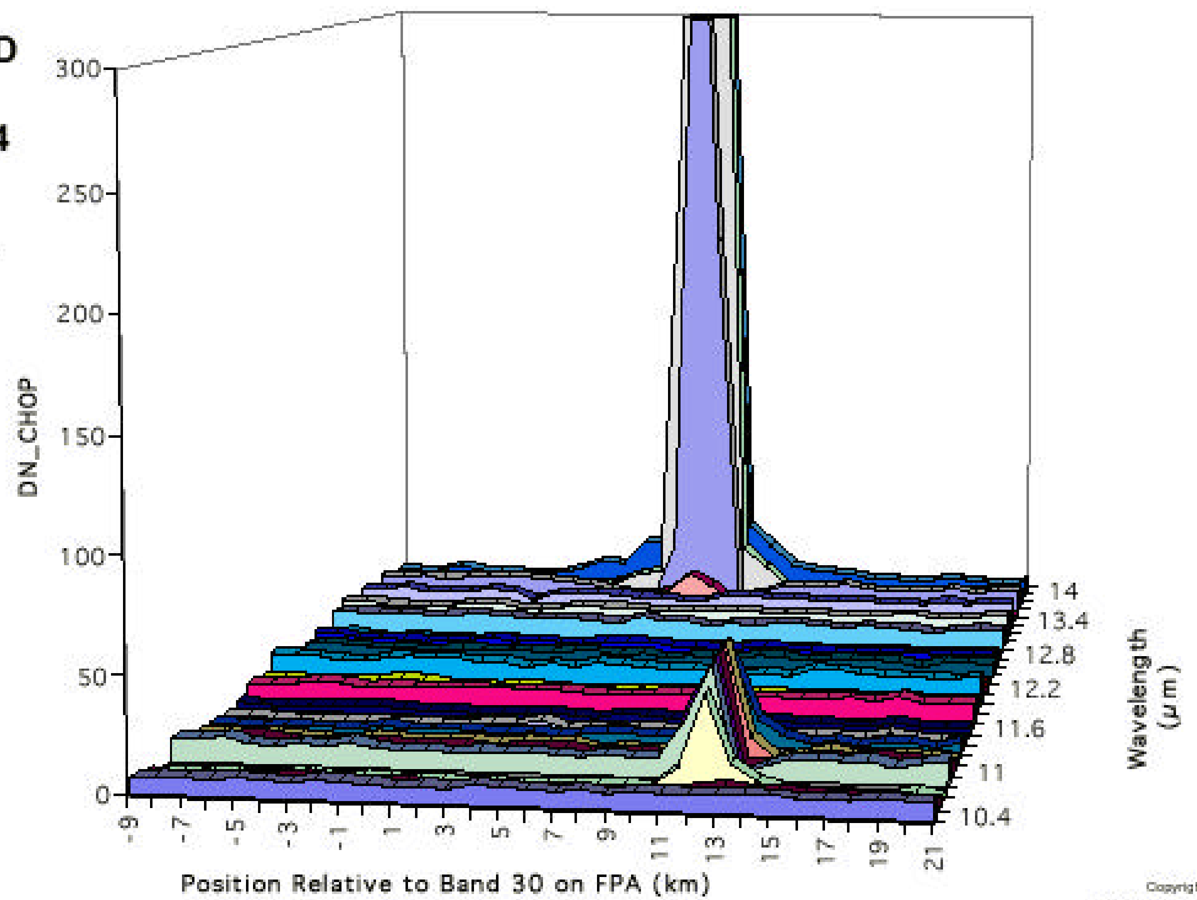
PC Bands 31-36



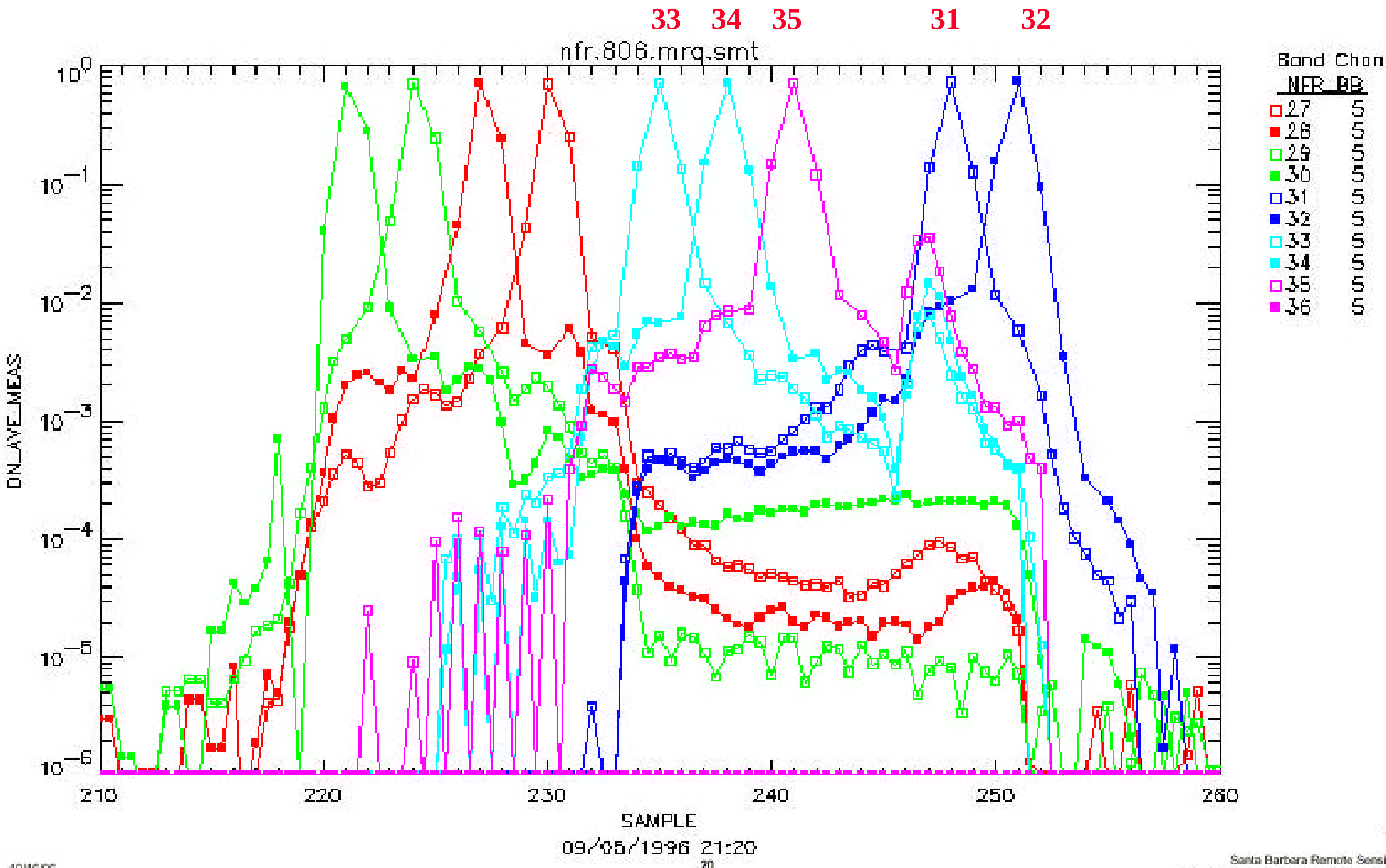
Pre-launch Crosstalk Observation
(Spatial/Spectral OOB Response Testing)

- DATA ACQUIRED DURING OOBD SCAN FROM 10.4 TO 14 µm
- RESPONSE NOT VISIBLE IN BANDS 31-33

BAND 35 SPECTRAL AND SPATIAL RESPONSE



Pre-launch Crosstalk Observation
(Near Field Response Testing)



10/16/96

96
ny
Santa Barbara Remote Sensing

Pre-launch Correction Algorithm

- Assumptions
  - Only B31 to other PC bands (32 - 36) considered
  - Possible along track crosstalk not included

- Algorithm
  - Apply to B32-36 dn_{BB} and dn_{EV} for calibration and retrieval
  - LUT with channel to channel flexibility in L1B code

$$dn_{B(i)}^{True}(F) = dn_{B(i)}^{Cont}(F) - Xtalk_{B31->B(i)} \; dn_{B31}(F + FO_{31-B(i)}) \; p_{B(i)} + q_{B(i)}$$

(F: Frame; FO: Frame Offset; p and q parameters for use in on-orbit correction)

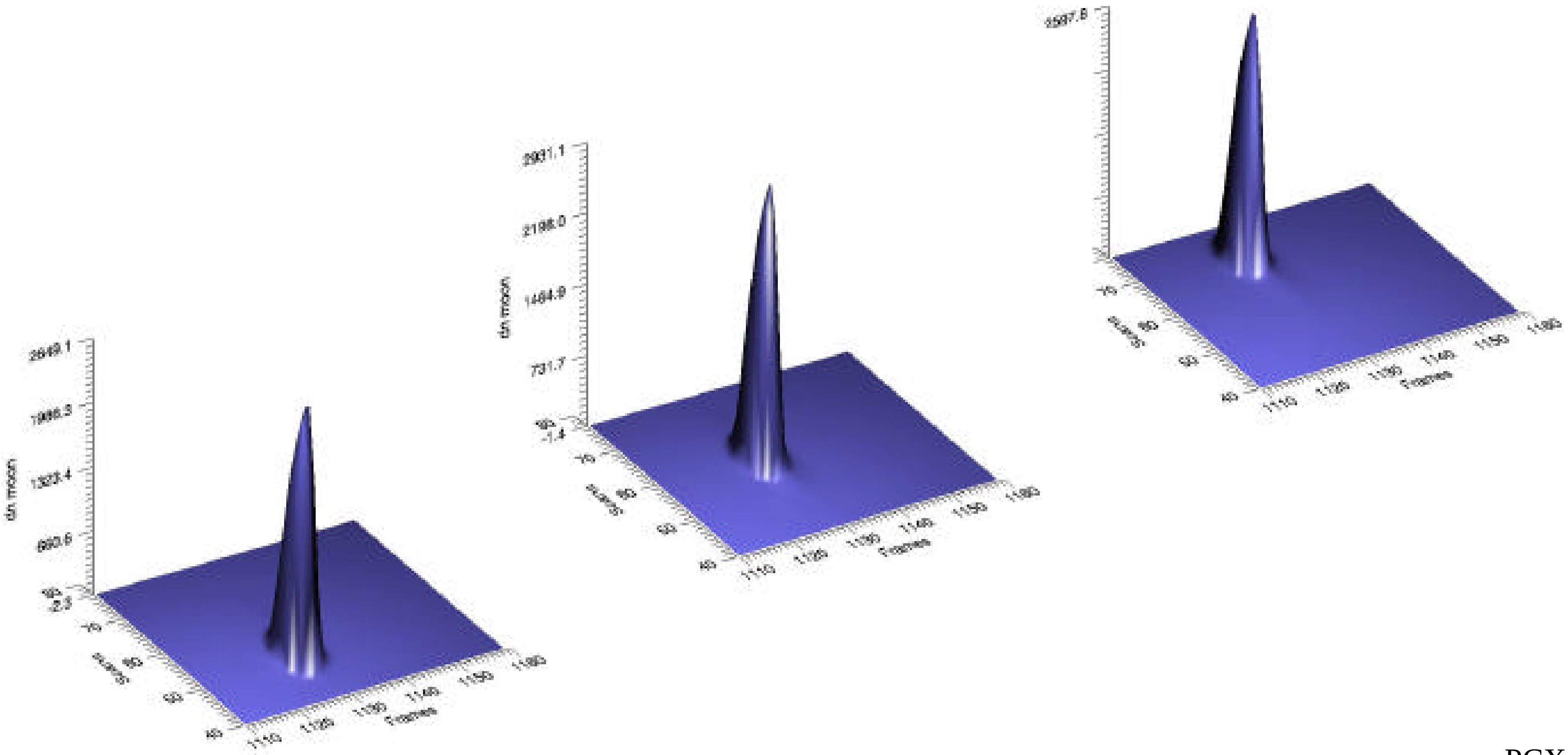
Pre-launch Coefficients Determination

- Coefficients Determination
  - Same type of PC detectors on the same FPA
  - Non-linearity (NL) depends on the detector gain setting
  - B31 crosstalk changes the NL behavior of other PC bands
  - Quadratic fitting using RC02 TV BCS data
- Pre-launch Coefficients (LUT in L1B)

B(i)	Ch	Xtalk	FO	p	q
32	1	1.0	4	1	0
32	2	1.0	4	1	0
...	...	...	...	...	…
32	10	1.0	4	1	0
33	1	1.0	-12	1	0
...	...	...	...	...	…
34	1	3.5	-9	1	0
...	...	...	...	...	...
35	1	8.3	-6	1	0
...	...	...	...	...	...
36	1	6.5	-3	1	0
...	...	...	...	...	...

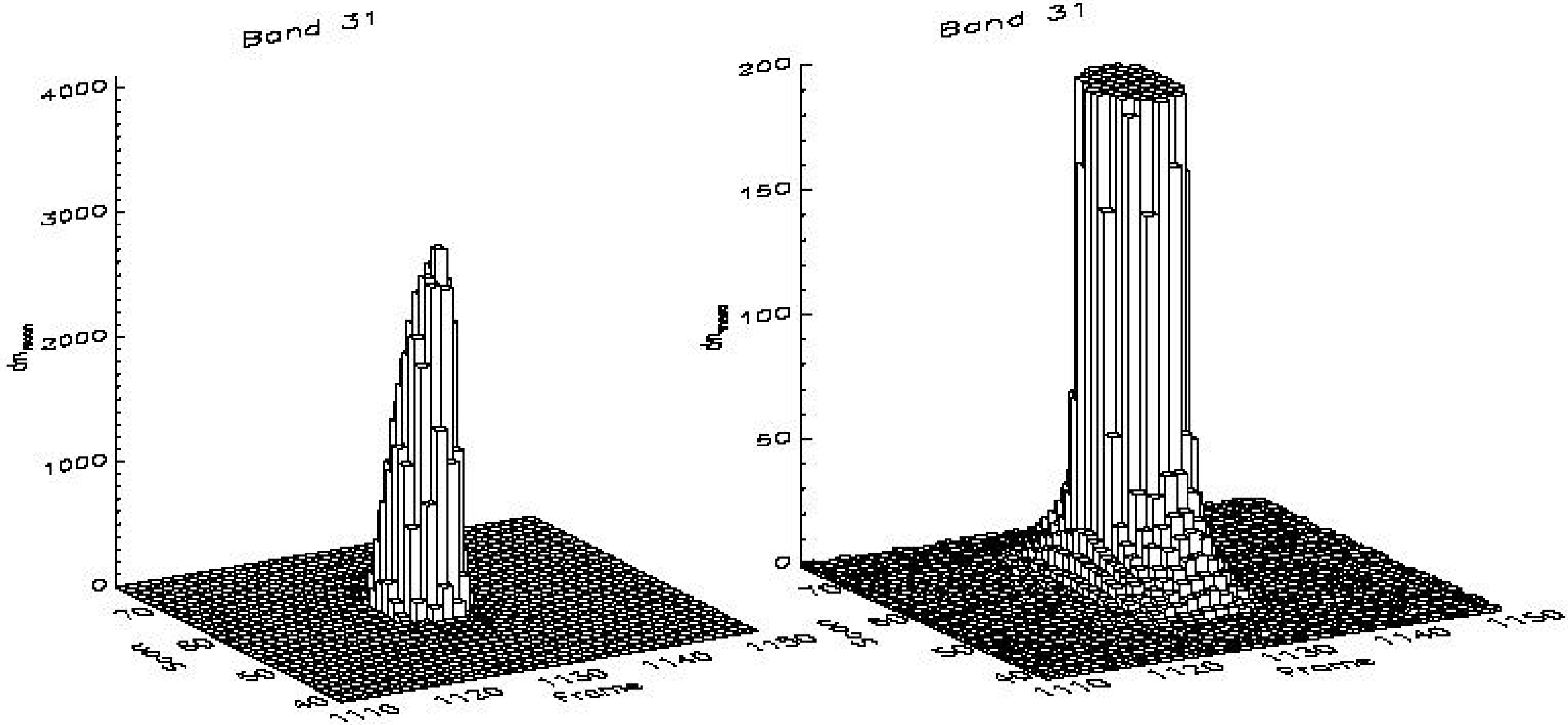
On-orbit Analysis Results
(Moon in SVP)

B31 D1, D5, and D10 Moon View



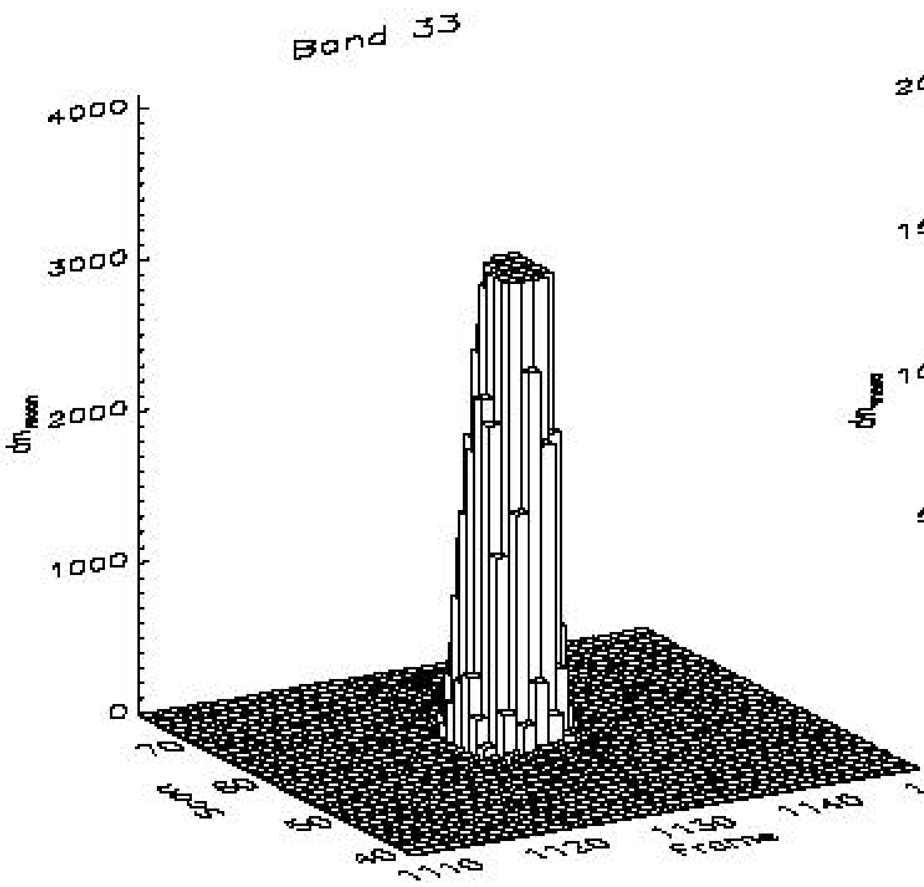
On-orbit Analysis Results
(B31 D5 View of the Moon)

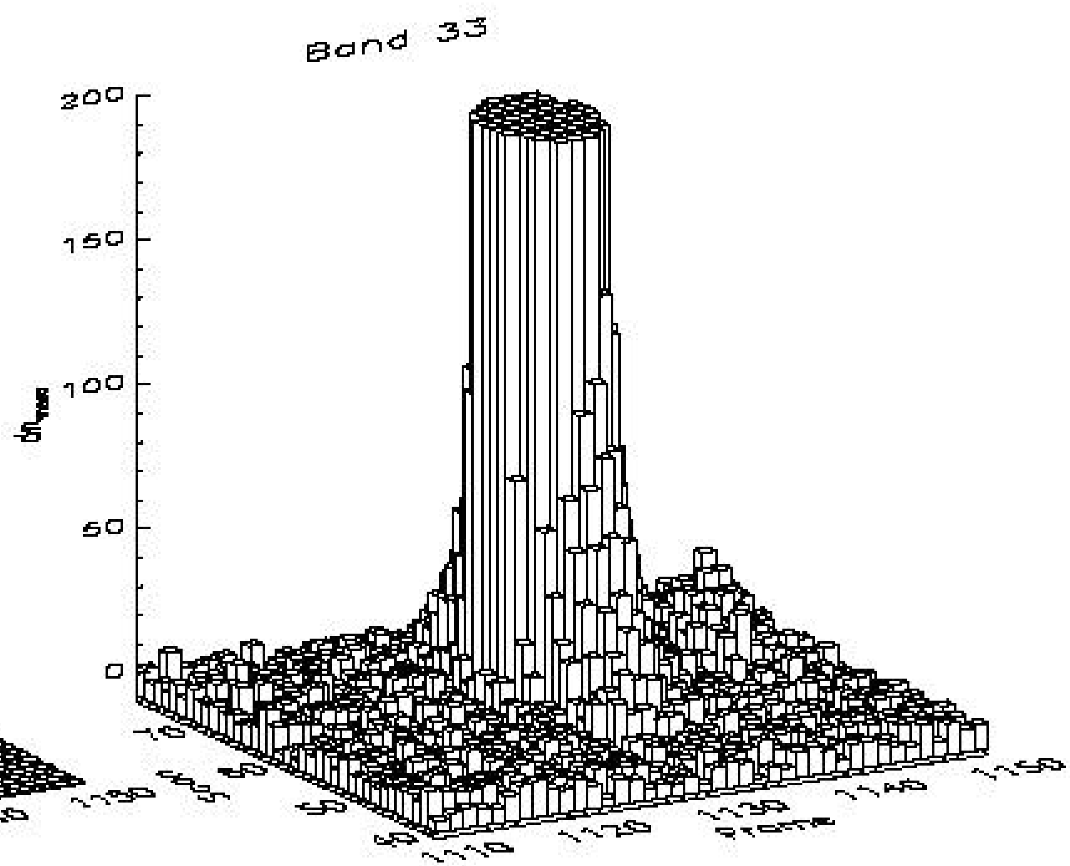
84/20:20 Moon View Event



On-orbit Analysis Results
(B33 D5 View of the Moon)

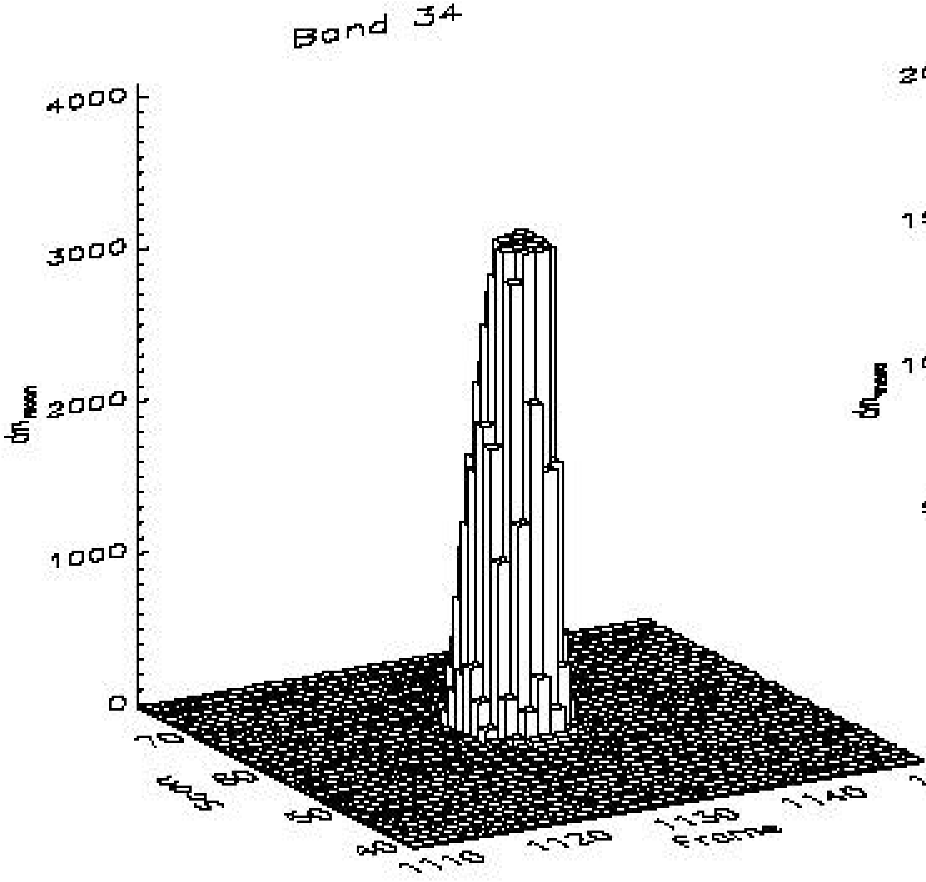
84/20:20 Moon View Event

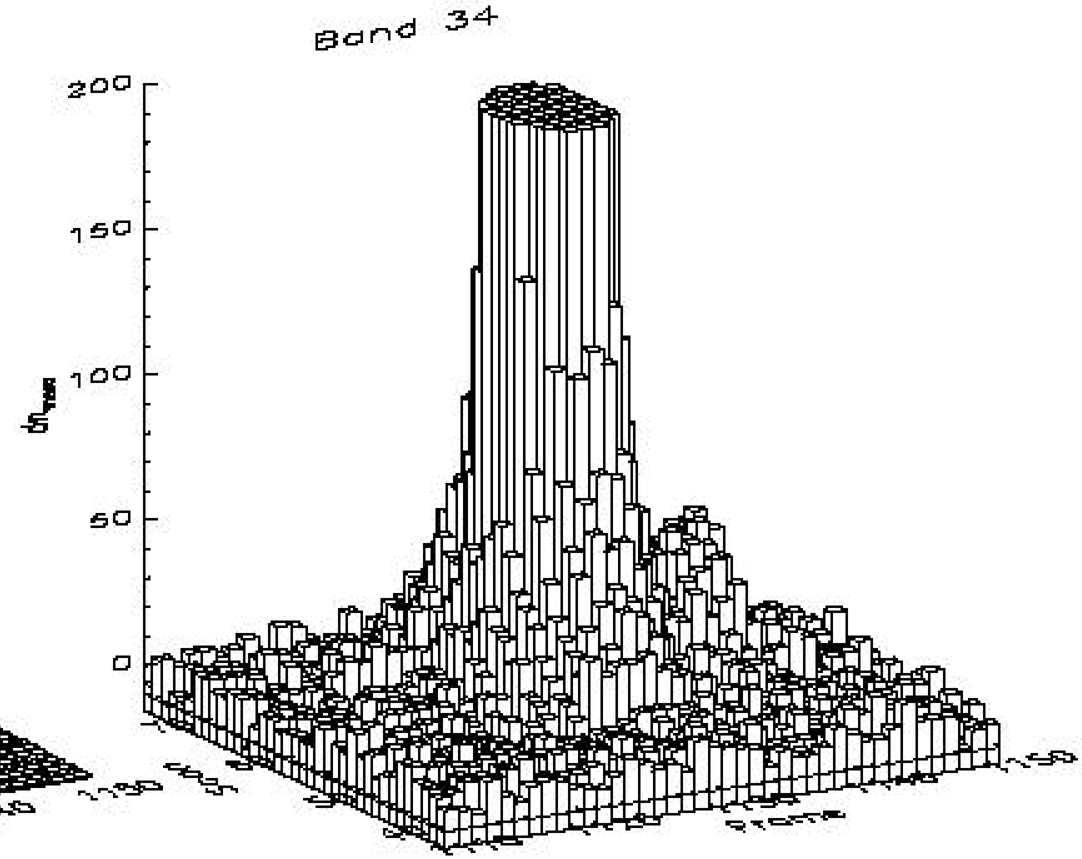




On-orbit Analysis Results
(B34 D5 View of the Moon)

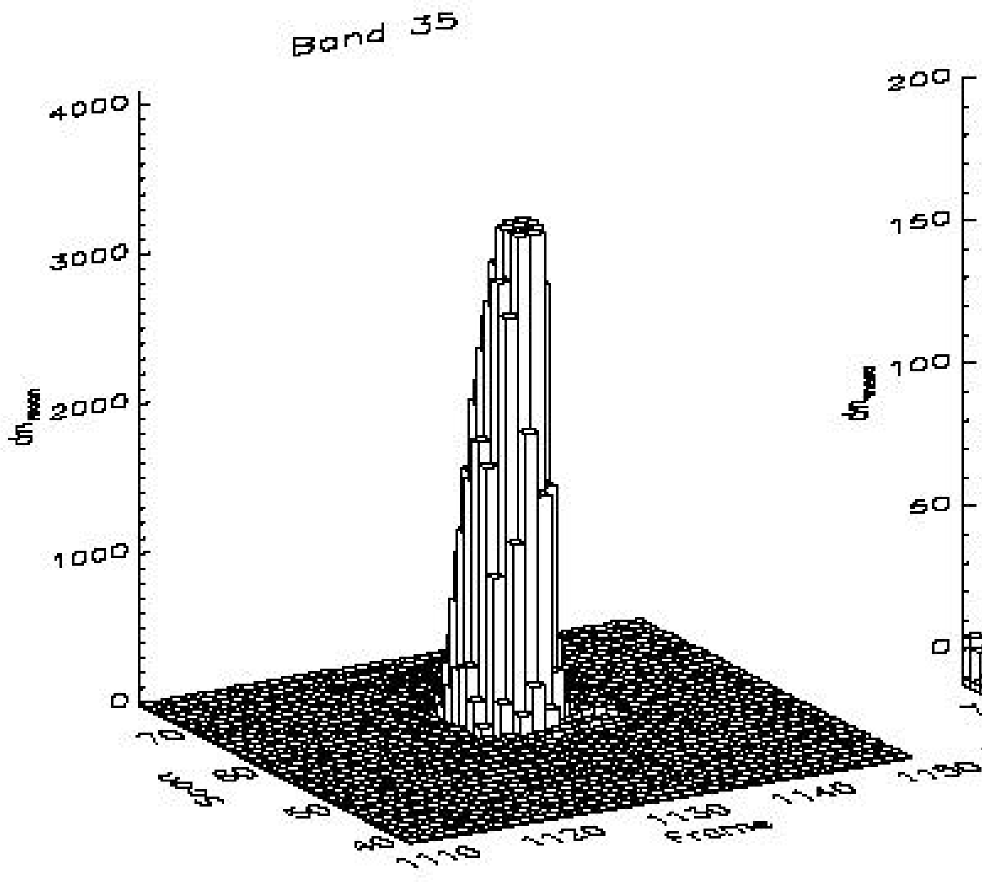
84/20:20 Moon View Event

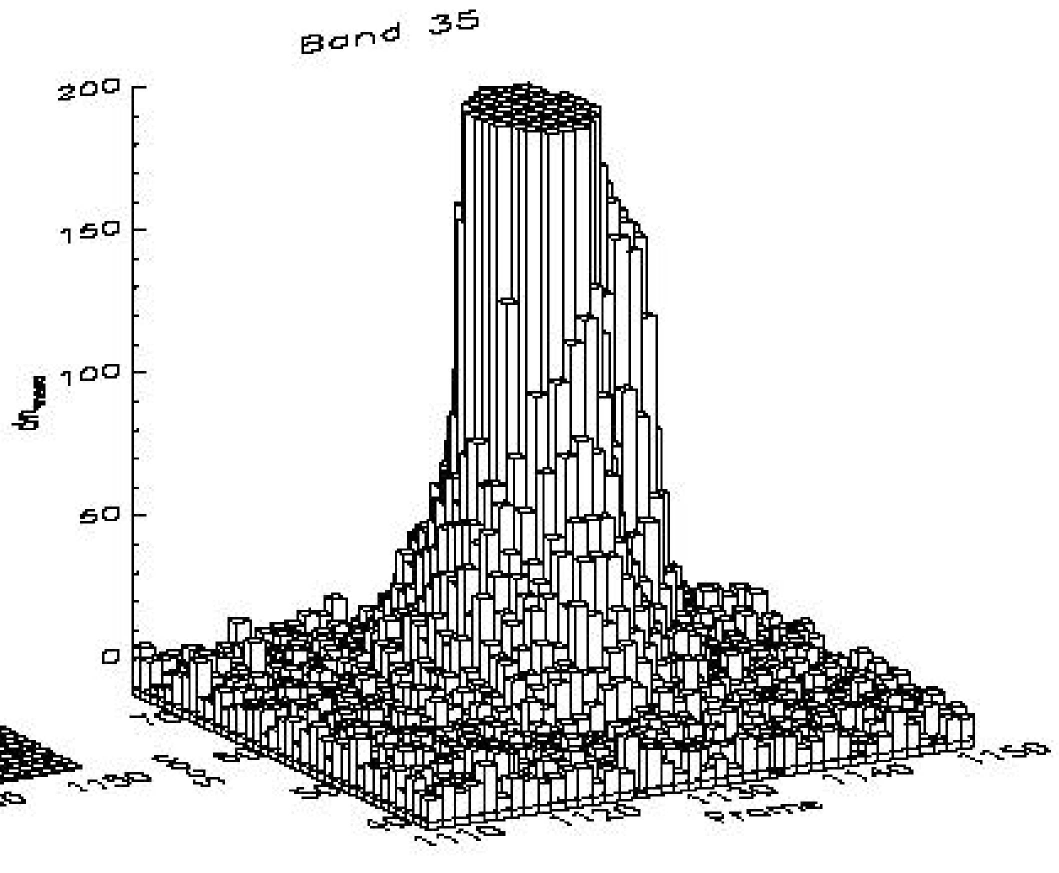




On-orbit Analysis Results
(B35 D5 View of the Moon)

84/20:20 Moon View Event





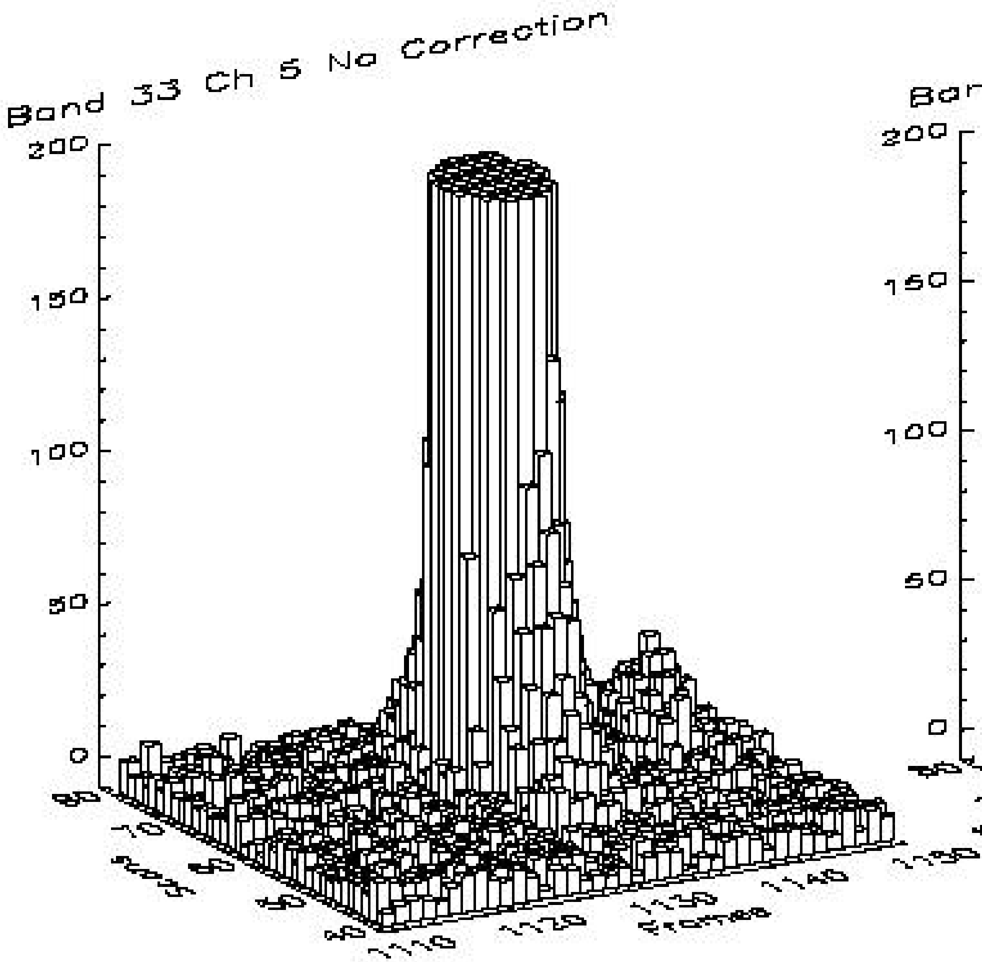
On-orbit Analysis Results
(Moon in SVP)

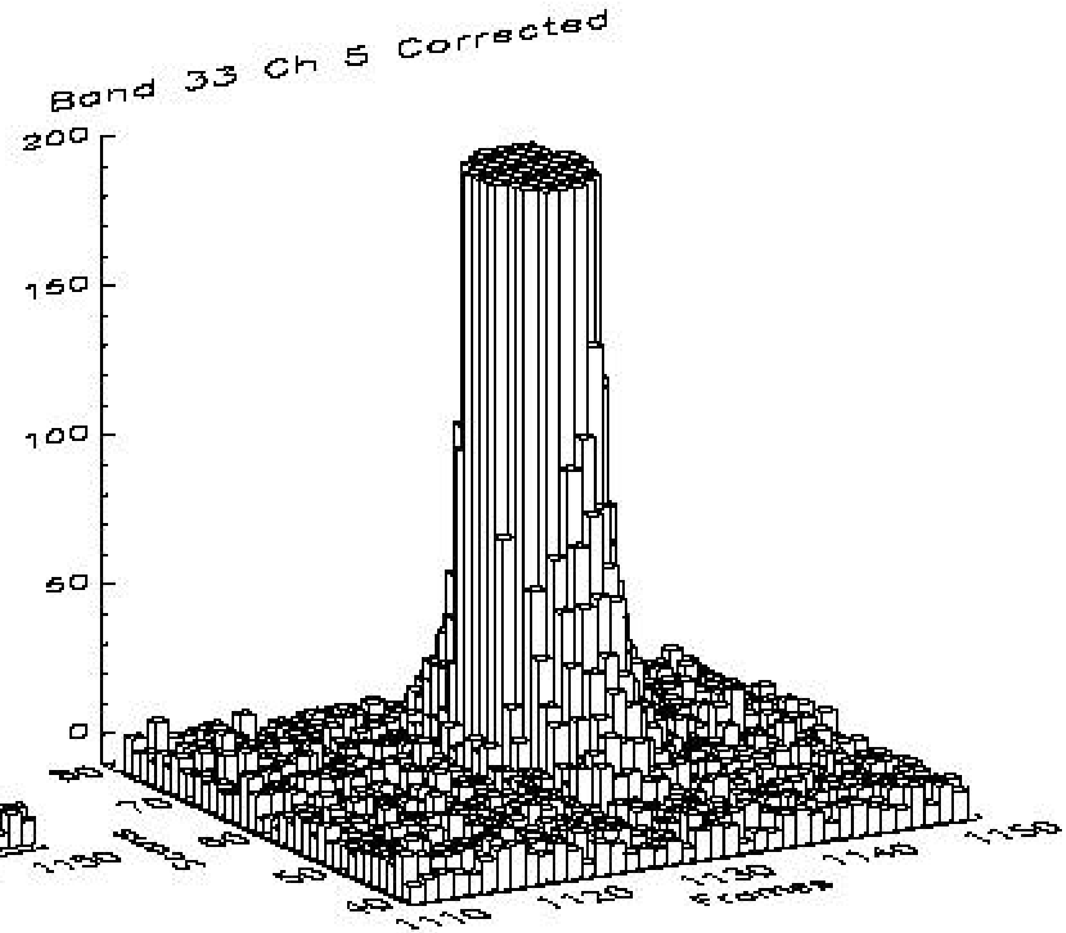
- New Coefficients Determined for B33, 34, 35
  - Same assumption & same algorithm
  - B32 coefficients unchanged
  - B36 coefficients estimated (due to small frame offset)

Detecor	B32	B33	B34	B35	B36
1	0.010	0.012	0.023	0.045	0.025
2	0.010	0.014	0.024	0.045	0.025
3	0.010	0.014	0.022	0.045	0.025
4	0.010	0.014	0.022	0.045	0.025
5	0.010	0.014	0.020	0.045	0.025
6	0.010	0.015	0.019	0.045	0.025
7	0.010	0.015	0.020	0.045	0.025
8	0.010	0.014	0.023	0.050	0.025
9	0.010	0.015	0.025	0.055	0.025
10	0.010	0.007	0.027	0.060	0.025

On-orbit Analysis Results
(B33 D5 View of the Moon)

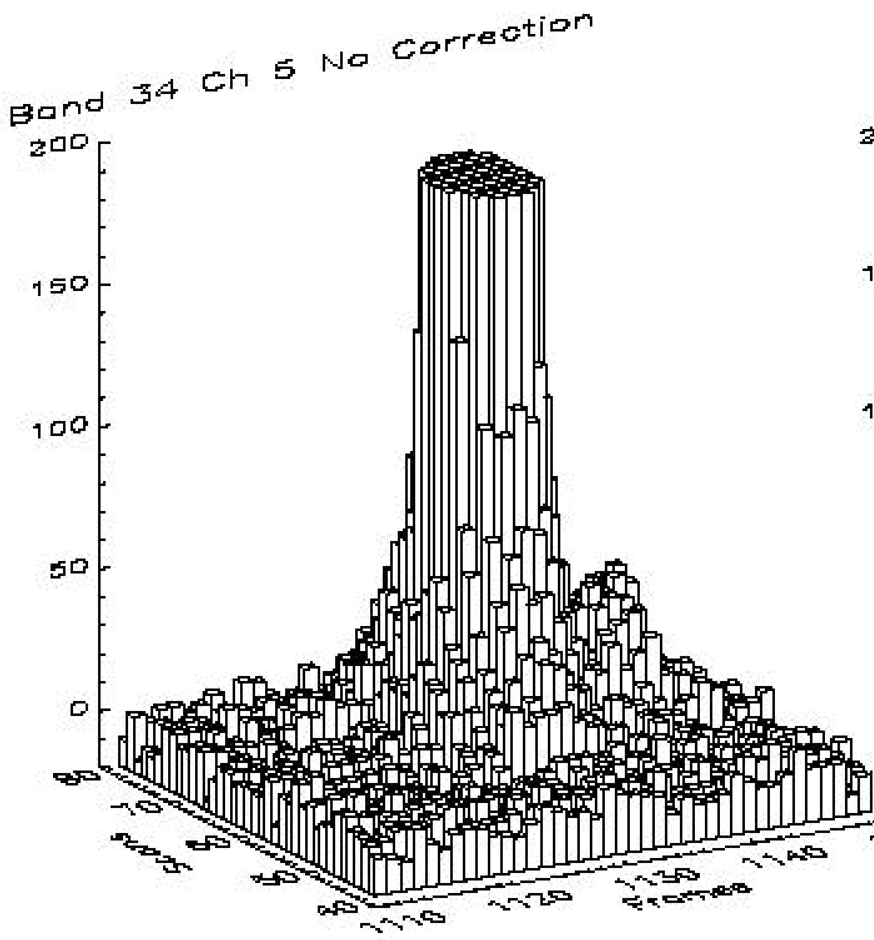
84/20:20 Moon View Event

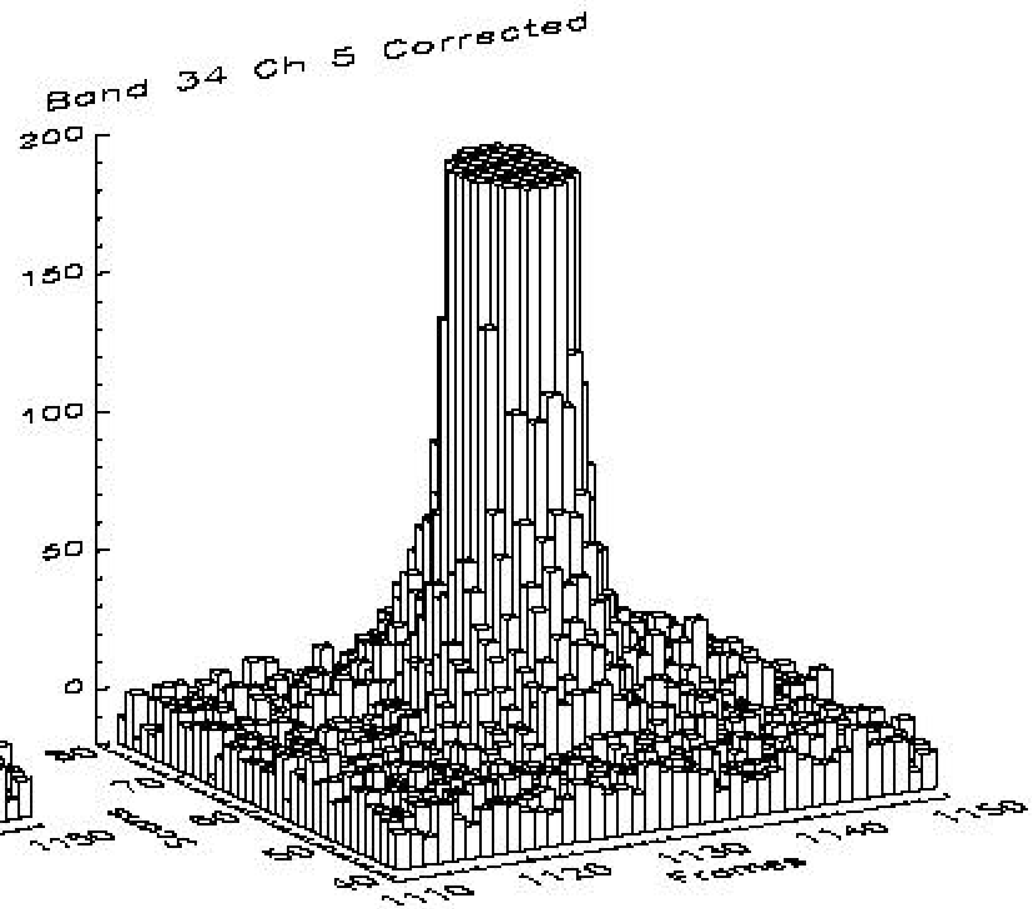




On-orbit Analysis Results
(B34 D5 View of the Moon)

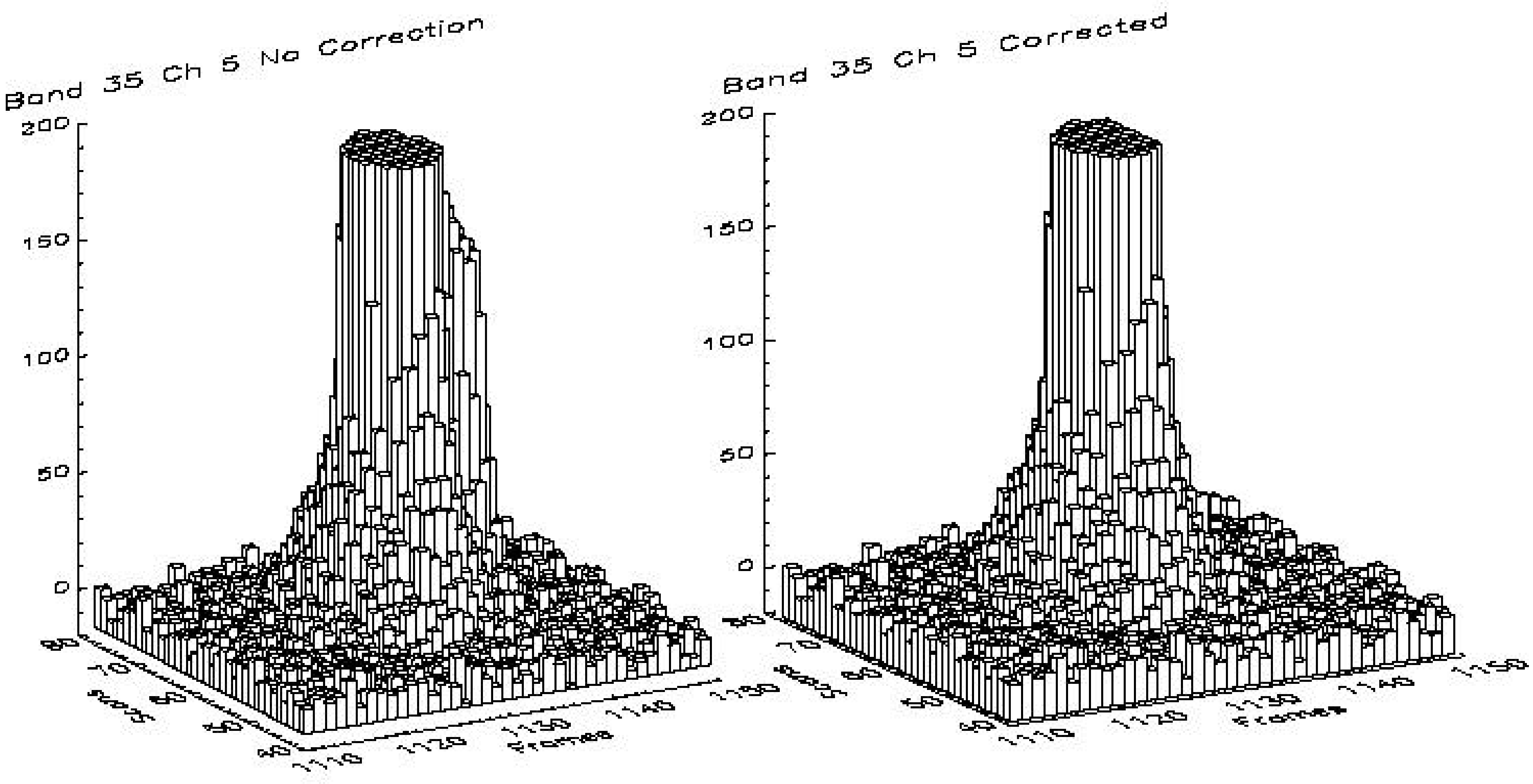
84/20:20 Moon View Event





On-orbit Analysis Results
(B35 D5 View of the Moon)

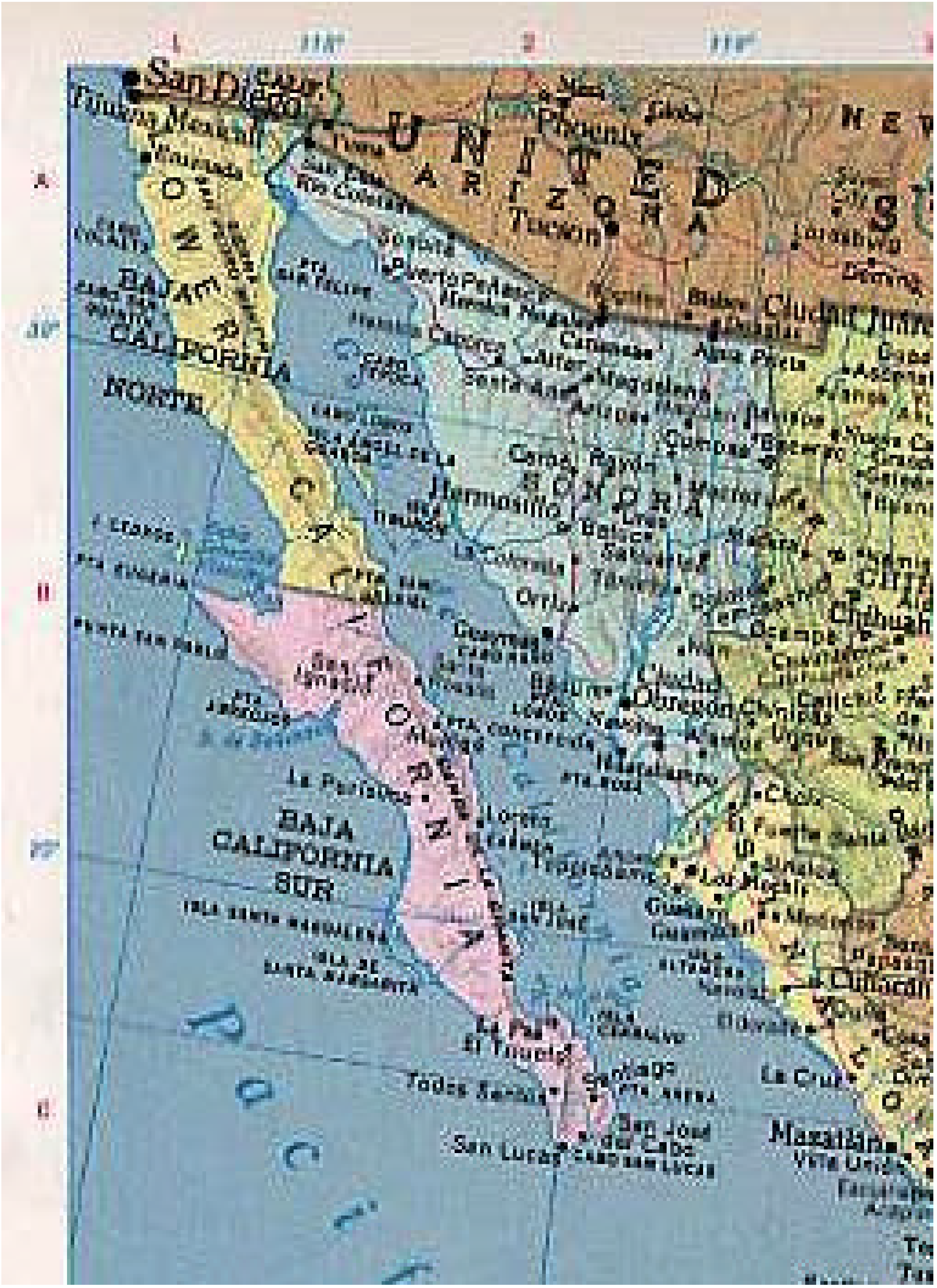
84/20:20 Moon View Event



On-orbit Analysis Results
(Scene Applications)

- Selected scene (1353km x 2030km, Day mode)
- B34 and B35 Images (75km x 75km) with
  - No correction
  - Pre-launch correction coefficients
  - New correction coefficients
- New Coefficients are Better
- Planning LUT Update

  (Coordinating with Chris Moeller of U. of Wisconsin)

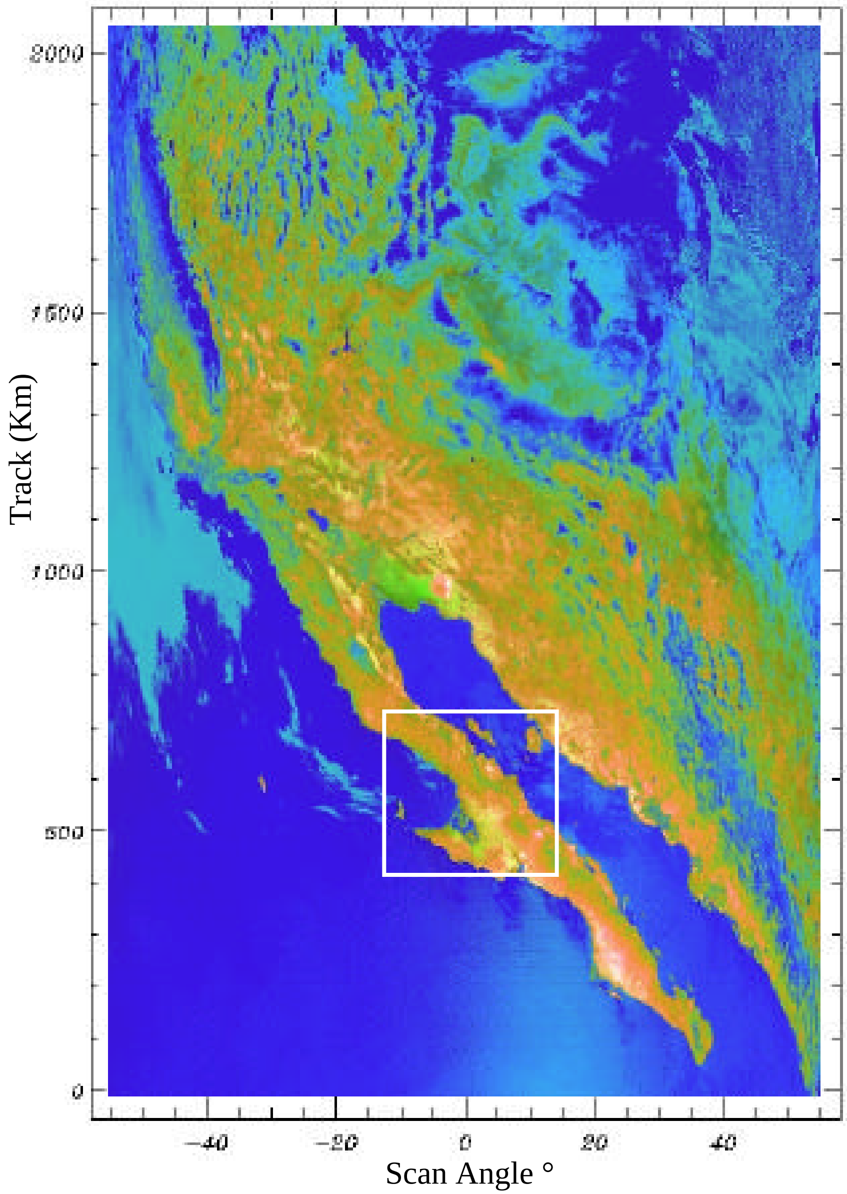


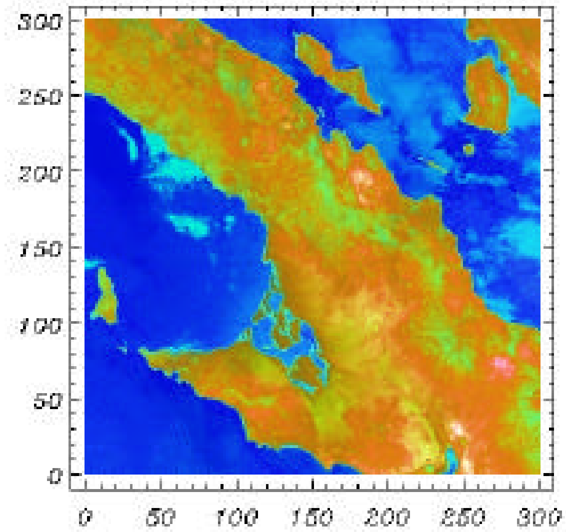
Baja, California

Selected Image Area
(28N 114W)
Isla Angel de la Guarda

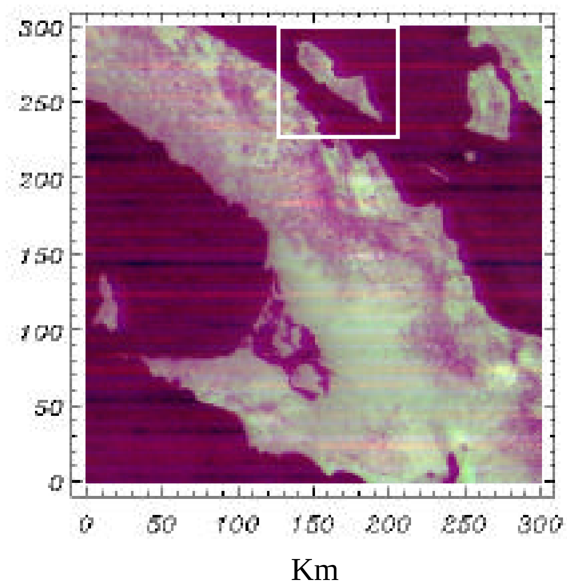
Baja California (094.1835; Day Mode)

Enhanced Radiance Images (*before* PC_XT Correction) in True Color





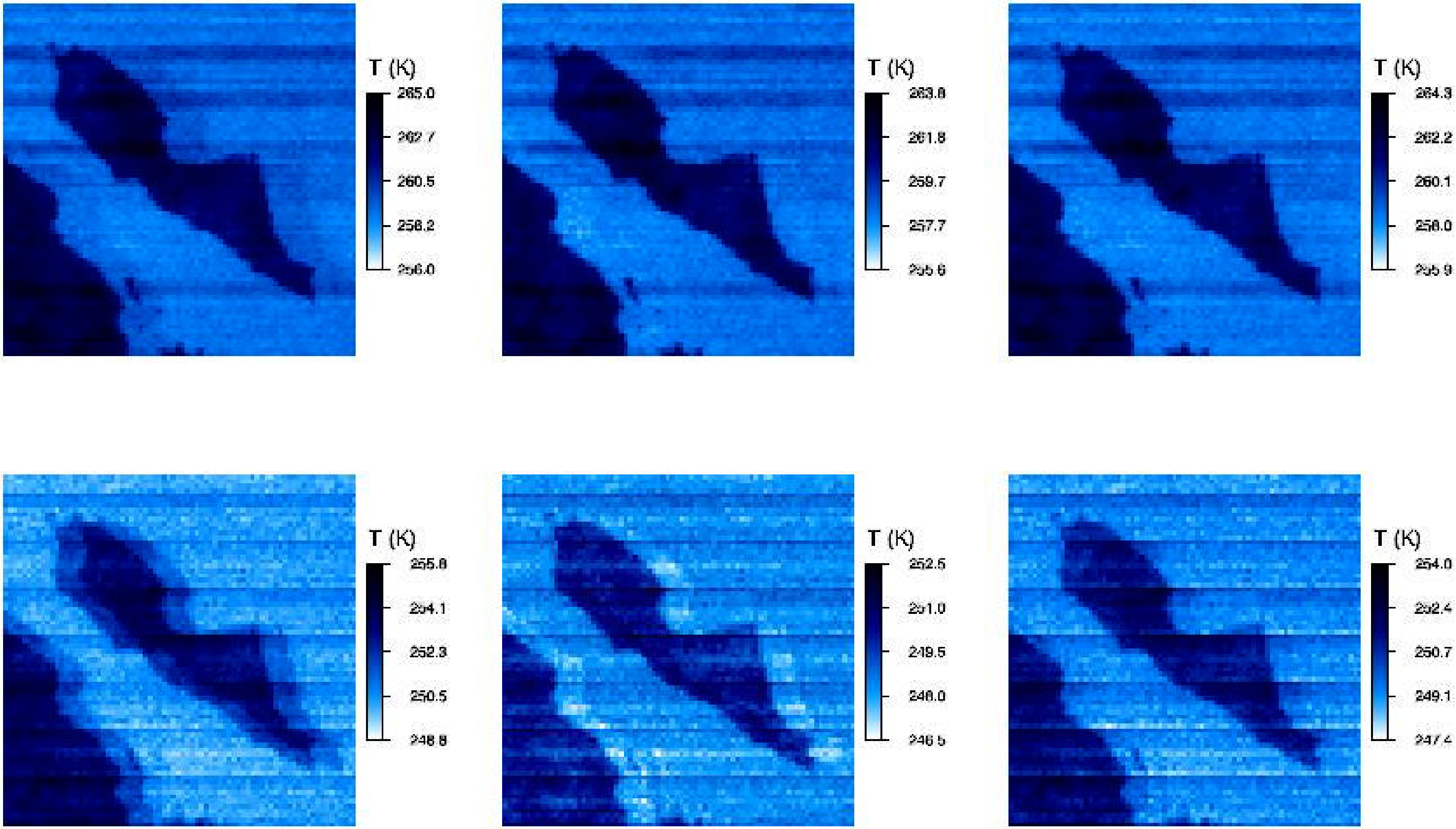
B29 (**R**)
B20 (**G**)
B31 (**B**)



B***34*** (**R**)
B31 (**G**)
B***35*** (**B**)
Cross-Talk Observed

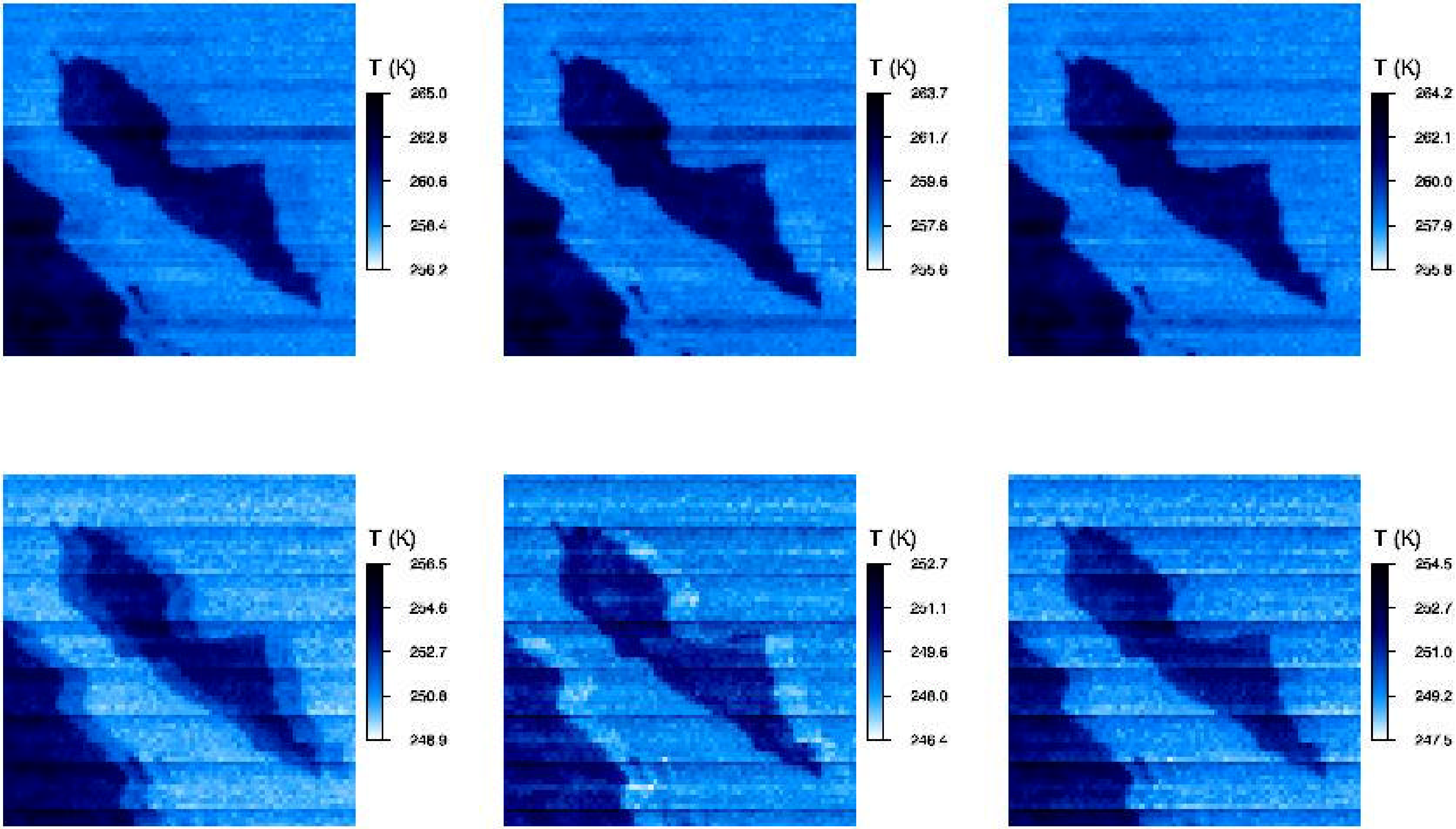
Band 34 (Top) & Band 35 (Bottom) (94/18:35)

No Correction | Pre-launch Correction | New Correction



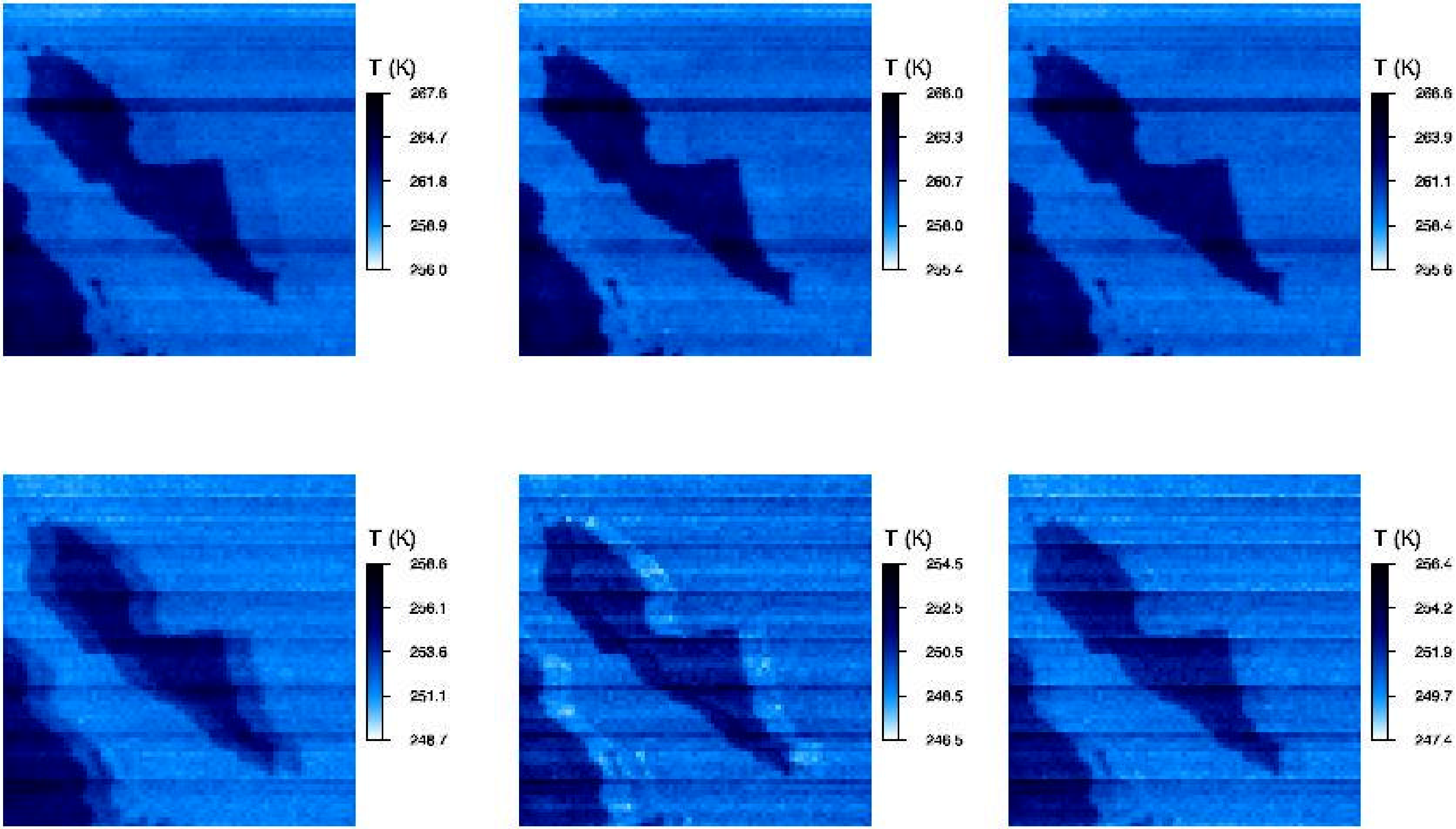
Band 34 (Top) & Band 35 (Bottom) (78/18:35)

No Correction | Pre-launch Correction | New Correction



Band 34 (Top) & Band 35 (Bottom) (103/18:30)

No Correction | Pre-launch Correction | New Correction



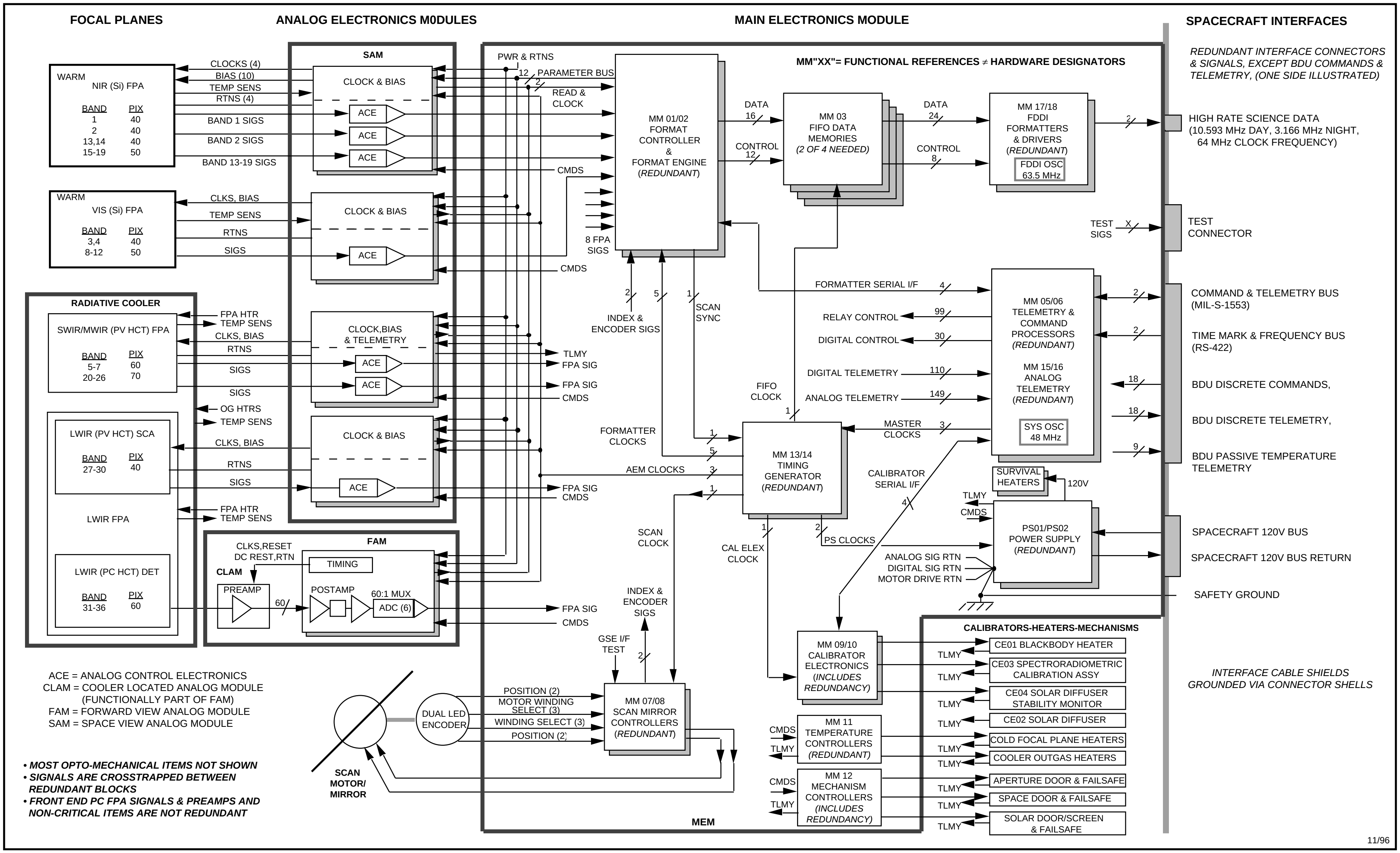
ADC Performance

- **Pre-launch** ADC Testing and Evaluation
  - Component Level Testing
  - System Level (Ramp) Testing
  - Spacecraft TV Testing (TEB only)

- **On-orbit** ADC Performance

SBRS Analysis Results Included

MODIS Electronic Block Diagram



ADC List

ADC #	ADC Name	Bands
1	VIS (p)	3,4, 8-12
2	VIS (r)	
3	NIR1 (p)	1
4	NIR1 (r)	
5	NIR2 (p)	2
6	NIR2 (r)	
7	NIR3 (p)	13-19
8	NIR3 (r)	
9	SMIR5 (p)	5,6,7
10	SMIR5 (r)	
11	**SMIR20 (p)**	**20-26**
12	**SMIR20 (r)**	
13	**LWIR (p)**	**27-30**
14	**LWIR (r)**	

PV Bands ADC Conversion Time: 800 ns

ADC #	ADC Name	Bands
15	PCB31 (p)	31
16	PCB31 (r)	
17	PCB32 (p)	32
18	PCB32 (r)	
19	PCB33 (p)	33
20	PCB33 (r)	
21	PCB34 (p)	34
22	PCB34 (r)	
23	PCB35 (p)	35
24	PCB35 (r)	
25	PCB36 (p)	36
26	PCB36 (r)	

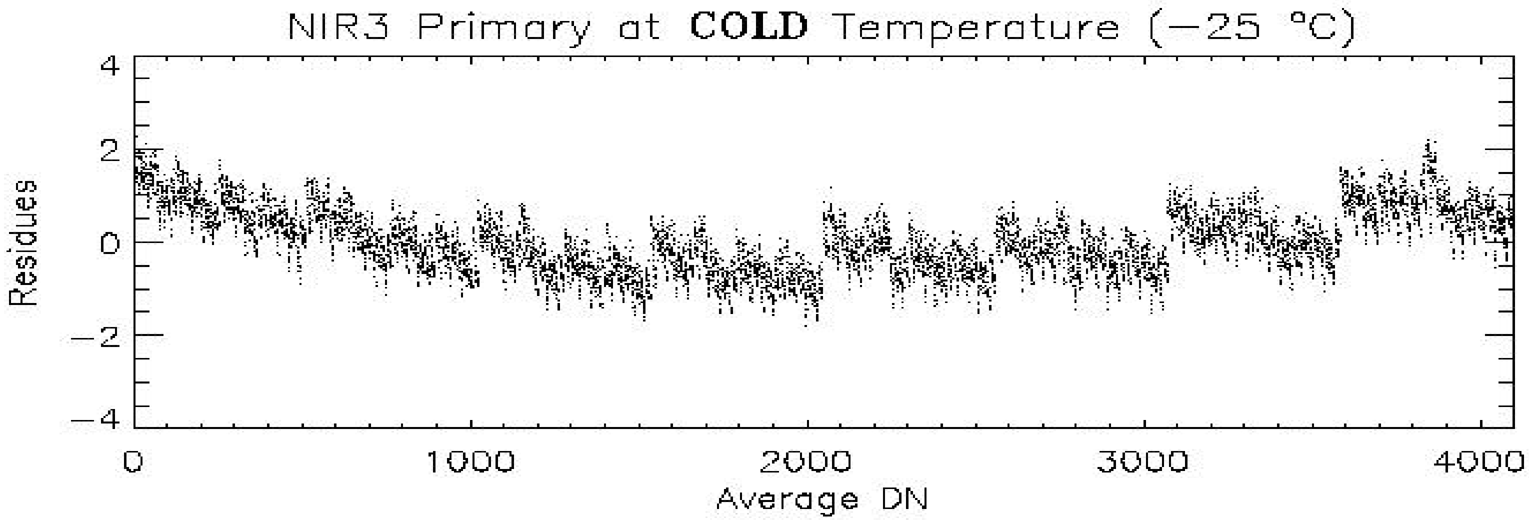
PC Bands ADC Conversion Time: 15 μs

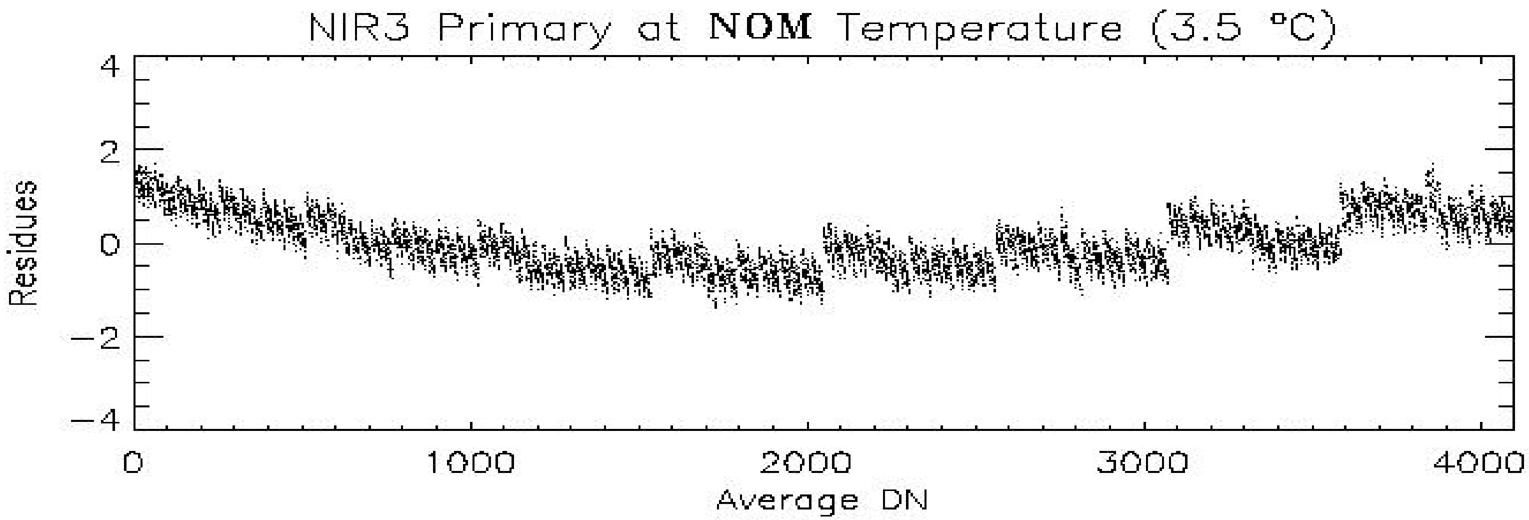
p / r: primary / redundant

Component Level Testing

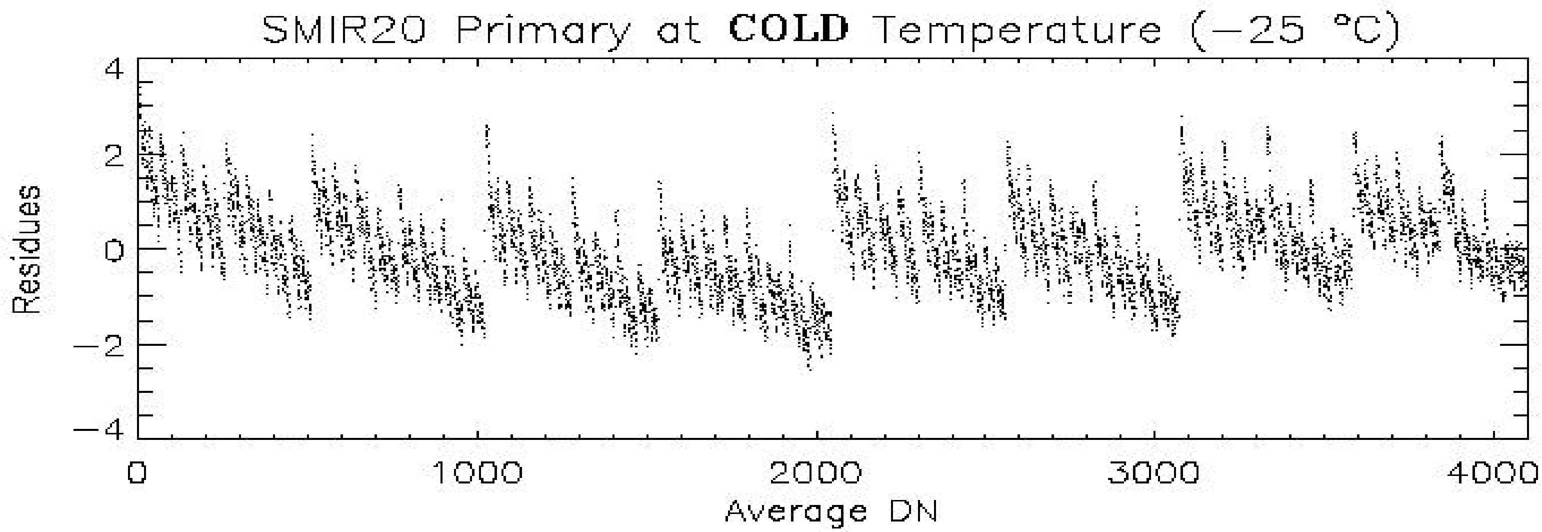
- 16-bit DAC used as calibrator for the 12-bit ADC
- Minimum 2 DAC steps for each of the ADC DN step (level)
- Averaging 200 - 400 samples per DAC step
- BFSL method used to fit the averaged ADC DN data set -> Integral Non-linearity (INL)
- No test for LWIR PC bands ADCs
- Periodic pattern observed

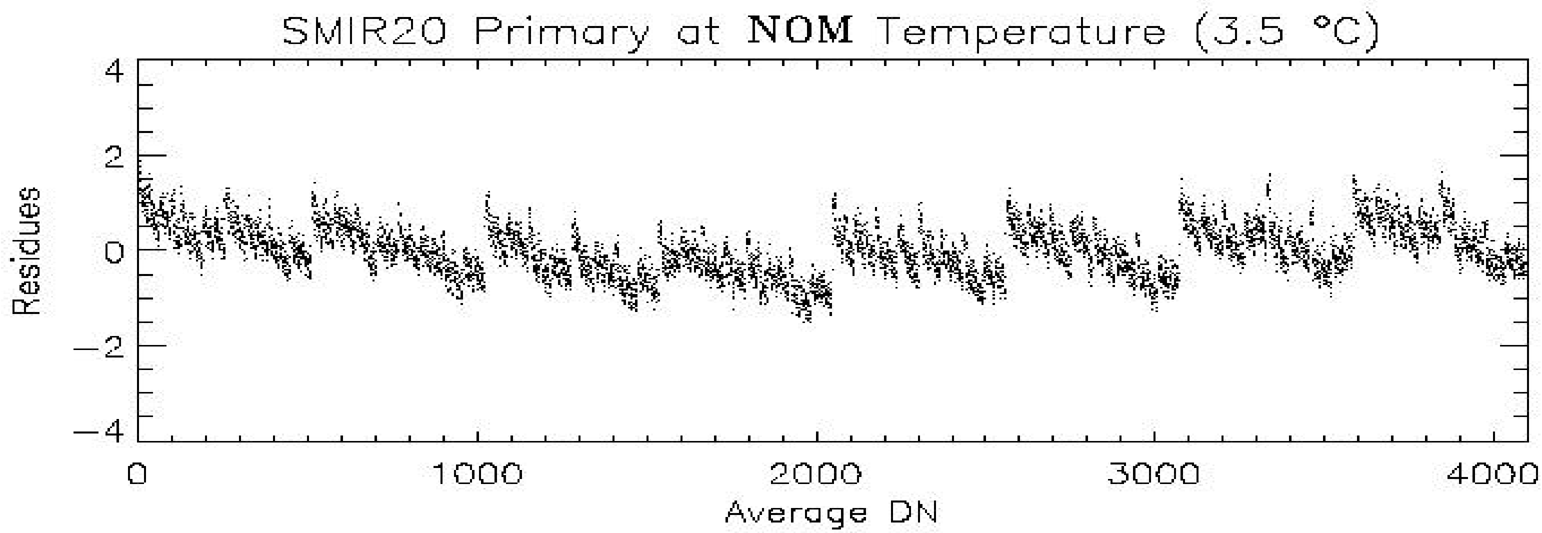
Component Level Testing





Component Level Testing





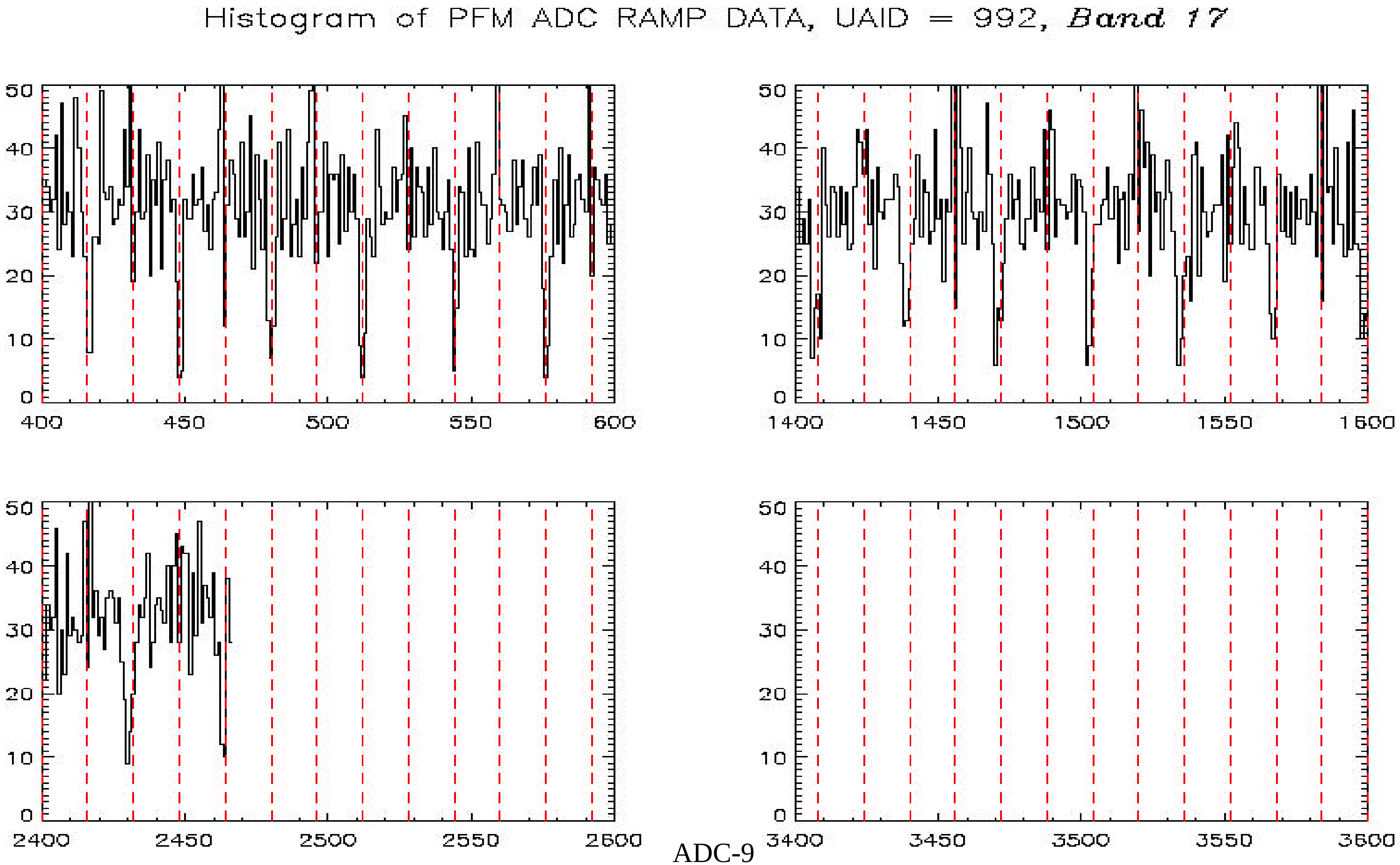
System Level (Ramp) Testing

- Ramp generator with triangle waveform covering most of the dynamic range
- ALL ADCs Evaluated
- SBRS analysis -> Differential Non-linearity (DNL)
- MCST histogram plots show some periodic patterns

ADC Name	UAID	Band	A vs B	Note
PCB31	901	31	A	Data not found
PCB32	904	32	A	Data on Channel 1 only
PCB33	905	33	A	
PCB34	906	34	A	
PCB35	907	35	A	
PCB36	908	36	A	
PCB36	909/1	36	B	
PCB35	909/2	35	B	
PCB34	910/1	34	B	
PCB33	910/2	33	B	
PCB32	910/3	32	B	
PCB31	910/4	31	B	
VIS	949	11,12	A	Data not found.
NIR1	950	2	A	Channel 5 Ploted
NIR2	951	1	A	
NIR3	952	14,15	A	
SMIR1	953	6,7	A	
SMIR2	954	20,22	A	
LWIR	955	27-30	A	
VIS	956	3,12	A	
NIR1	957	2	A	
NIR2	958	1	A	
NIR3	959	14	A	
SMIR1	960	6,7	A	
SMIR2	961	20,22	A	
LWIR	962	27,30	A	
VIS	963	8	B	
NIR1	964	2	B	
NIR2	965	1	B	
NIR3	966	14,15	B	
SMIR1	967	6,7	B	
SMIR2	968	23-26	B	
SMIR1	969	5,6,7	B	
SMIR2	970	24	B	
LWIR	971	27	B	
VIS	972	3,12	B	
NIR1	973	2	B	
NIR2	974	1	B	
NIR3	975	14-16	B	
SMIR1	976	6,7	B	
SMIR2	977	24	B	
LWIR	978	27	B	
NIR2	990	2	A	
NIR1	991	1	A	
NIR3	992	13-19,37,38	A	
NIR2	993	2	B	
NIR1	994	1	B	
NIR3	995	13--19,37,38	B	

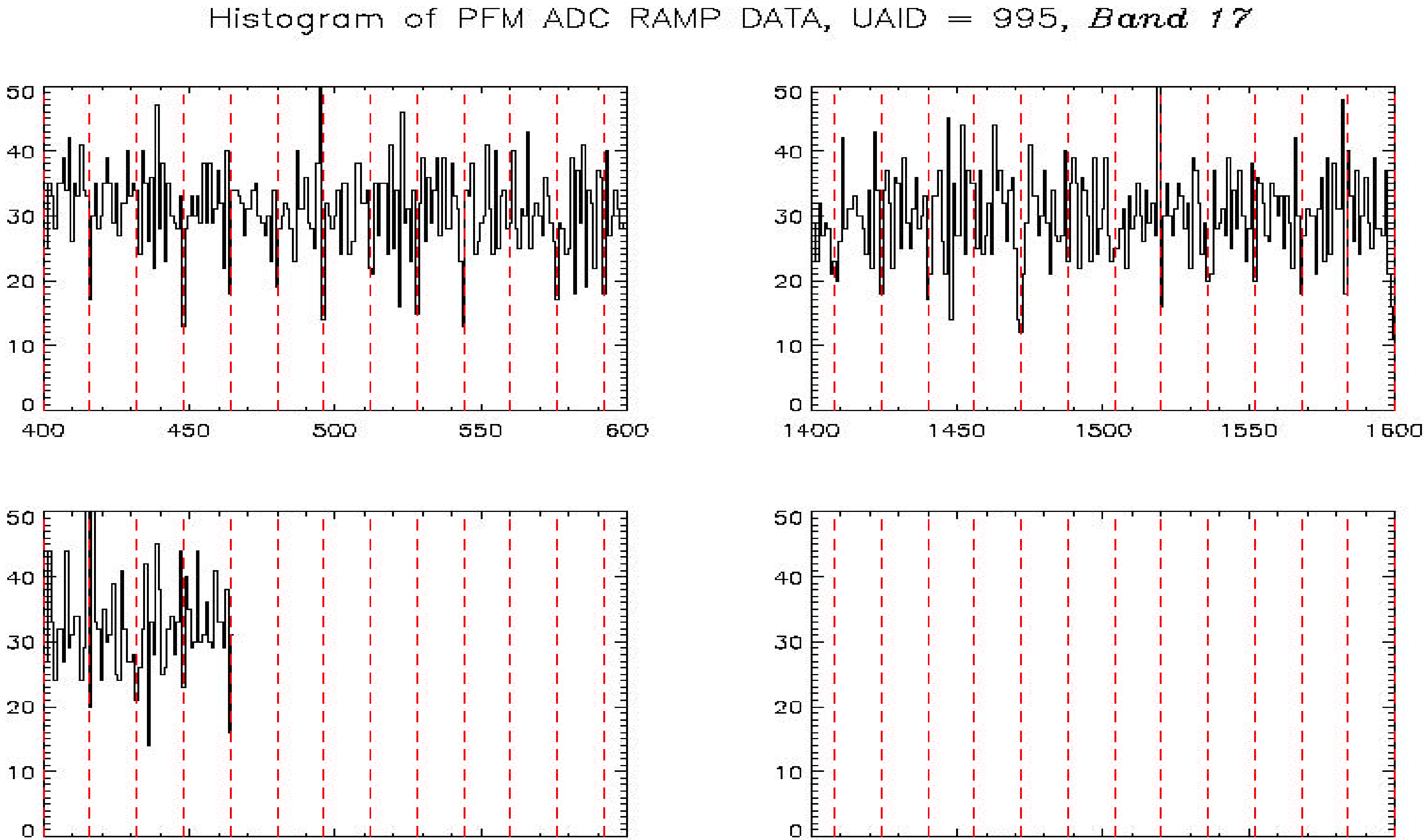
System Level (Ramp) Testing

B17, primary, channel 5



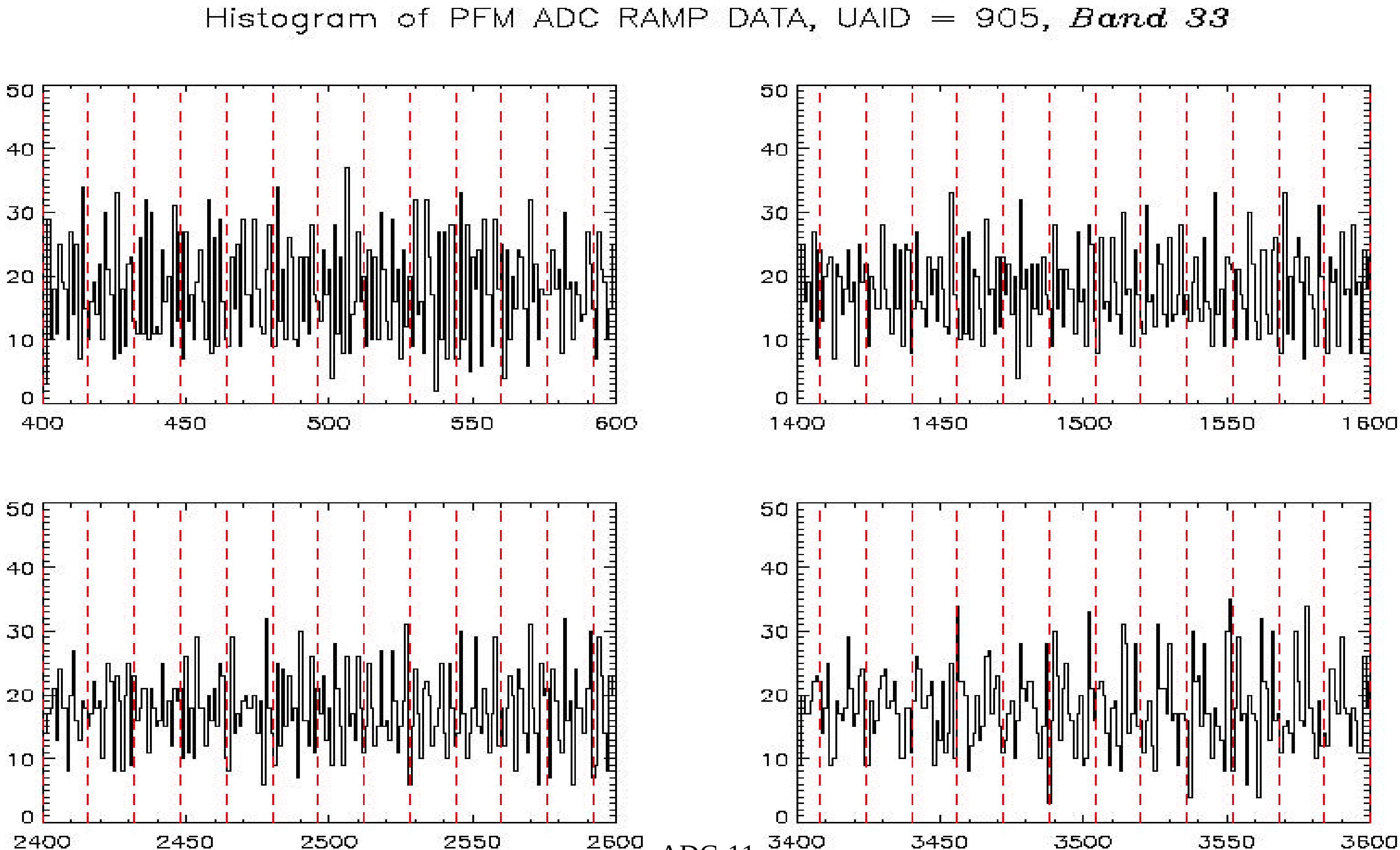
System Level (Ramp) Testing

B17, redundant, channel 5



System Level (Ramp) Testing

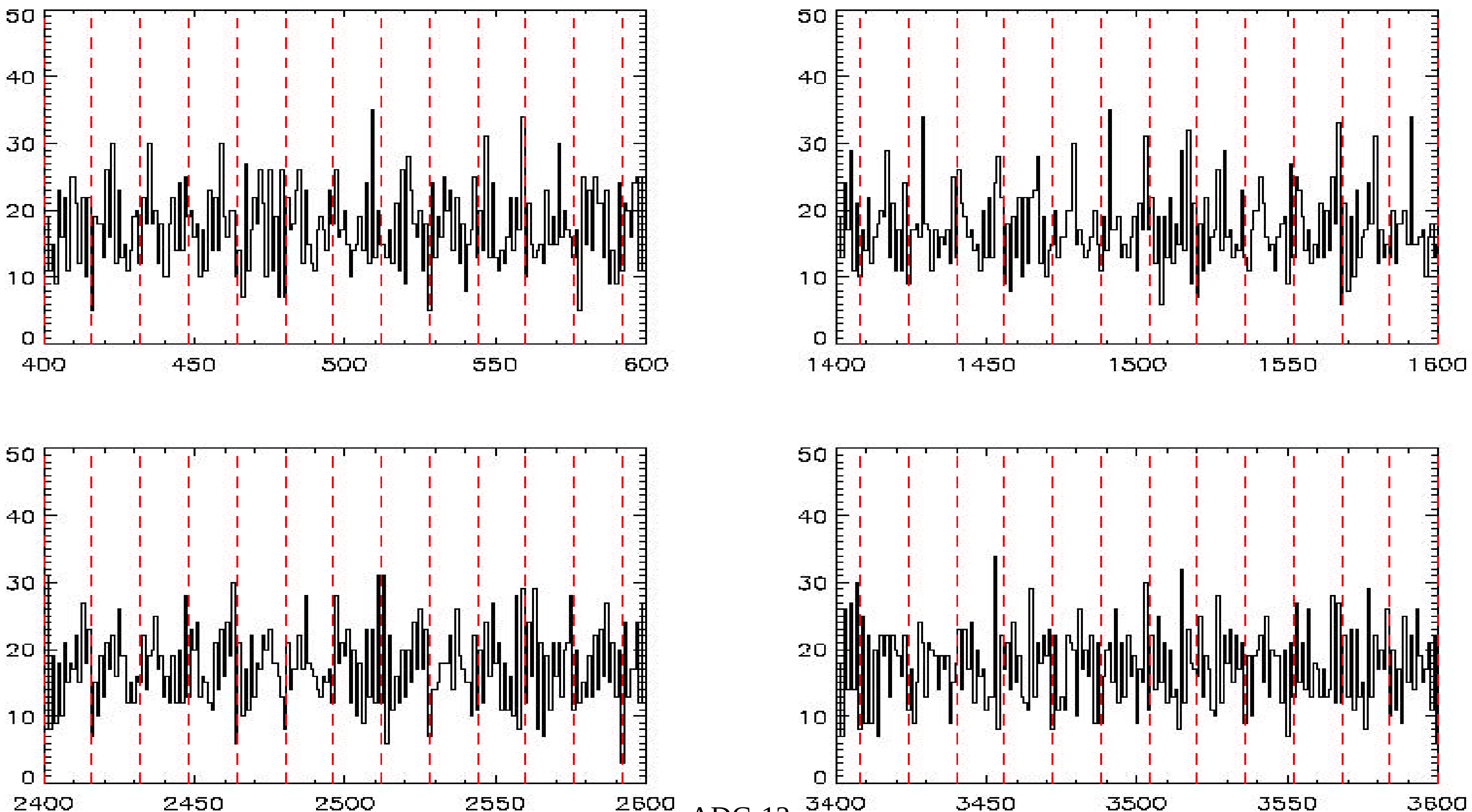
B33, primary, channel 1



System Level (Ramp) Testing

B33, redundant, channel 1

Histogram of PFM ADC RAMP DATA, UAID = 910, *Band 33*



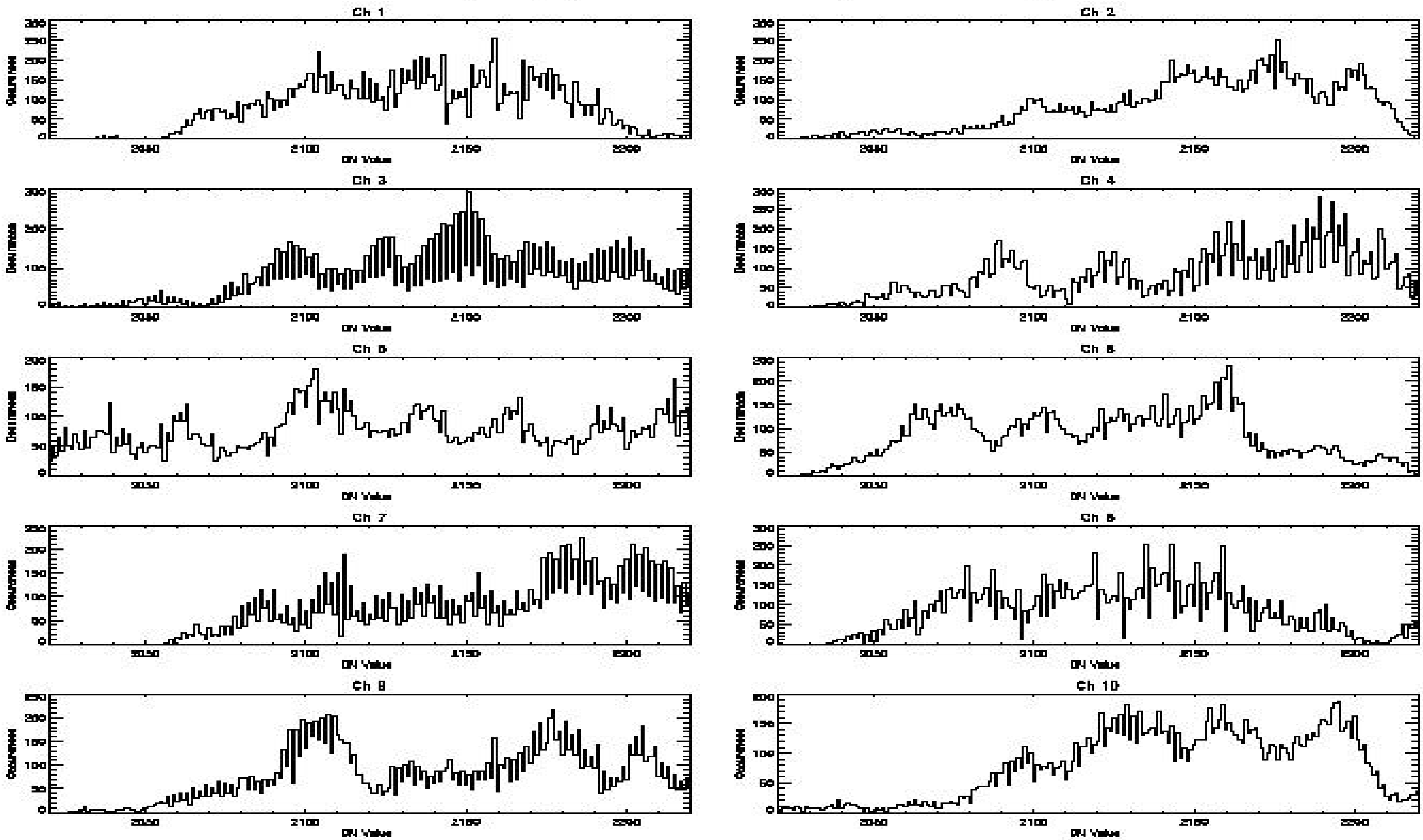
Spacecraft TV Testing

- OBC BB warm-up / cool-down data (TEB)
- Limited dynamic range
- PC Bands ADC performance evaluated

Protoflight S/C T/V Orbital MODIS Configuration List				
CONFIG	**PRI/RED**	**PWR SPLY**	**ANALOG**	**DIGITAL**
			PCLW, PVVIS, PVNIR, PVSM, PVLW	**TG, CE, SA, FR, FI**
1	**PRI**	**PS1**	**A**	**A**
2	**PRI**	**PS1**	**A**	**B**
3	**PRI**	**PS1**	**B**	**A**
4	**RED**	**PS2**	**B**	**B**
5	**RED**	**PS2**	**A**	**A**
6	**RED**	**PS2**	**A**	**B**

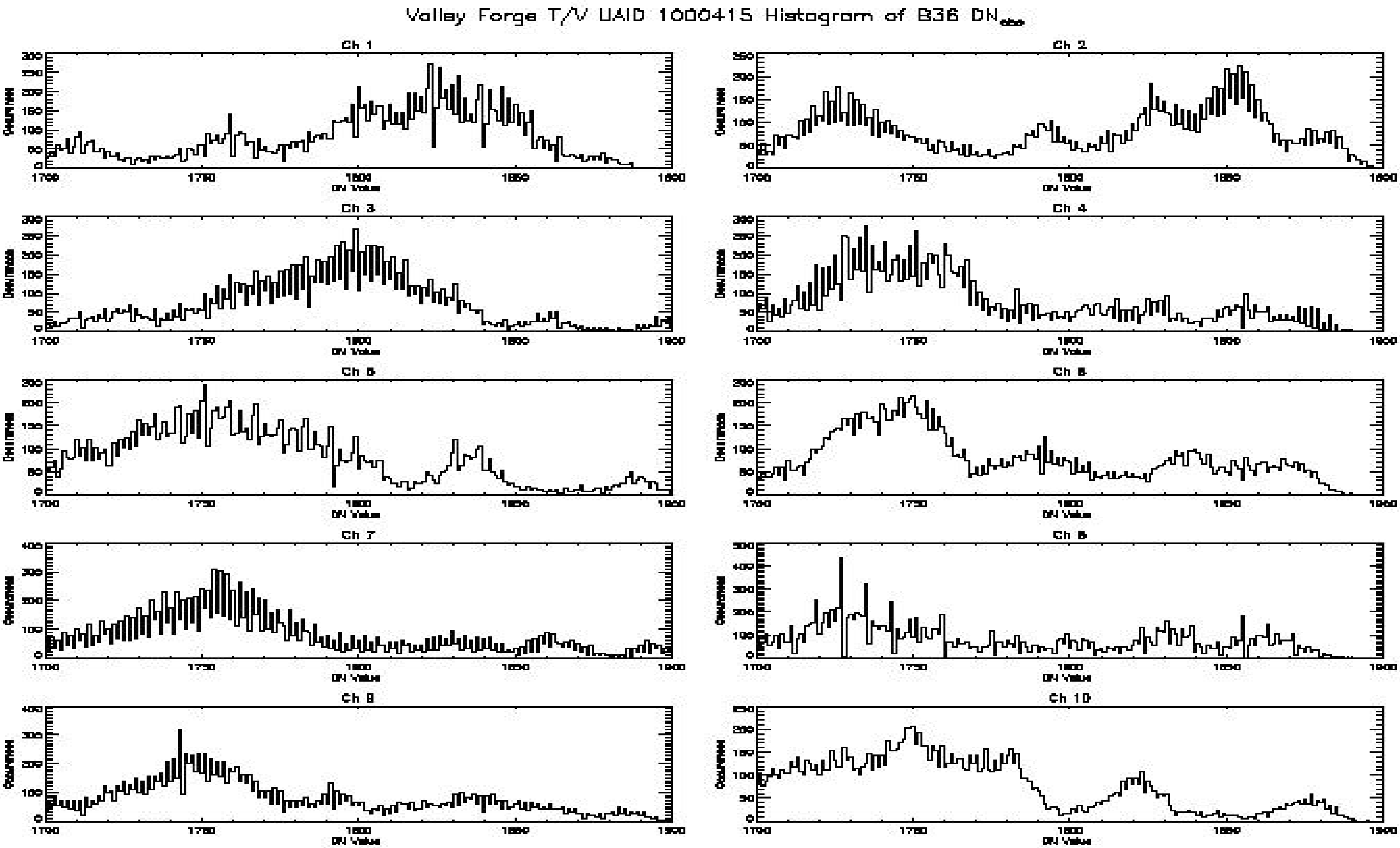
Spacecraft TV Testing
(A side, CPB)

Valley Forge T/V UAID 1000415 Histogram of B35 DN_{obs}



Spacecraft TV Testing

(A side, CPB)



Spacecraft TV Testing
(SBRS Analysis)

(Processed configurations)

UAID	Config	Orbit	Temp	Test	UAID Comment	Scans	Sector	Samples
1000305	1		-4.64	ECAL	PC ECAL, CPT-A	800	3	50
1000383	4	5B	-18.46	SRCA	ORBIT 5B CONFIG 4 SRCA	1070	3	50
1000401	5	14B	-12.11	SRCA	ORBIT 14B, CONFIG 5 SRCA	1000	3	50
1000298	6	17B	5.21	SRCA	SRCA COLLECT, ORBIT B, CYCLE 17, CONFIG 6, TRANSITIONING TO HOT CYCLE 4, DAY MODE	1070	3	50
1000405	CPB		-14.99	ECAL	CPT COLD W/CPB PC ECAL	800	3	50
1000325	TT		-8.48	NOISE	TRANS TOL, DISABLED MOPITT PUMP	50	5	1354

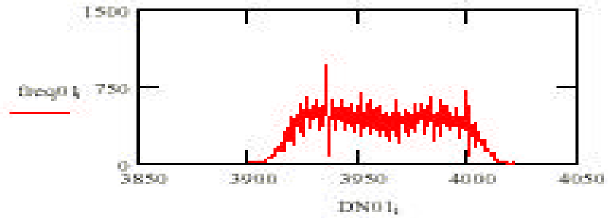
(Configurations to be processed)

UAID	Orbital Config	Date - Time
1000225	2	2/13/97 20:34
1000226	2	2/13/97 22:15
1000227	2	2/13/97 23:26
1000228	2	2/14/97 00:14
1000163	3	2/12/97 13:12
1000164	3	2/12/97 13:23
1000165	3	2/12/97 14:09

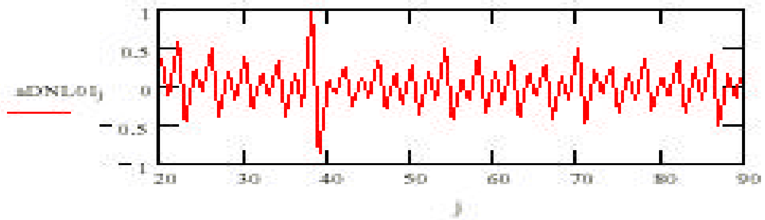
UAID 1000305, Configuration 1

Detector 1

min(aDNL01) = −0.85   max(aDNL01) = 0.97
stdev (aDNL01) = 0.29



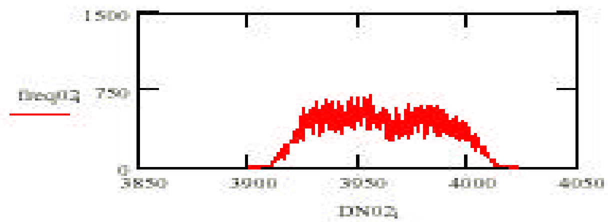
Histogram



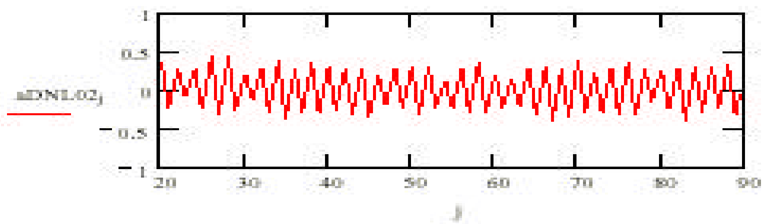
Differential Non-Linearity

Detector 2

min(aDNL02) = −0.4   max(aDNL02) = 0.43
stdev (aDNL02) = 0.25



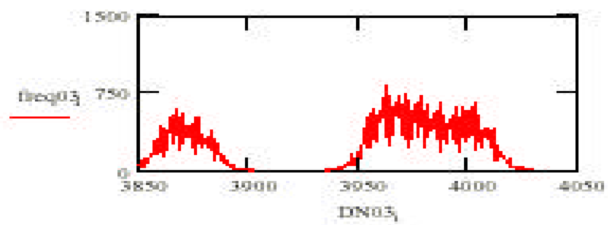
Histogram



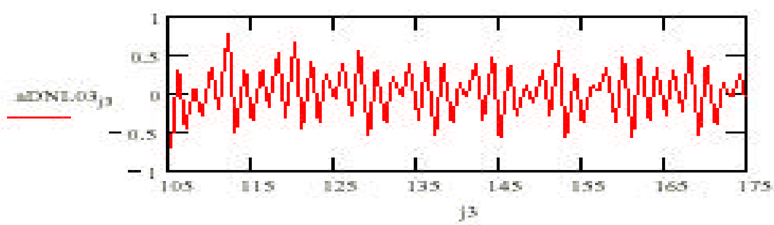
Differential Non-Linearity

Detector 3

min(aDNL03) = −0.71   max(aDNL03) = 0.76
stdev (aDNL03) = 0.24



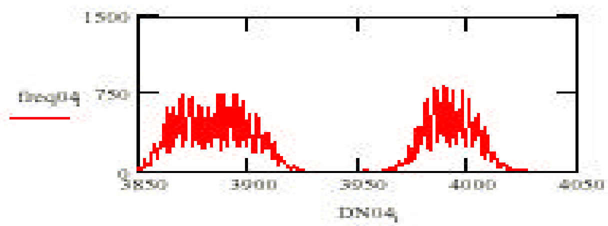
Histogram



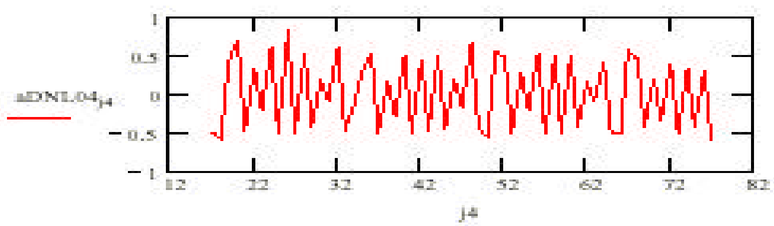
Differential Non-Linearity

Detector 4

min(aDNL04) = −0.62   max(aDNL04) = 0.8
stdev (aDNL04) = 0.4



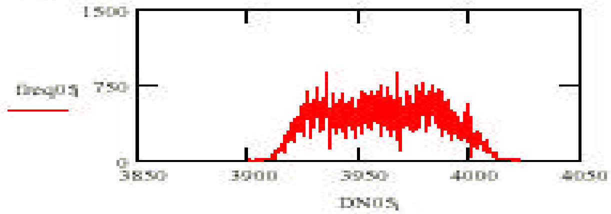
Histogram



Differential Non-Linearity

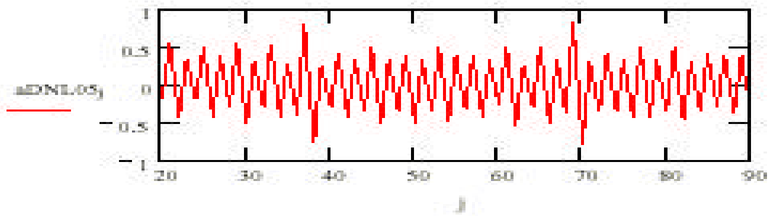
UAID 1000305, Configuration 1

Detector 5



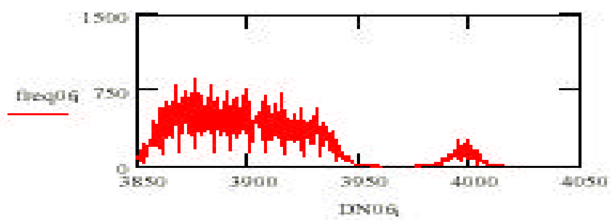
Histogram

min(aDNL05) = −0.79   max(aDNL05) = 0.81
stdev (aDNL05) = 0.37



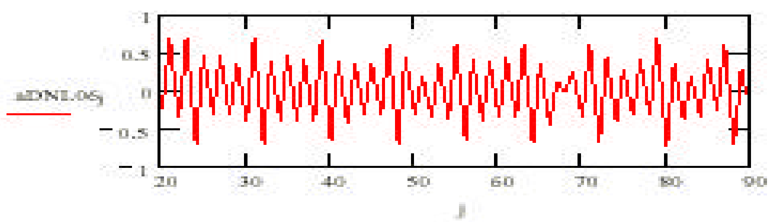
Differential Non-Linearity

Detector 6



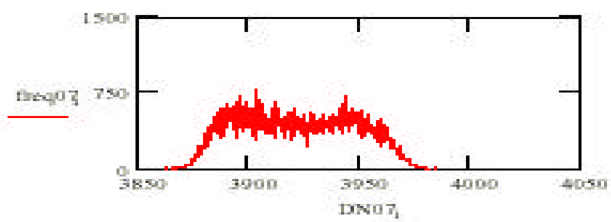
Histogram

min(aDNL06) = −0.73   max(aDNL06) = 0.7
stdev (aDNL06) = 0.41



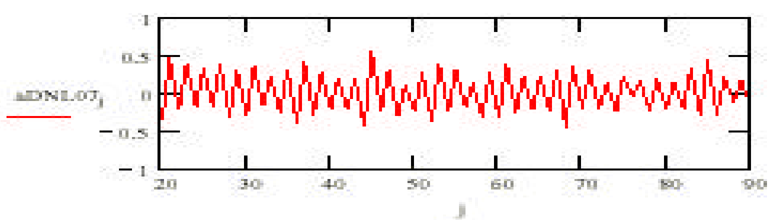
Differential Non-Linearity

Detector 7



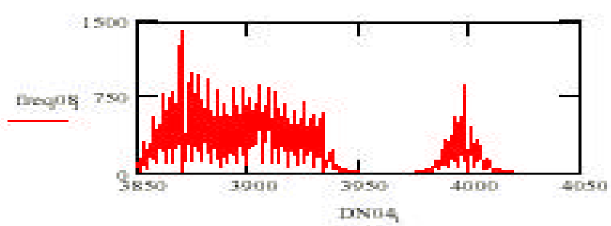
Histogram

min(aDNL07) = −0.45   max(aDNL07) = 0.53
stdev (aDNL07) = 0.25



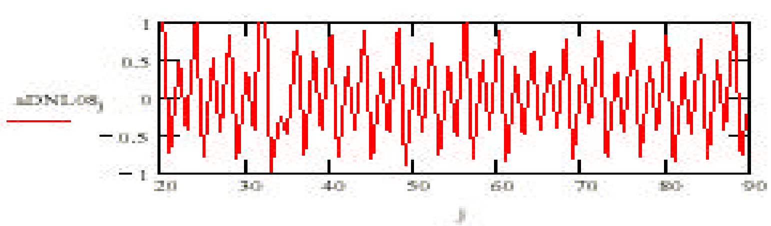
Differential Non-Linearity

Detector 8



Histogram

min(aDNL08) = −1   max(aDNL08) = 1.87
stdev (aDNL08) = 0.62

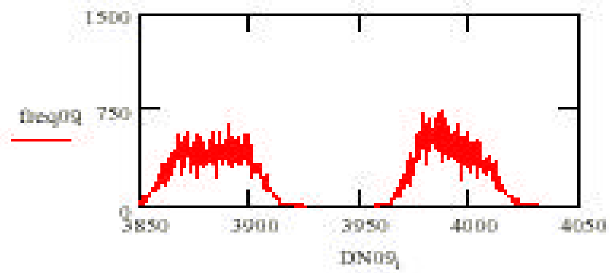


Differential Non-Linearity

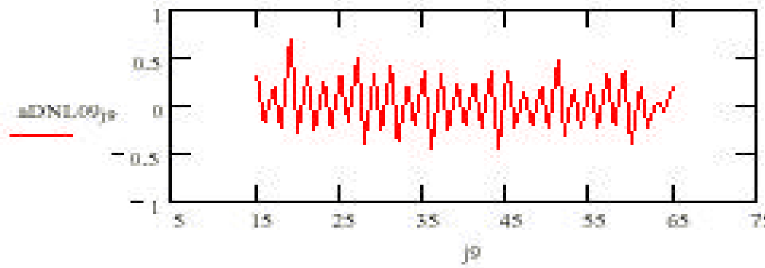
UAID 1000305, Configuration 1

Detector 9

min(aDNL09) = −0.45   max(aDNL09) = 0.69
stdev (aDNL09) = 0.26



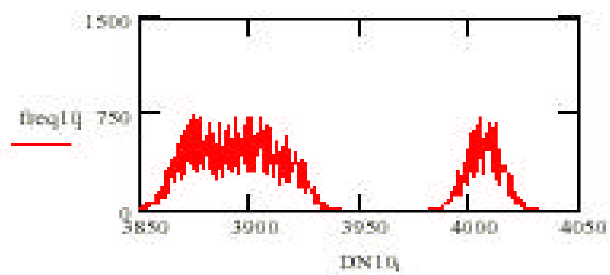
Histogram



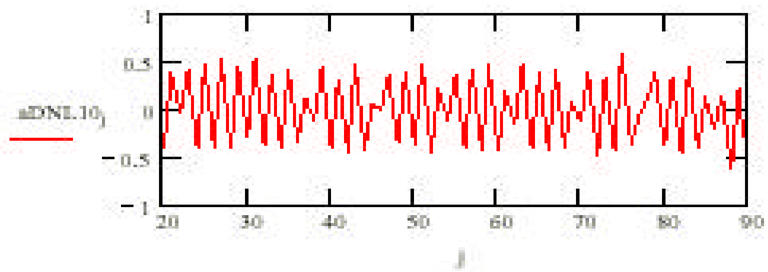
Differential Non-Linearity

Detector 10

min(aDNL10) = −0.81   max(aDNL10) = 0.56
stdev (aDNL10) = 0.33



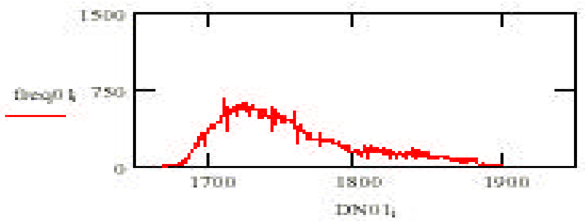
Histogram



Differential Non-Linearity

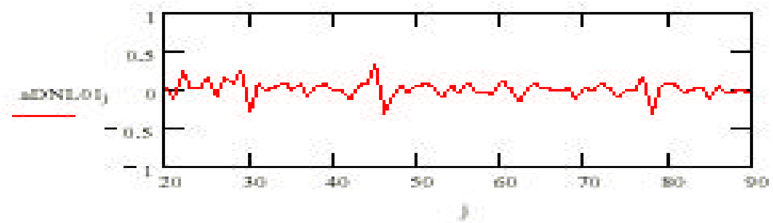
UAID 1000383, Configuration 4

Detector 1



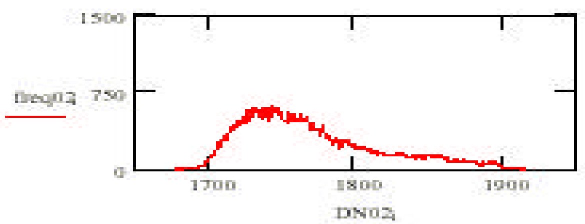
Histogram

min(aDNL01) = −0.3   max(aDNL01) = 0.35
stdev (aDNL01) = 0.09



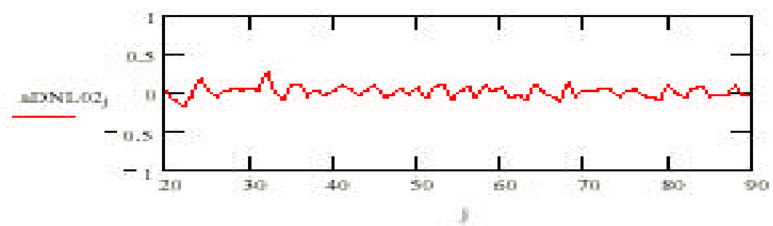
Differential Non-Linearity

Detector 2



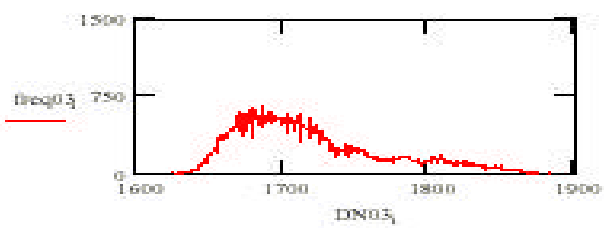
Histogram

min(aDNL02) = −0.17   max(aDNL02) = 0.27
stdev (aDNL02) = 0.07



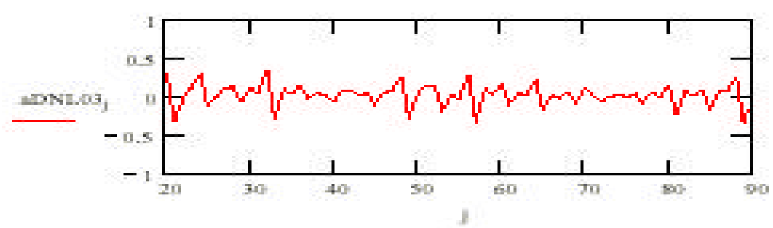
Differential Non-Linearity

Detector 3



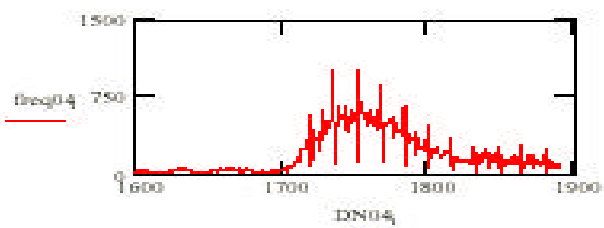
Histogram

min(aDNL03) = −0.35   max(aDNL03) = 0.33
stdev (aDNL03) = 0.13



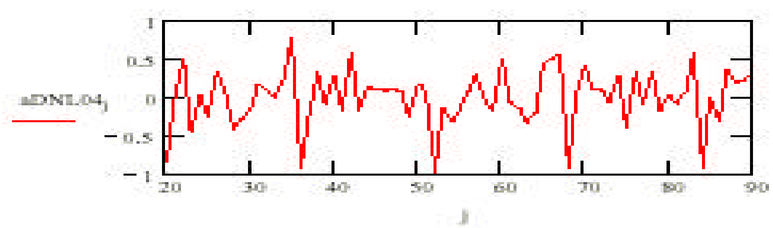
Differential Non-Linearity

Detector 4



Histogram

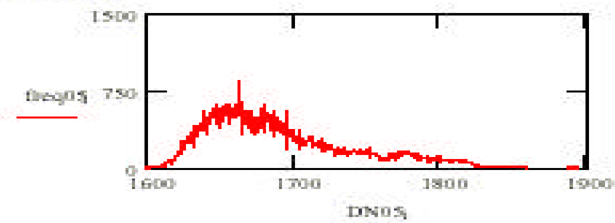
min(aDNL04) = −1   max(aDNL04) = 0.76
stdev (aDNL04) = 0.32



Differential Non-Linearity

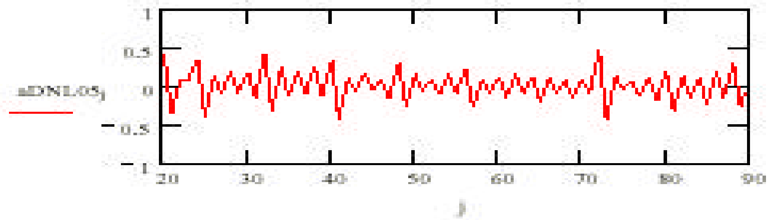
UAID 1000383, Configuration 4

Detector 5



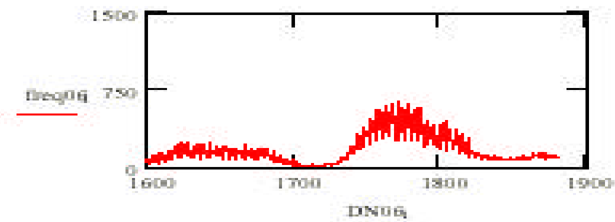
Histogram

min(aDNL05) = −0.42 max(aDNL05) = 0.47
stdev (aDNL05) = 0.18



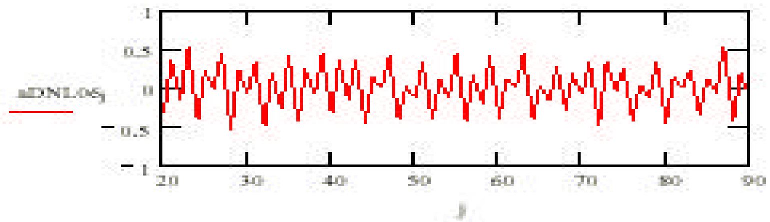
Differential Non-Linearity

Detector 6



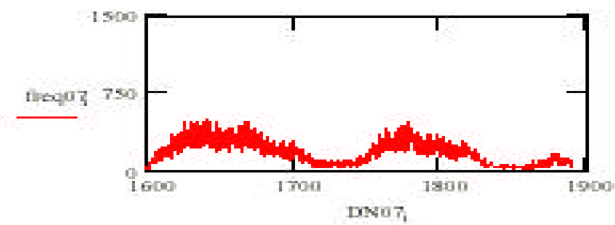
Histogram

min(aDNL06) = −0.53 max(aDNL06) = 0.54
stdev (aDNL06) = 0.27



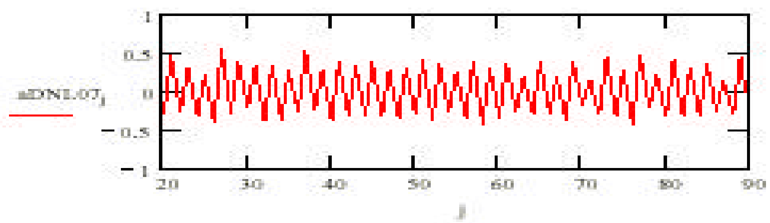
Differential Non-Linearity

Detector 7



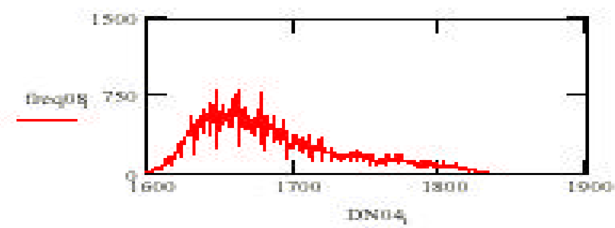
Histogram

min(aDNL07) = −0.44 max(aDNL07) = 0.54
stdev (aDNL07) = 0.29



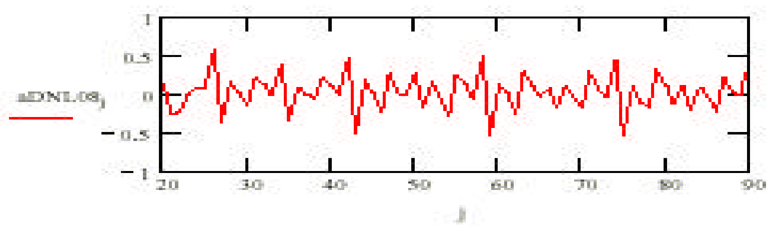
Differential Non-Linearity

Detector 8



Histogram

min(aDNL08) = −0.55 max(aDNL08) = 0.58
stdev (aDNL08) = 0.21

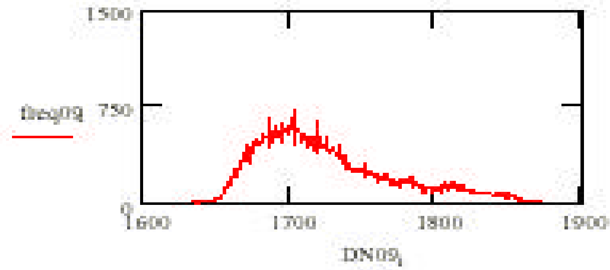


Differential Non-Linearity

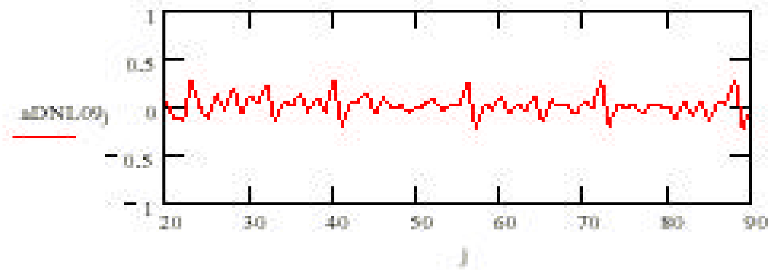
UAID 1000383, Configuration 4

Detector 9

min(aDNL09) = −0.22 max(aDNL09) = 0.29
stdev (aDNL09) = 0.1



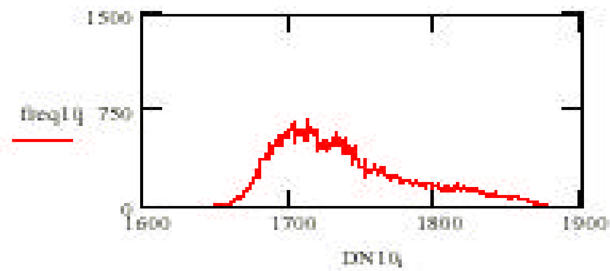
Histogram



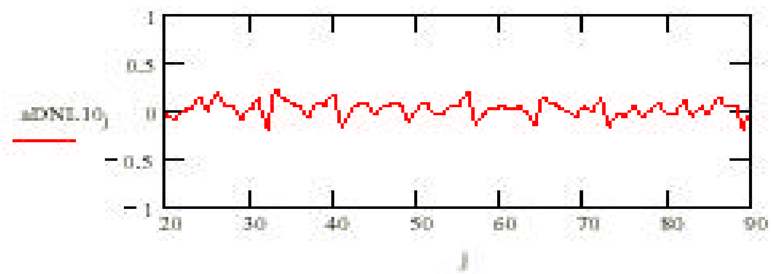
Differential Non-Linearity

Detector 10

min(aDNL10) = −0.2 max(aDNL10) = 0.21
stdev (aDNL10) = 0.08



Histogram



Differential Non-Linearity

On-orbit ADC Performance

- MCST EV data histogram for RSB and TEB
  - More than 10 granules L1A EV sector data used in examples
  - Some periodic patterns observed
  - PC bands (B31-36) show same channel dependent structure
- SBRS differential non-linearity (DNL) analysis (preliminary)
  - MOD01SS.A2000102.0125.001.001.hdf (from Miami)
  - SST Bands 20, 22, 23, 31, and 32 analyzed

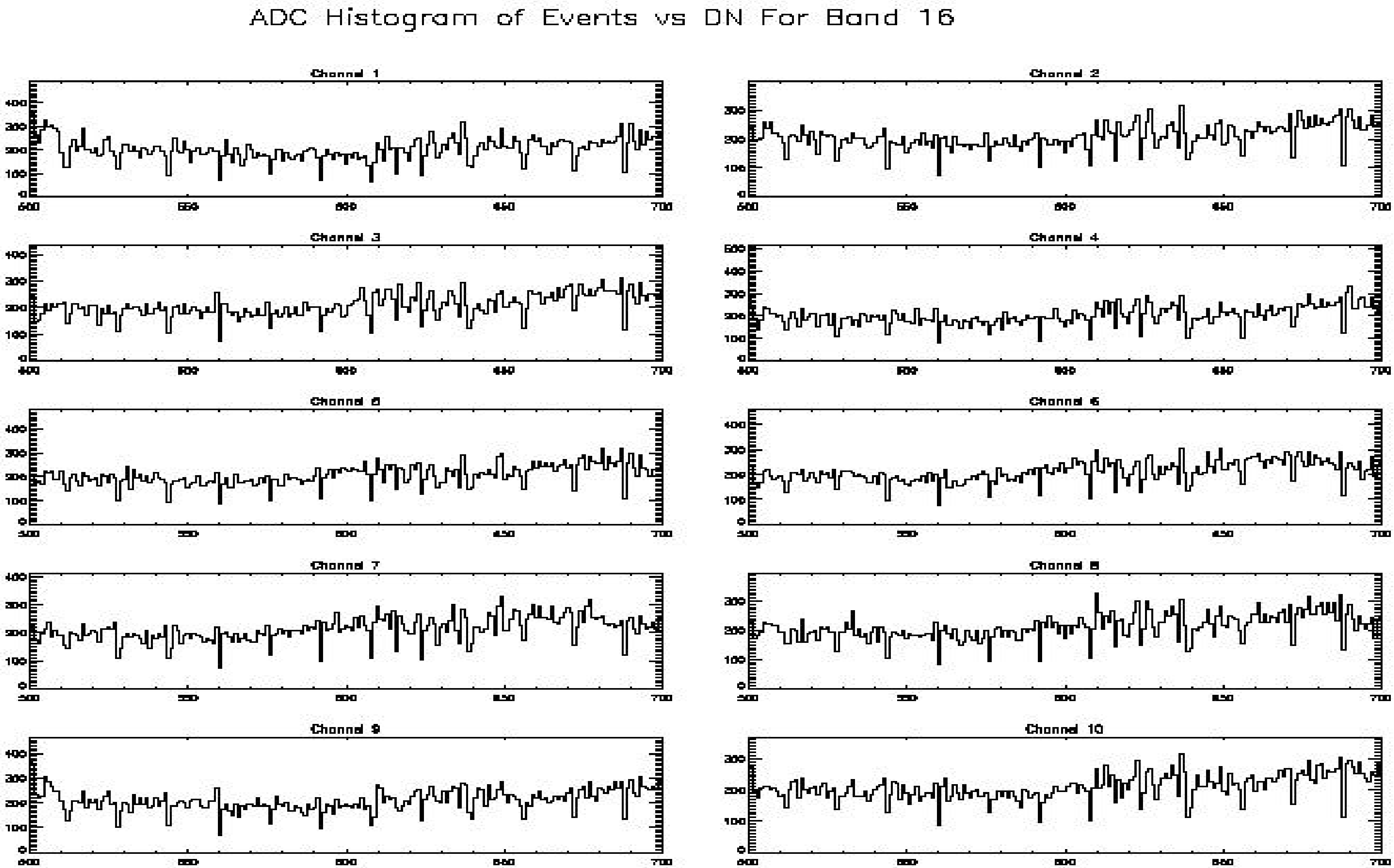
On-orbit ADC Performance

L1A Files Processed for the Examples

MOD01.A2000075.1505.001.2000077092232.hdf
MOD01.A2000075.1510.001.2000077092818.hdf
MOD01.A2000075.1515.001.2000077091209.hdf
MOD01.A2000075.1520.001.2000077091512.hdf
MOD01.A2000075.1525.001.2000077091613.hdf
MOD01.A2000075.1530.001.2000077092615.hdf
MOD01.A2000075.1535.001.2000077092815.hdf
MOD01.A2000075.1540.001.2000077093023.hdf
MOD01.A2000075.1545.001.2000077091120.hdf
MOD01.A2000075.1550.001.2000077091245.hdf
MOD01.A2000075.1555.001.2000077091345.hdf
MOD01.A2000075.1600.001.2000077151143.hdf

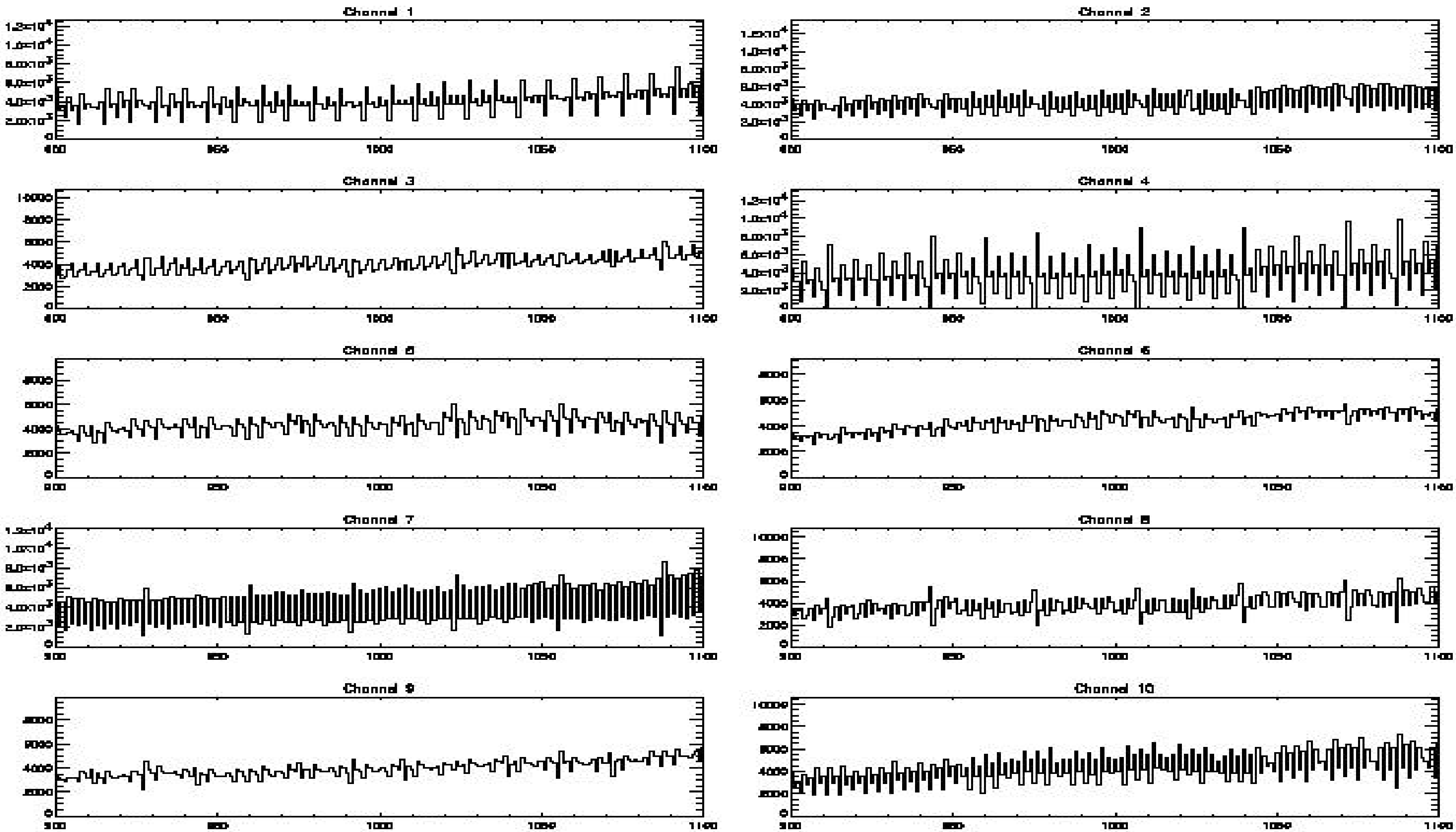
ALL RSB & TEB (bands & channels) Analyzed

On-orbit ADC Performance

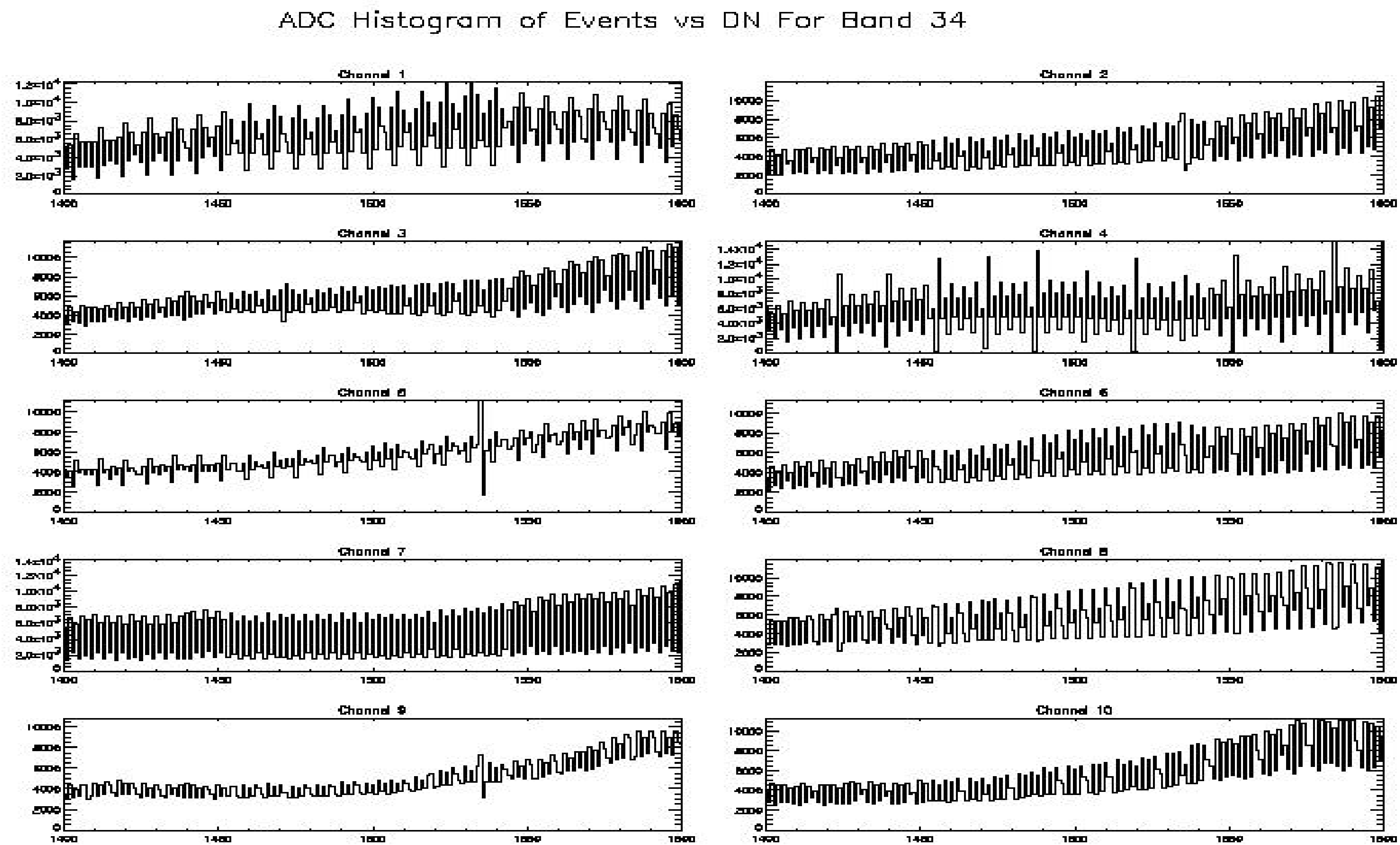


On-orbit ADC Performance

ADC Histogram of Events vs DN For Band 32



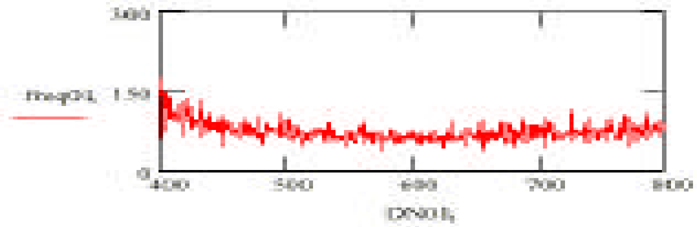
On-orbit ADC Performance



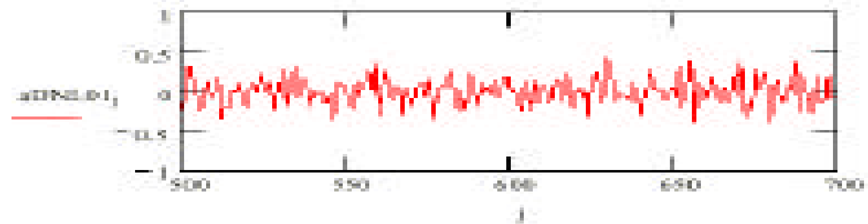
Band 20, PFM On-orbit Data

Detector 1

min(aDNL01) = −0.41 max(aDNL01) = 0.43
stdev (aDNL01) = 0.09



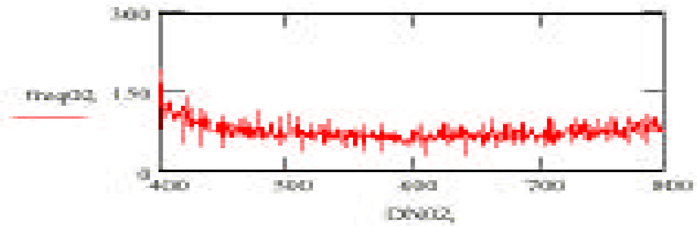
Histogram



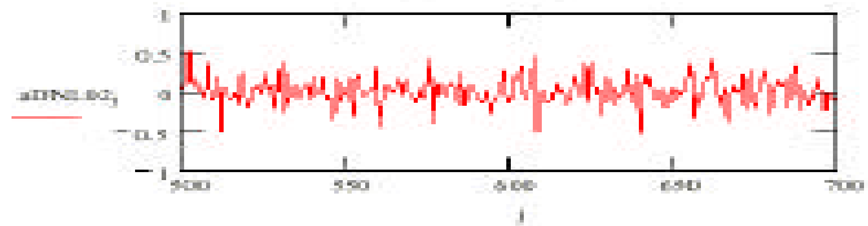
Differential Non-Linearity

Detector 2

min(aDNL02) = −0.54 max(aDNL02) = 0.51
stdev (aDNL02) = 0.1



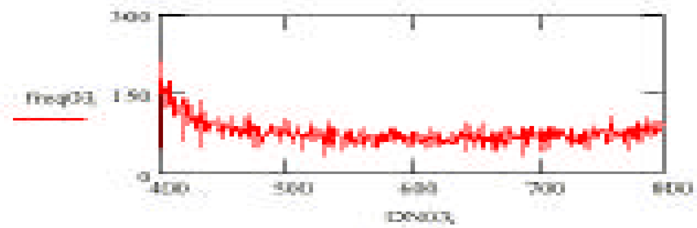
Histogram



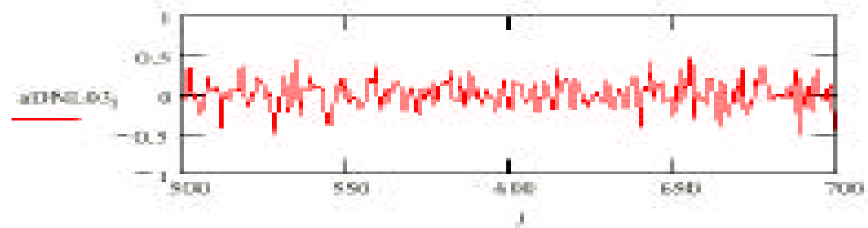
Differential Non-Linearity

Detector 3

min(aDNL03) = −0.51 max(aDNL03) = 0.45
stdev (aDNL03) = 0.1



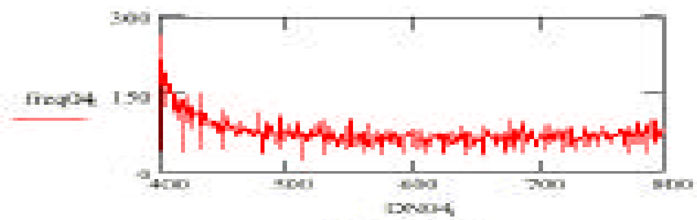
Histogram



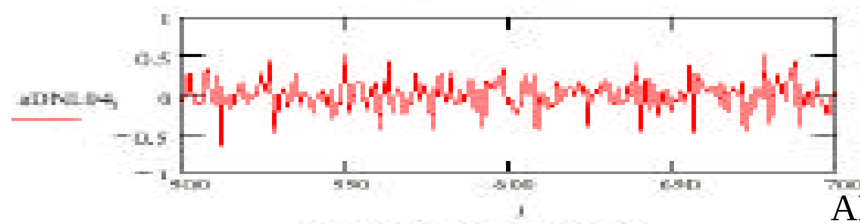
Differential Non-Linearity

Detector 4

min(aDNL04) = −0.64 max(aDNL04) = 0.5
stdev (aDNL04) = 0.1



Histogram

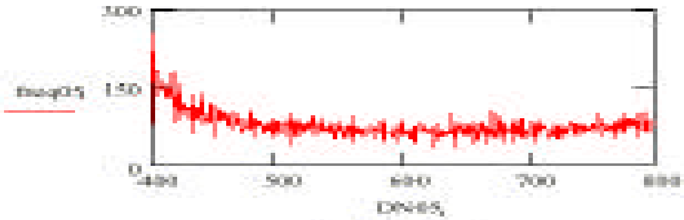


Differential Non-Linearity

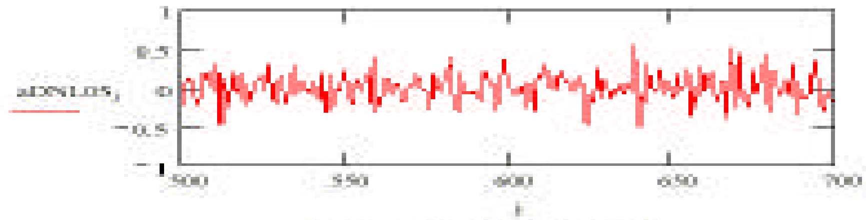
Band 20, PFM On-orbit Data

Detector 5

$\min(aDNL05) = -0.5$ $\max(aDNL05) = 0.53$
$\text{stdev}(aDNL05) = 0.1$



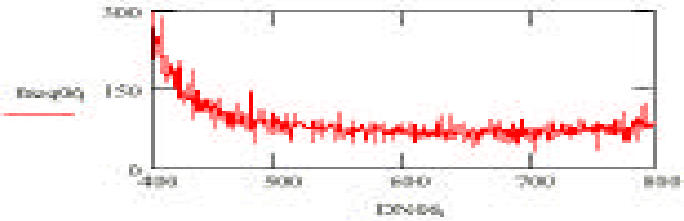
Histogram



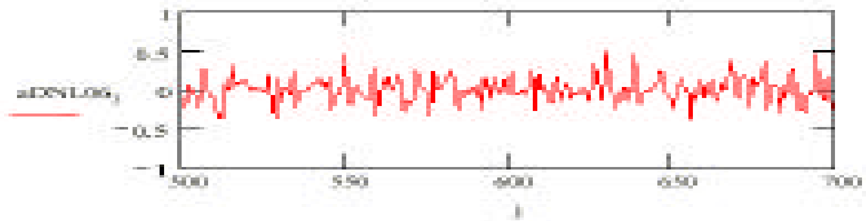
Differential Non-Linearity

Detector 6

$\min(aDNL06) = -0.39$ $\max(aDNL06) = 0.48$
$\text{stdev}(aDNL06) = 0.09$



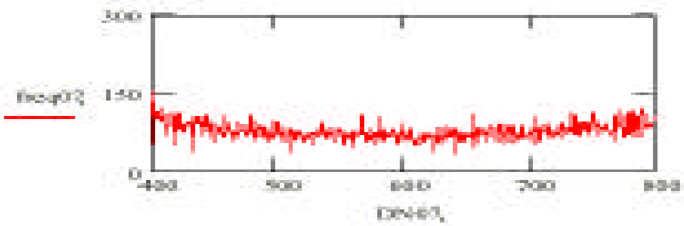
Histogram



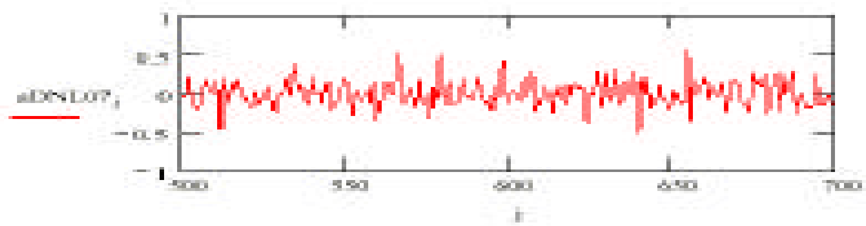
Differential Non-Linearity

Detector 7

$\min(aDNL07) = -0.52$ $\max(aDNL07) = 0.55$
$\text{stdev}(aDNL07) = 0.09$



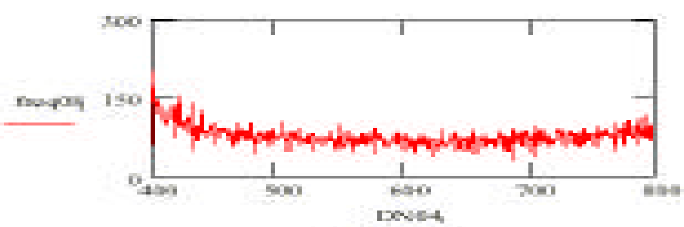
Histogram



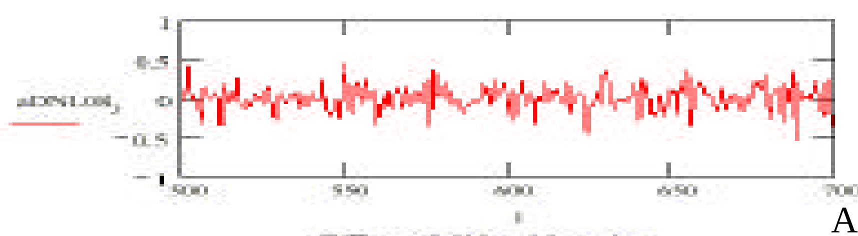
Differential Non-Linearity

Detector 8

$\min(aDNL08) = -0.55$ $\max(aDNL08) = 0.44$
$\text{stdev}(aDNL08) = 0.09$



Histogram

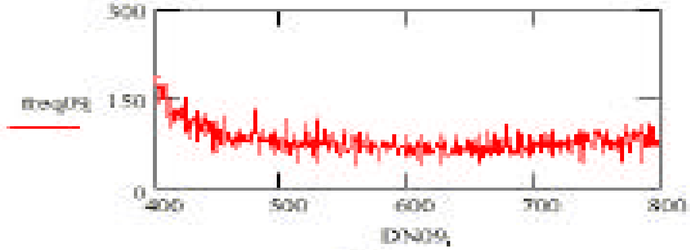


Differential Non-Linearity

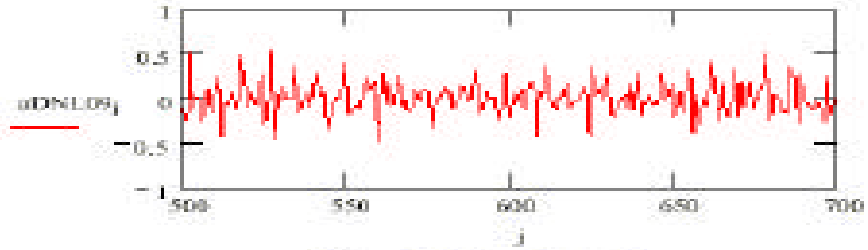
Band 20, PFM On-orbit Data

Detector 9

min(aDNL09) = −0.49 max(aDNL09) = 0.56
stdev(aDNL09) = 0.1



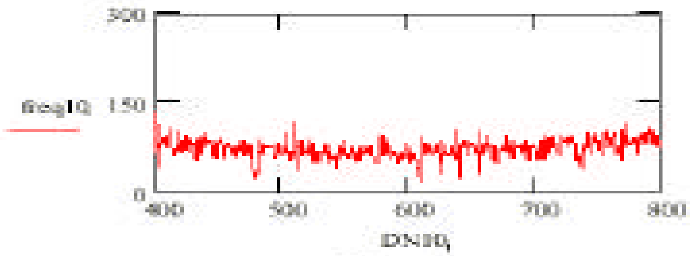
Histogram



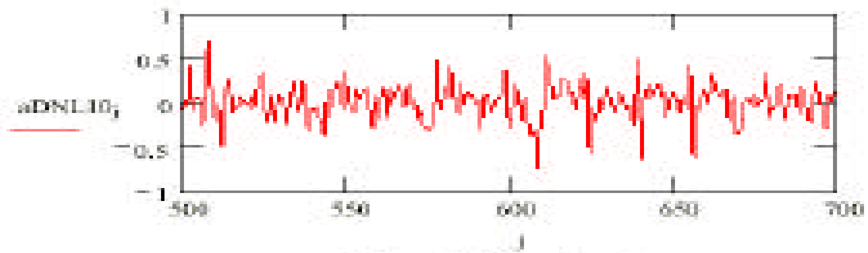
Differential Non-Linearity

Detector 10

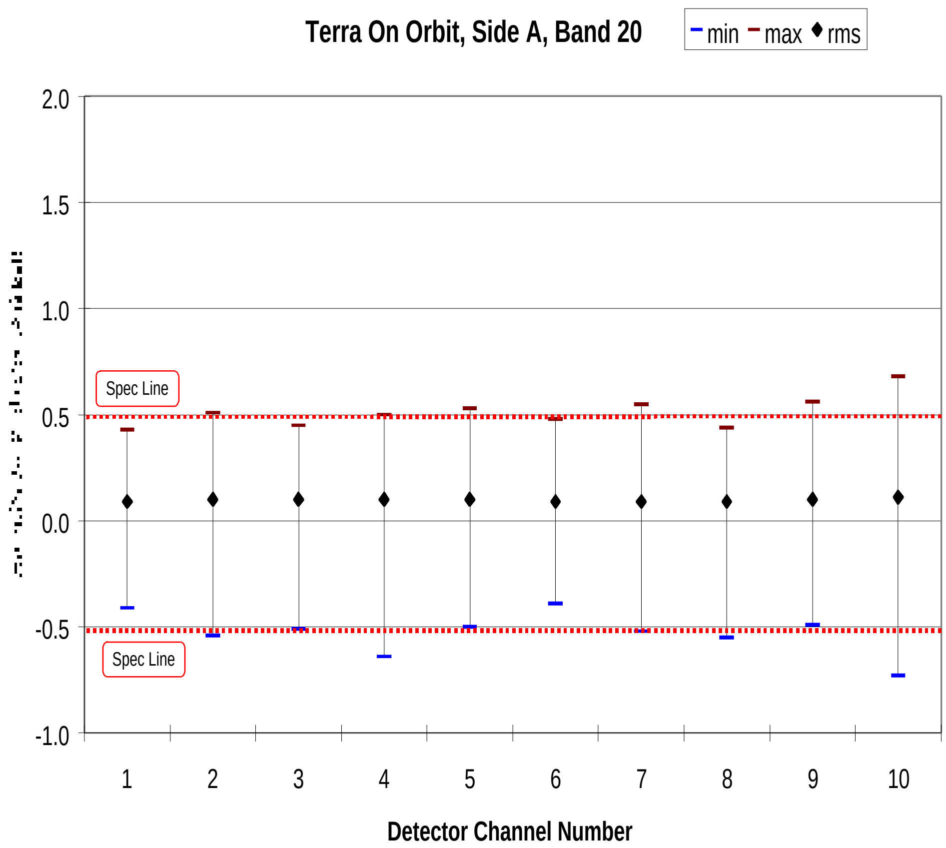
min(aDNL10) = −0.73 max(aDNL10) = 0.68
stdev(aDNL10) = 0.11



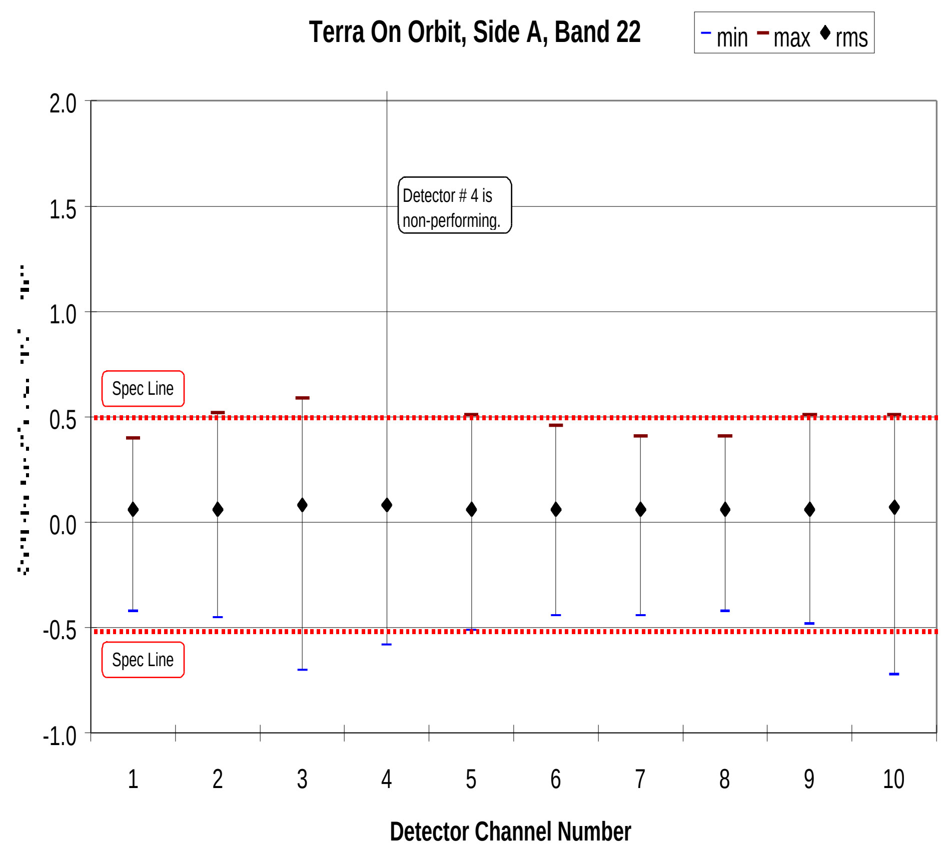
Histogram



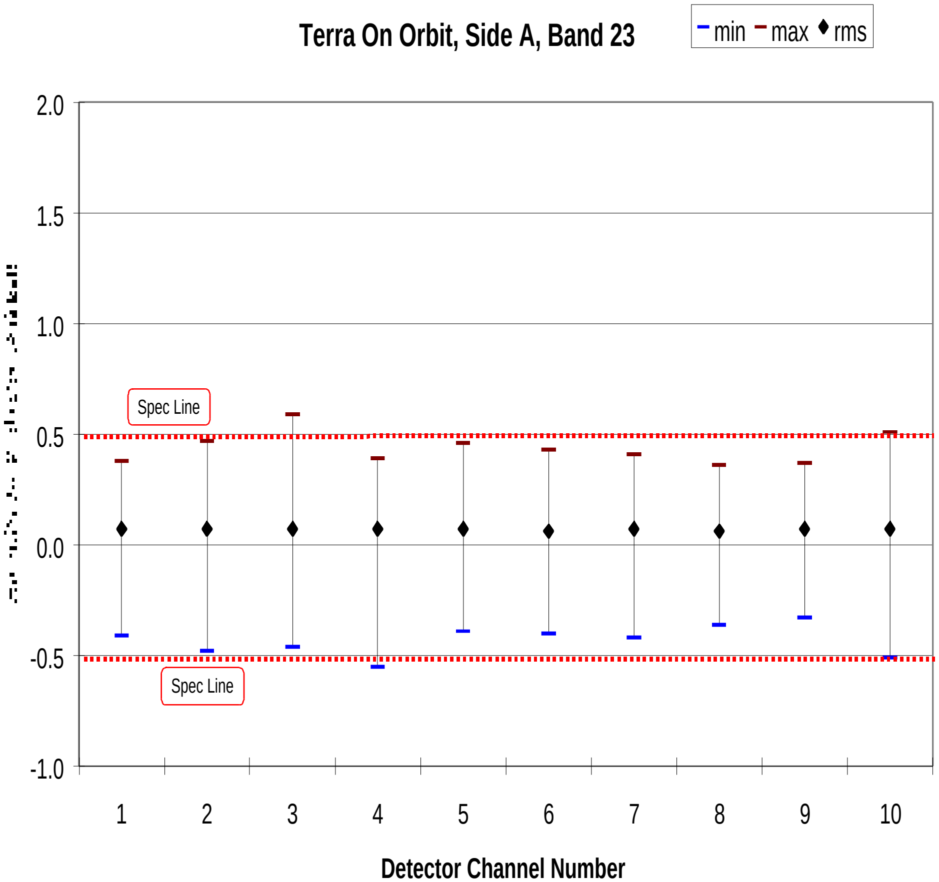
Differential Non-Linearity



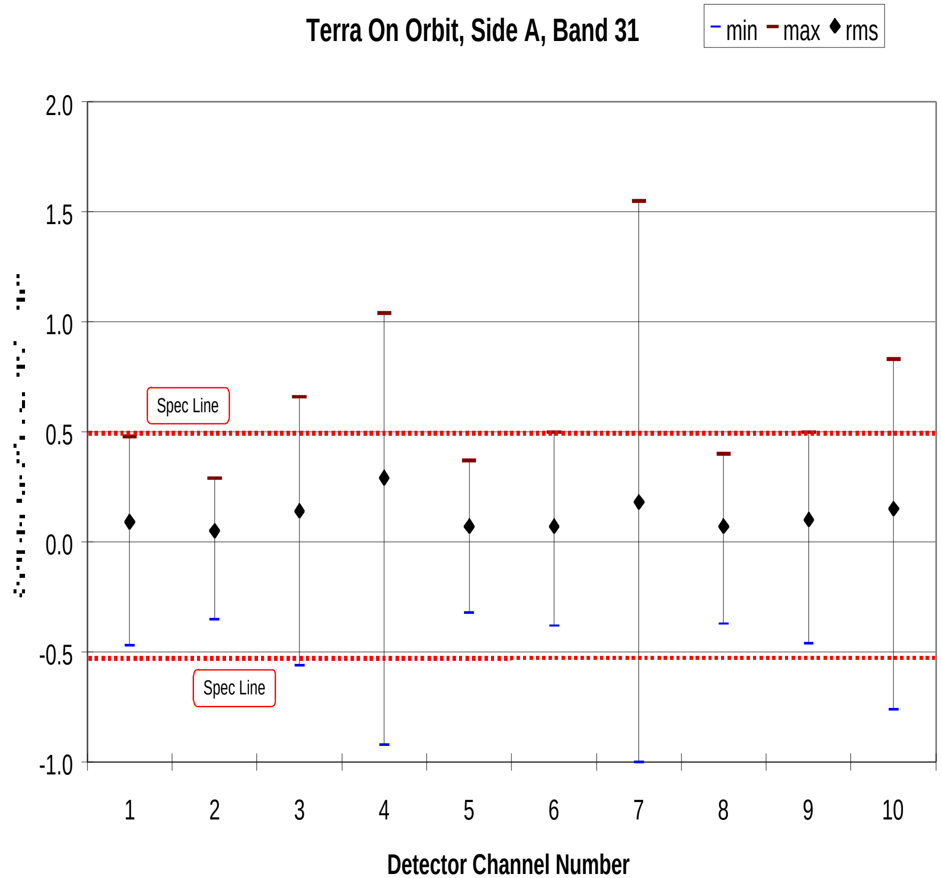
Terra On Orbit, Side A, Band 20
min
max
rms
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Spec Line
Spec Line
1
2
3
4
5
6
7
8
9
10
Detector Channel Number



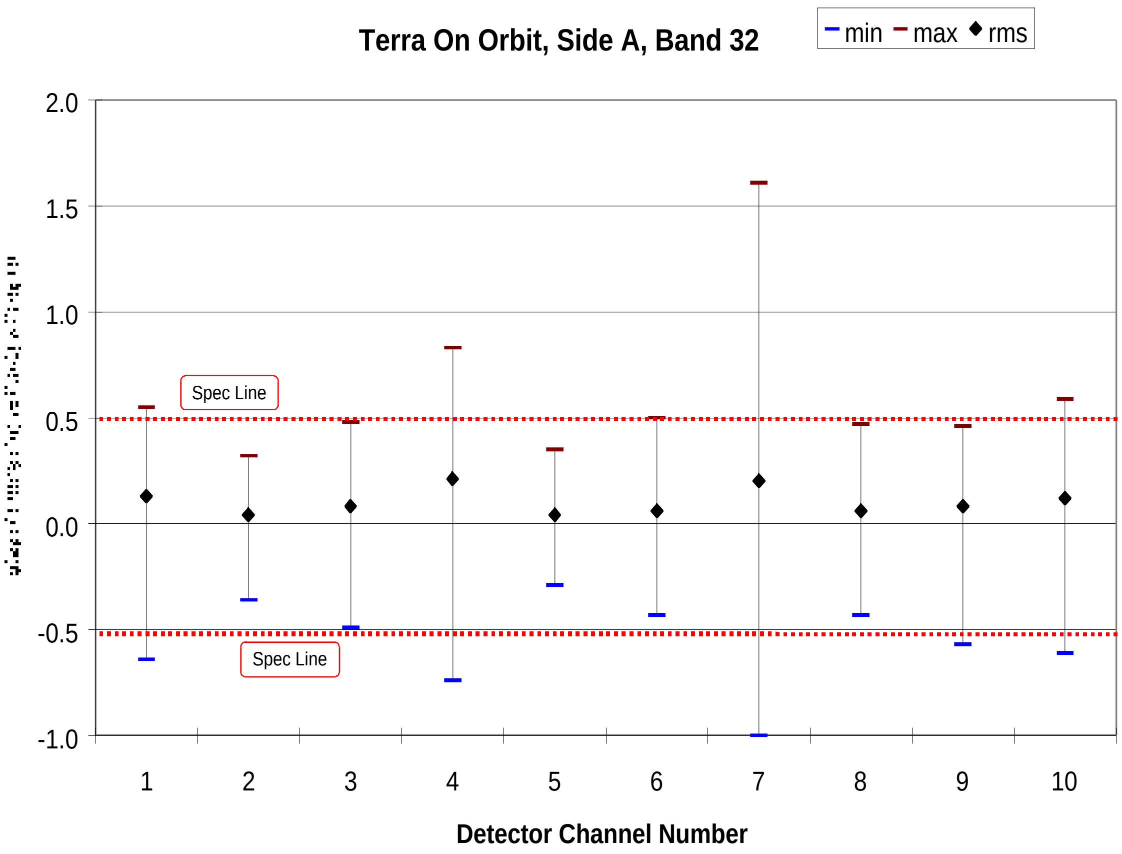
Terra On Orbit, Side A, Band 22
min
max
rms
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Detector # 4 is non-performing.
Spec Line
Spec Line
1
2
3
4
5
6
7
8
9
10
Detector Channel Number



Terra On Orbit, Side A, Band 23
min max rms
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Spec Line
Spec Line
1 2 3 4 5 6 7 8 9 10
Detector Channel Number



Terra On Orbit, Side A, Band 31
min max rms
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Spec Line
Spec Line
1 2 3 4 5 6 7 8 9 10
Detector Channel Number


Terra On Orbit, Side A, Band 32
min
max
rms
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Spec Line
Spec Line
1
2
3
4
5
6
7
8
9
10
Detector Channel Number

Preliminary Conclusions (2)

CAUTION - THESE RESULTS CAME FRIDAY, 2 JUNE, AND MUST BE VERIFIED. ESPECIALLY PC RESULTS SURPRISE US

- ADC On-orbit
  - A-side (PC Bands, 31 - 36) 3 or 4 of 10 channel pairs for SST (Bands 31 & 32) meet Differential Non-Linearity (DNL) requirement
  - A-side (PV Bands, 20 - 25) 3 of 10 channel sets for SST-4µm (Bands 20, 22 & 23) meet DNL requirement
- ADC Spacecraft Thermal Vacuum (S/C T/V) testing
  - Useful data for Band 36 only
  - A-side 1 of 10 channels meets DNL requirement
  - B-side 6 of 10 channels meets DNL requirement

    Expect significant improvements operating on B-side

    Need investigate NIR behavior now too