Resolving S-NPP VIIRS Thermal Emissive Band Performance Issues

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Thanks to all VIIRS SDR team partners in this work

2014 STAR JPSS Science Teams Anuual Mtg
May 12-16, 2014
College Park , MD

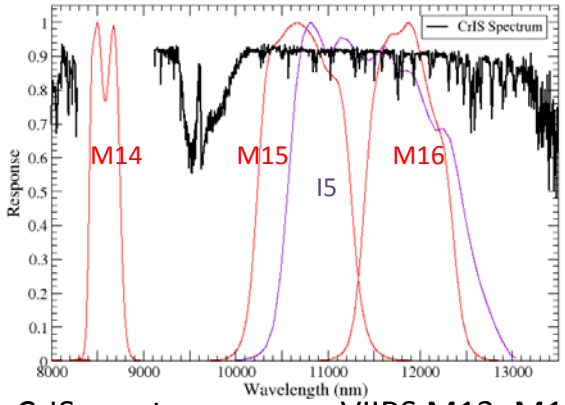
Outline

- VIIRS TEB Performance Status and Issues
  - Radiometric Comparisons
  - Trending
  - Scene Temperature Dependence (C0)
  - OBC Dependence Consistency
  - Mirror Side Dependence
  - Detector Dependence
- Summary

Objective: understand TEB SDR performance

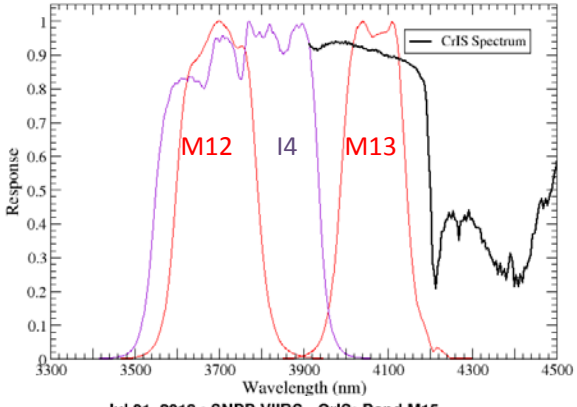
"On-orbit sensor performance characterized and calibration parameters adjusted accordingly".

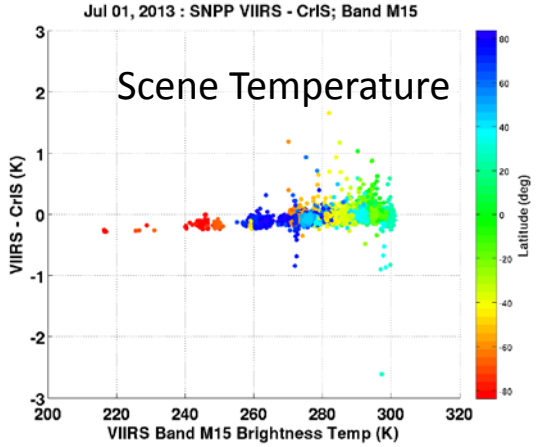
VIIRS-CrIS SDR Comparisons



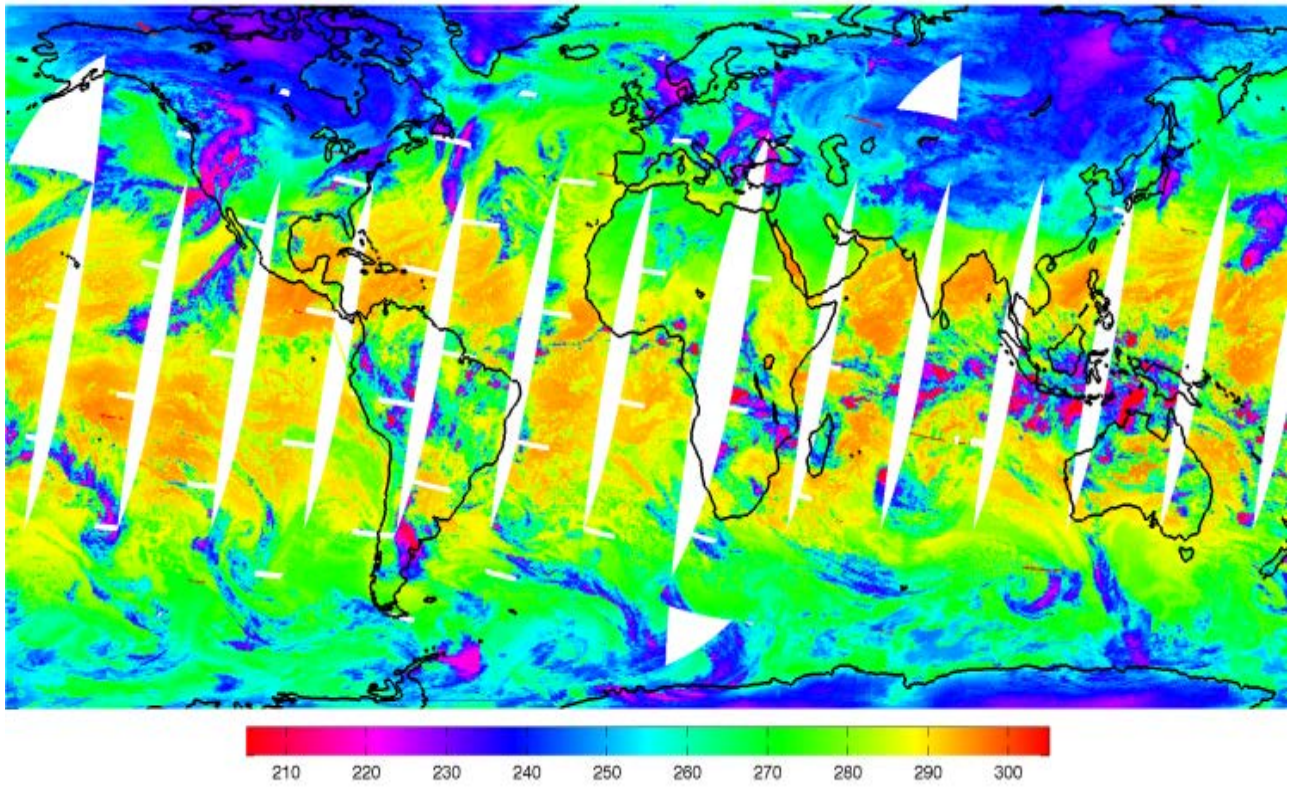
CrIS spectrum covers VIIRS M13, M15, M16, and I5 but does not include OOB response in M15 and M16

- VIIRS SDR accuracy/stability plus RVS performance
- Global; 2.9 million matchups daily from SNPP platform
- Cross Track coverage
- In-band spectral radiance for M13, M15, M16 and I5
- Long term high quality data record to assess stability



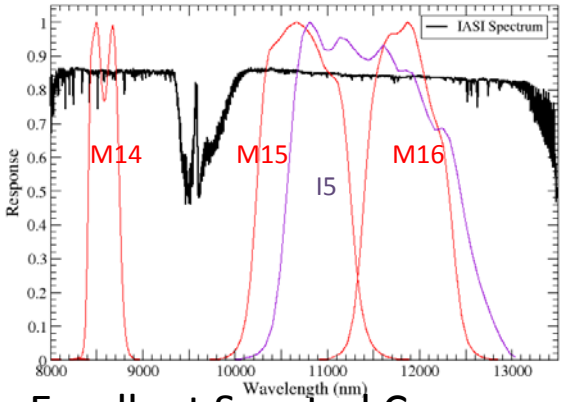


CrIS convolved with VIIRS SRF **VIIRS mean within CrIS FOVs**

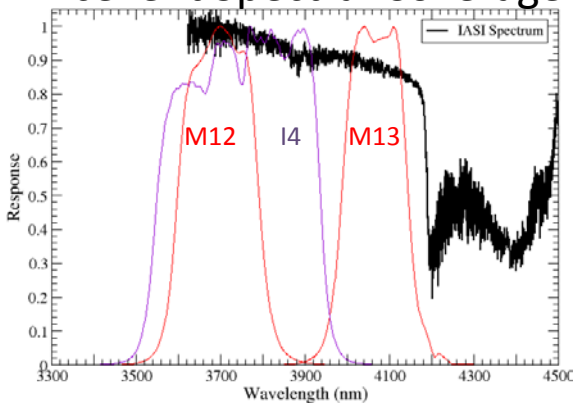


VIIRS-IASI SDR Comparisons

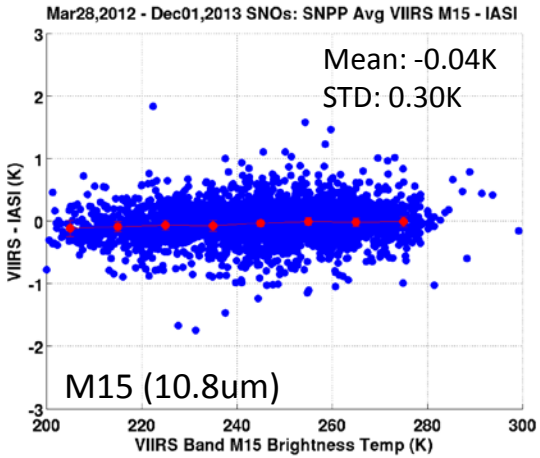
- Evaluate VIIRS SDR accuracy and OOB impact
- High latitude SNOs; limited data sample
- All FOVs inside 50 km radius around each SNO are retained:14-16 IASI FOVs and >10,000 VIIRS 750m FOVs
- 10 minute tolerance on SNO occurrence
- IASI spectral coverage of VIIRS M13-M16, I5; nearly complete spectral coverage of M12 (85%) and I4 (81%)



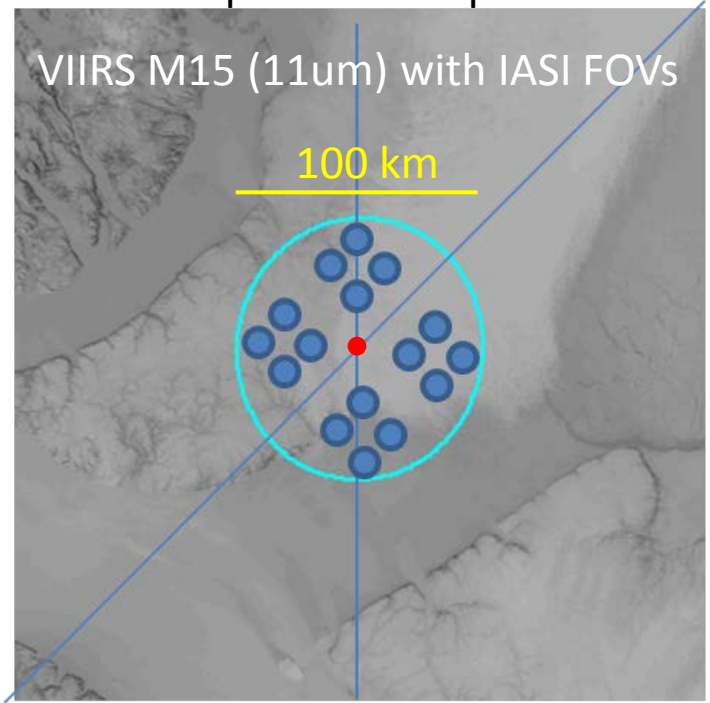
Excellent Spectral Coverage



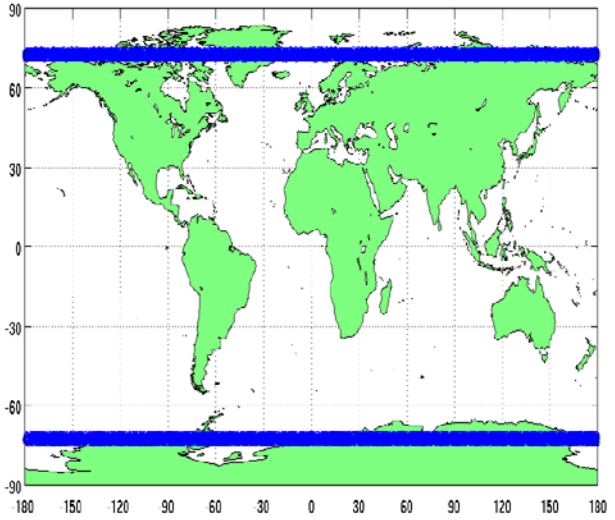
Difference as a function of scene temperature



+/-10 minute tolerance on overpass of SNO point

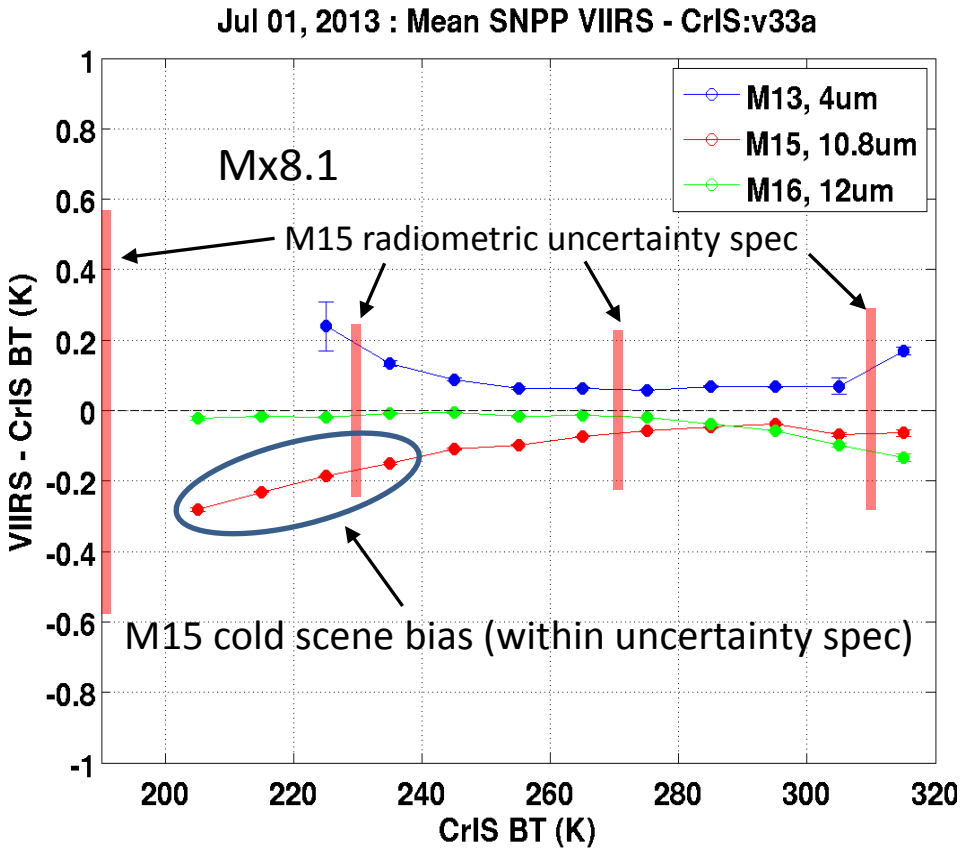


S-NPP/MetOp-A SNOs occur exclusively at polar latitudes

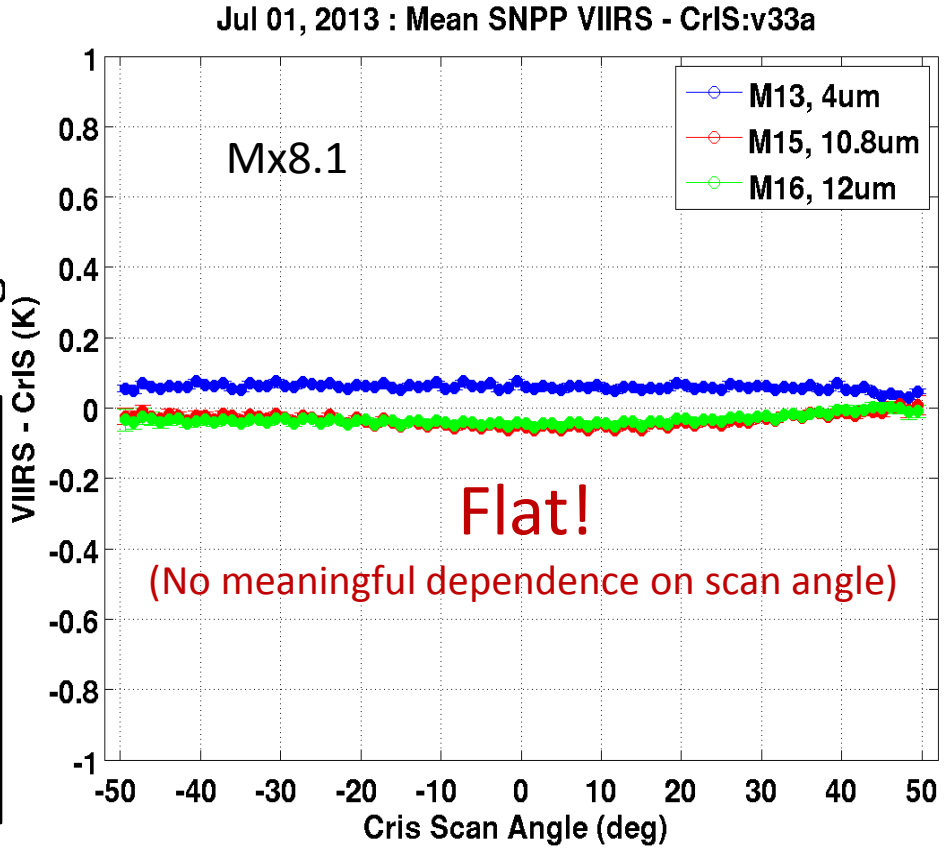


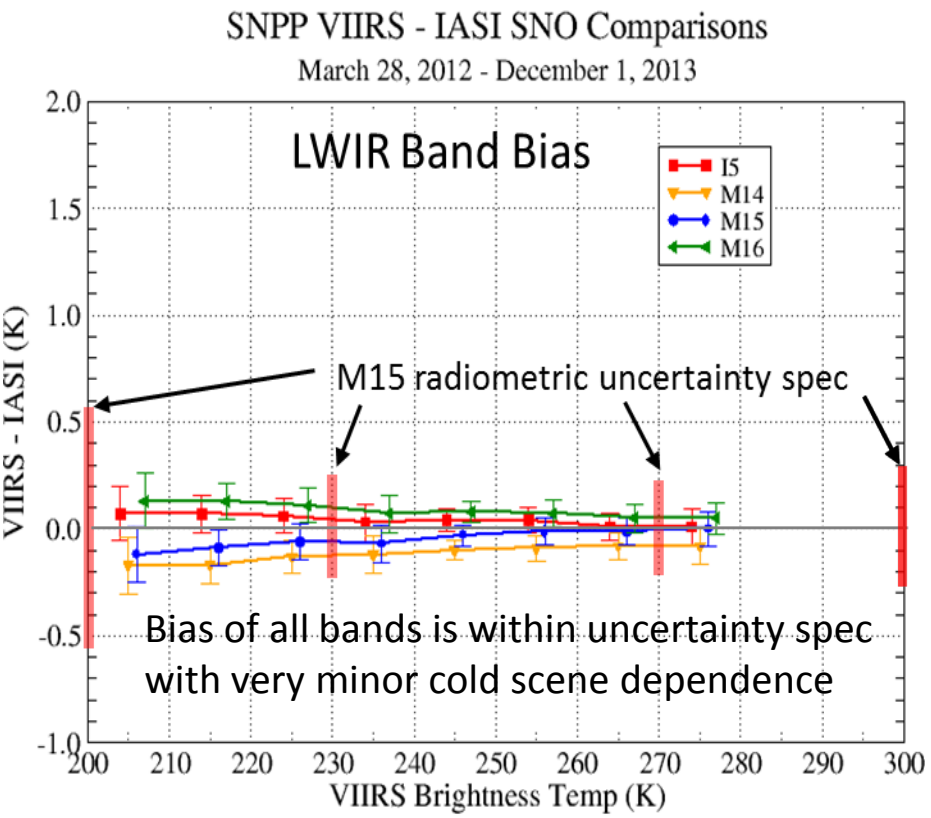
VIIRS-CrIS (Mx8.1)

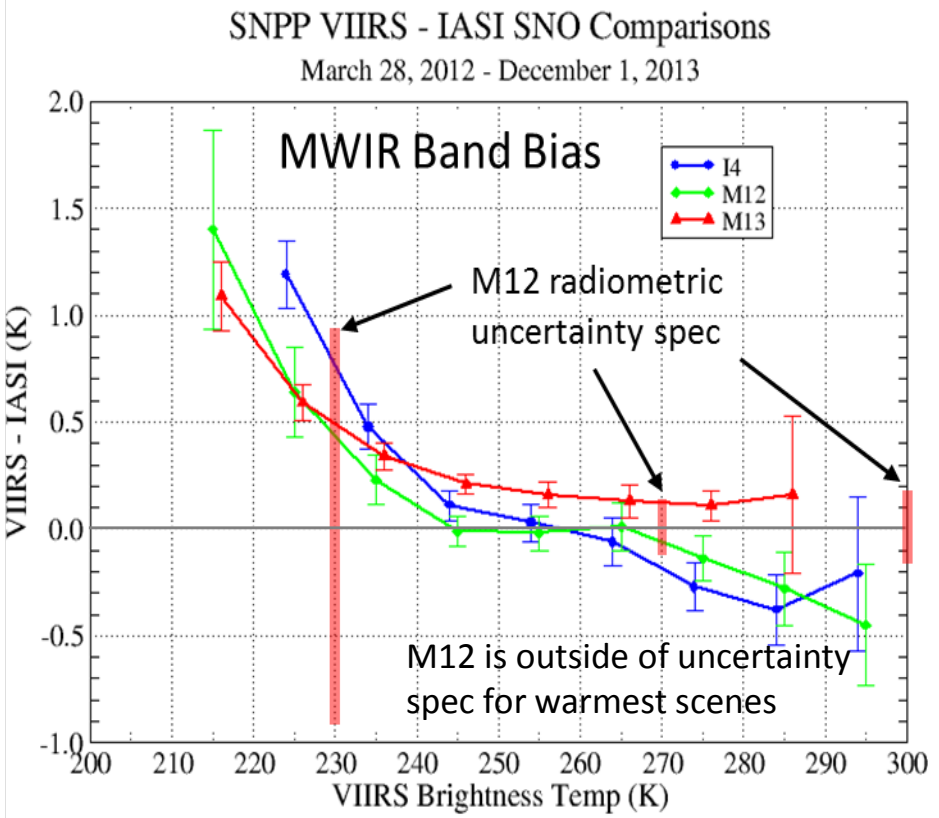
- Scene temperature provides insight on calibration coefficient performance.
- Scan angle provides insight on HAM RVS characterization quality.
- Data shown for July 1, 2013 is typical of all days. CrIS calibration Mx8.1.

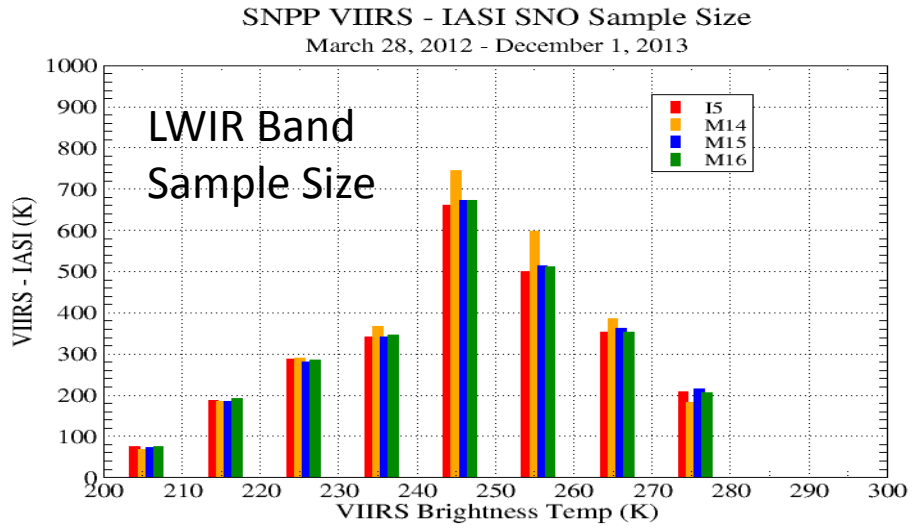


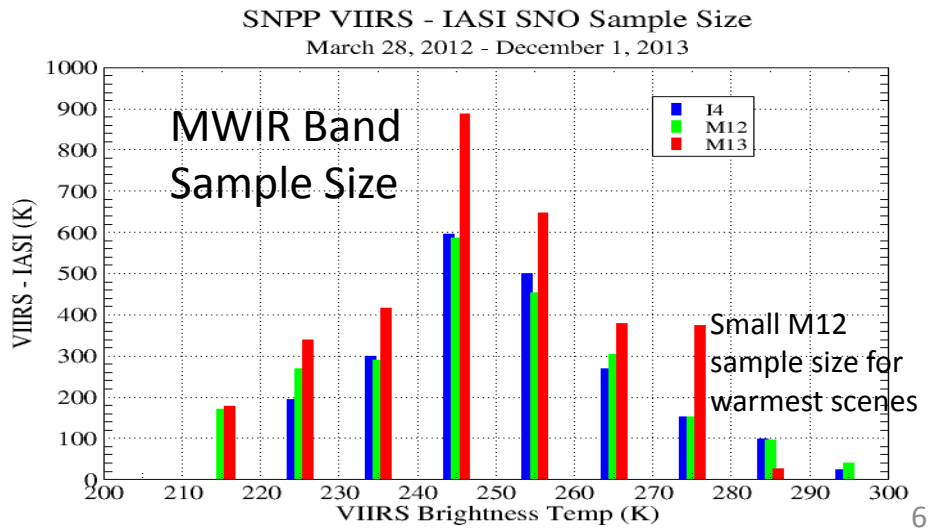
- M15 bias (above) has <u>minor cold scene dependence</u>, less so for M13. Suggests that C_0 coefficient may not be optimally set. Note: this dependence has been reduced by Mx8.1 CrIS calibration.
- Minimal dependence of bias on scan angle (right). <u>TEB RVS well characterized</u>.




SNPP VIIRS - IASI SNO Comparisons
March 28, 2012 - December 1, 2013
LWIR Band Bias
I5
M14
M15
M16
M15 radiometric uncertainty spec
Bias of all bands is within uncertainty spec
with very minor cold scene dependence
VIIRS - IASI (K)
VIIRS Brightness Temp (K)

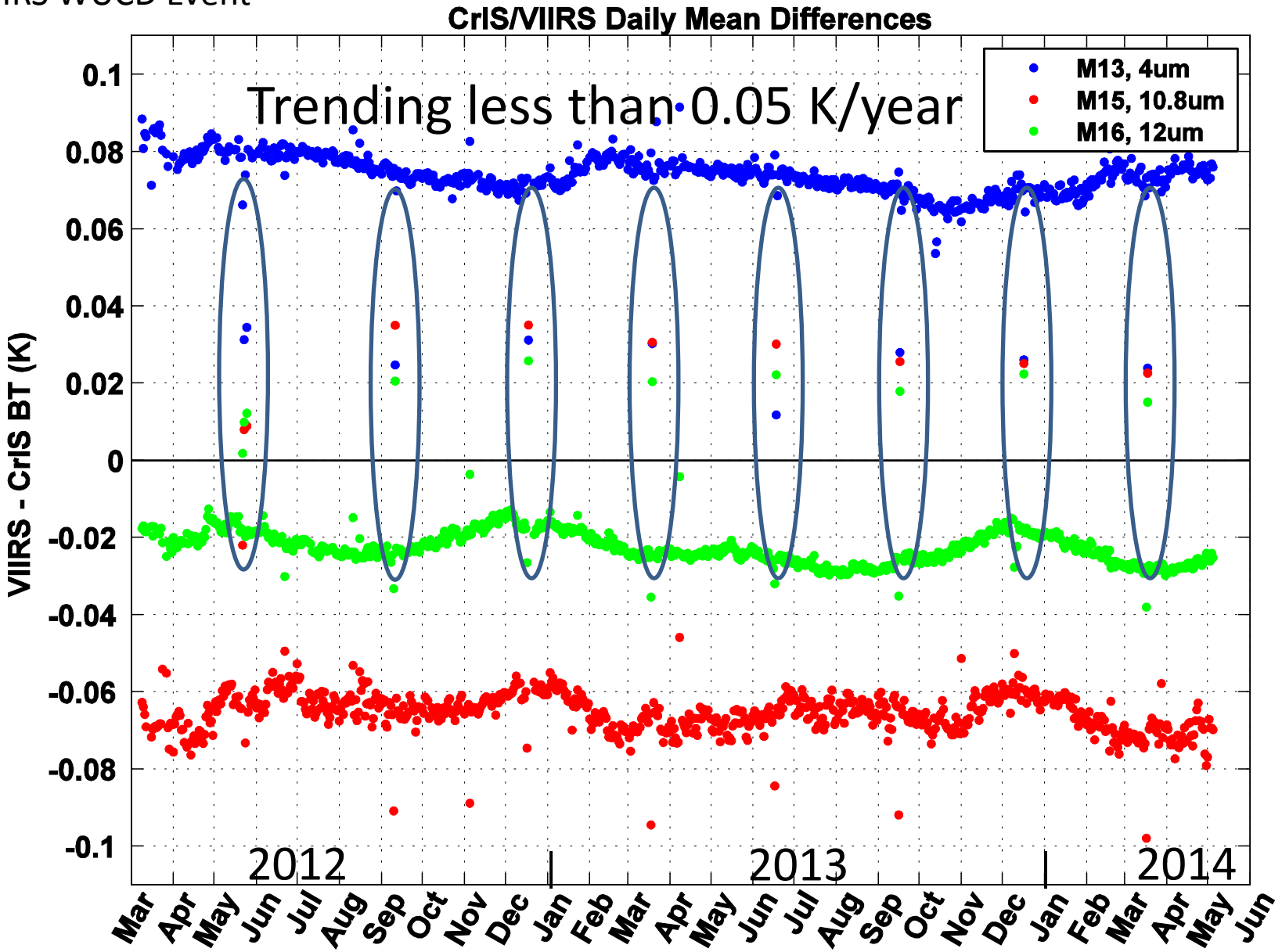

SNPP VIIRS - IASI SNO Comparisons
March 28, 2012 - December 1, 2013
MWIR Band Bias
I4
M12
M13
M12 radiometric
uncertainty spec
M12 is outside of uncertainty
spec for warmest scenes
VIIRS - IASI (K)
VIIRS Brightness Temp (K)

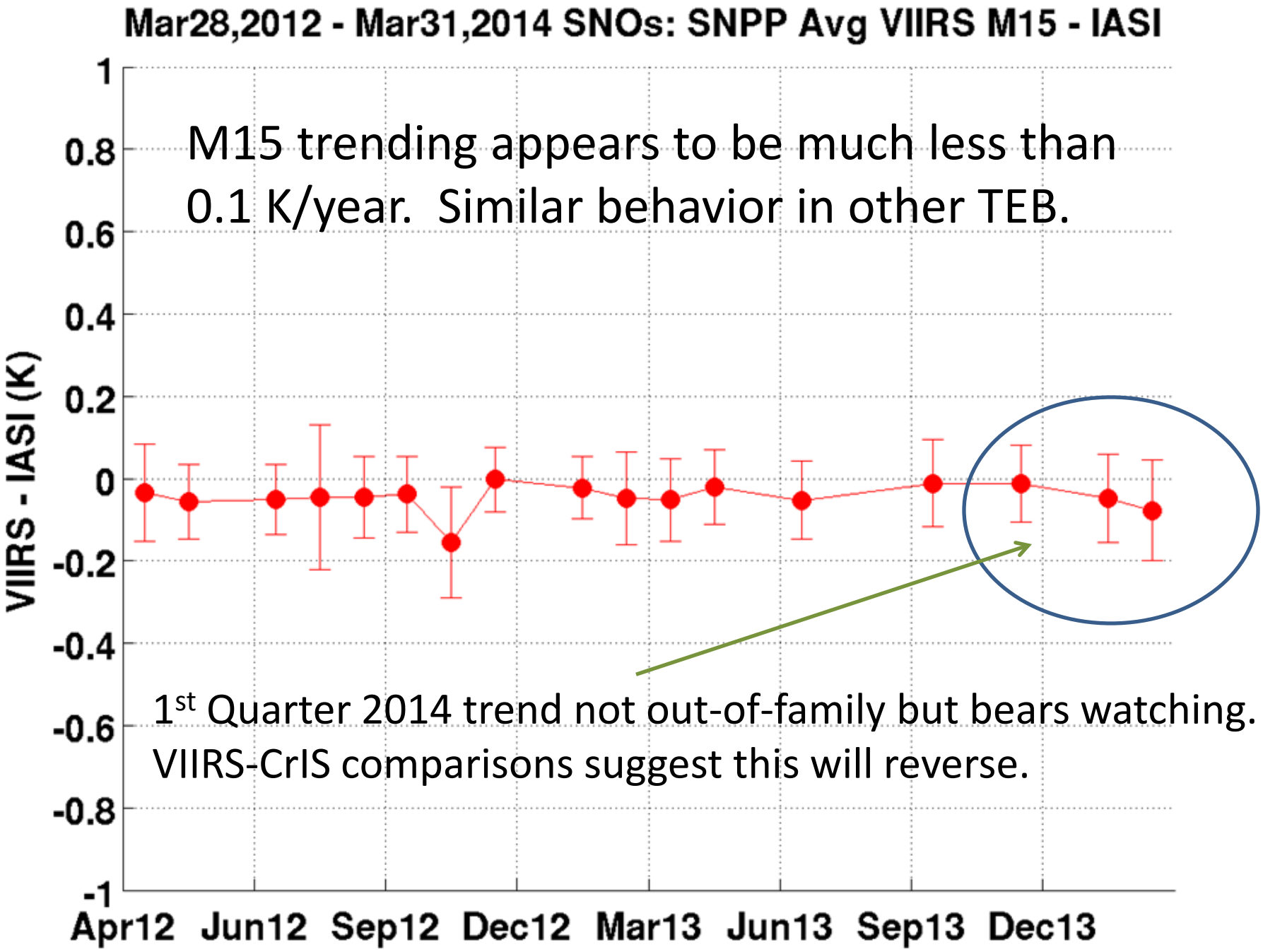

SNPP VIIRS - IASI SNO Sample Size
March 28, 2012 - December 1, 2013
LWIR Band
Sample Size
I5
M14
M15
M16
VIIRS - IASI (K)
VIIRS Brightness Temp (K)


SNPP VIIRS - IASI SNO Sample Size
March 28, 2012 - December 1, 2013
MWIR Band
Sample Size
I4
M12
M13
Small M12
sample size for
warmest scenes
VIIRS - IASI (K)
VIIRS Brightness Temp (K)

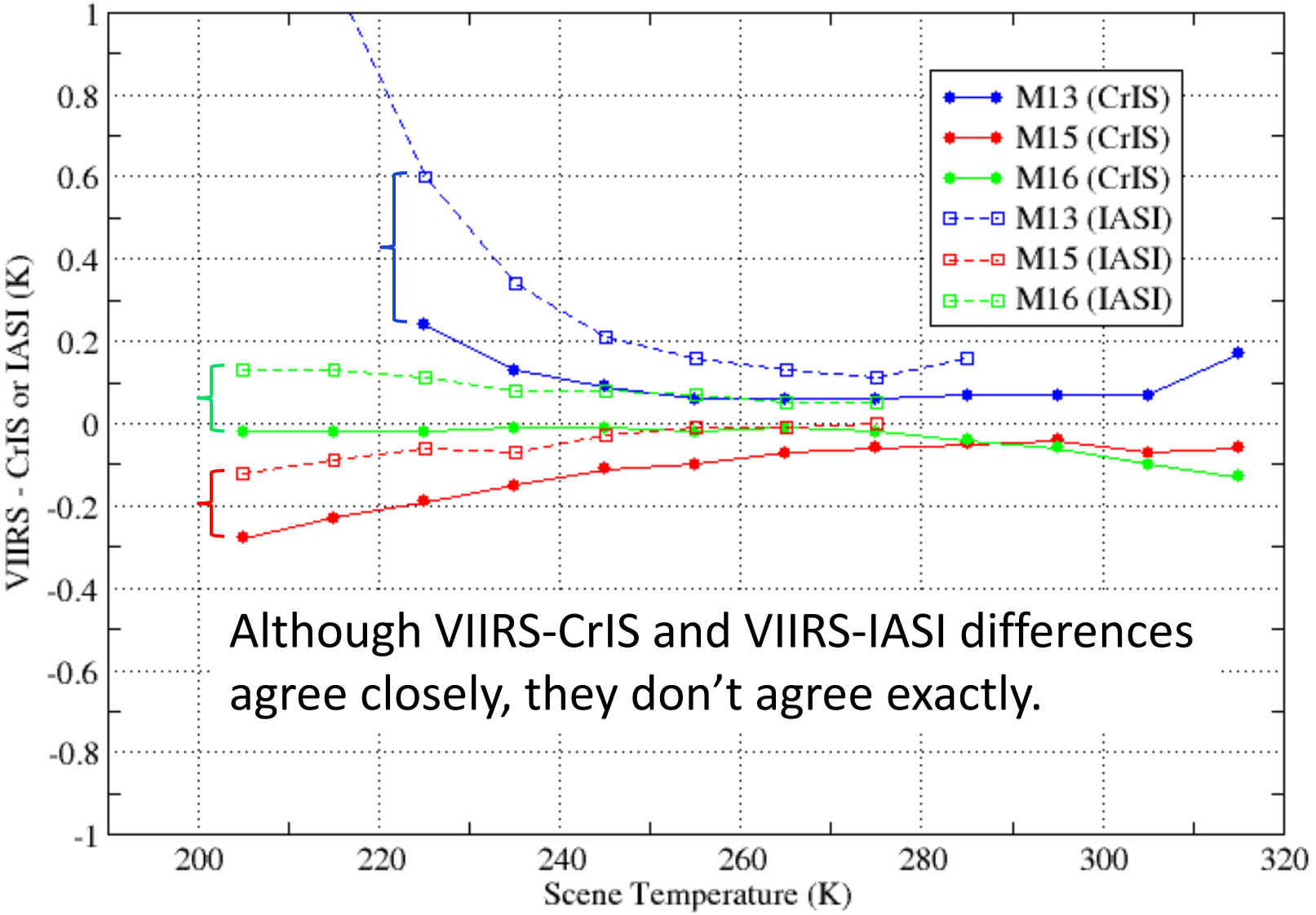
VIIRS-CrIS SDR Comparisons

VIIRS WUCD Event




Mar28,2012 - Mar31,2014 SNOs: SNPP Avg VIIRS M15 - IASI
VIIRS - IASI (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Apr12
Jun12
Sep12
Dec12
Mar13
Jun13
Sep13
Dec13
M15 trending appears to be much less than 0.1 K/year. Similar behavior in other TEB.
1st Quarter 2014 trend not out-of-family but bears watching.
VIIRS-CrIS comparisons suggest this will reverse.

SNPP VIIRS SDR Comparisons to CrIS and IASI



Although VIIRS-CrIS and VIIRS-IASI differences agree closely, they don't agree exactly.

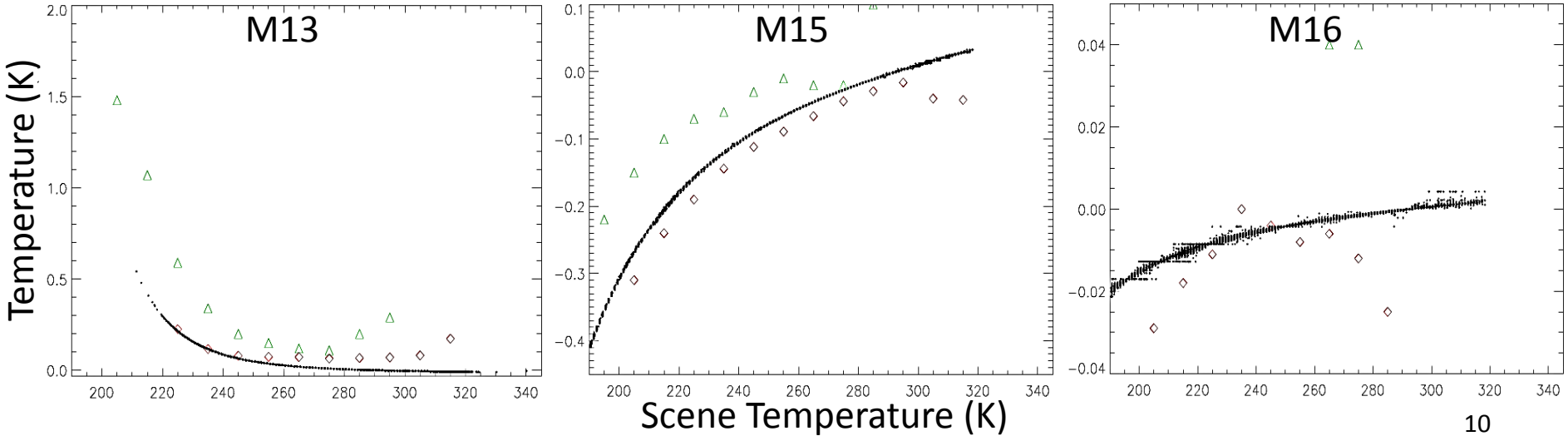
VIIRS C_0 Calibration Coefficient Modification

- Modify the VIIRS TEB delta C LUT to change the VIIRS cold brightness temperatures to better match CrIS and IASI on-orbit cold scene performance (brightness temperature).
- Preserves VIIRS detector-to-detector, HAM side and temperature relative "shape" in prelaunch tables.
- Latest testing uses CrIS calibration planned for Mx8.1.
- ADR-7414: TEB calibration coefficient C0 requires modification to … improve radiometric accuracy.

Residual Background Emission

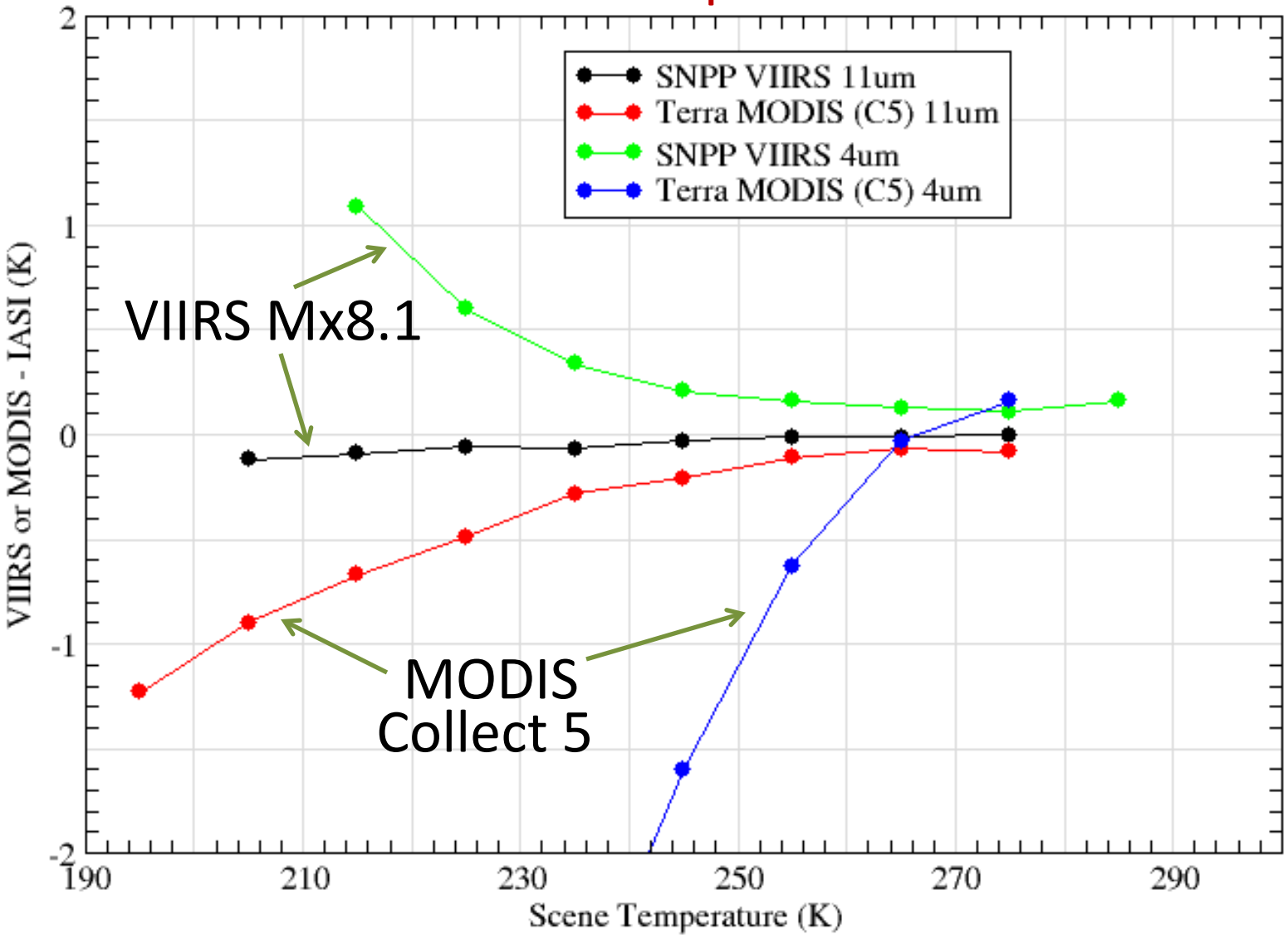
Calculated Radiance

$$L_{ap}(RVS_{EV}) = \frac{(RVS_{SV} - \mathrm{RVS}_{EV}) \cdot \left[\frac{(1-\rho_{rta}) \cdot L(T_{rta}) - L(T_{ham})}{\rho_{rta}} \right] + F \cdot \left(c_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^{\ 2} \right)}{\mathrm{RVS}_{EV}}$$



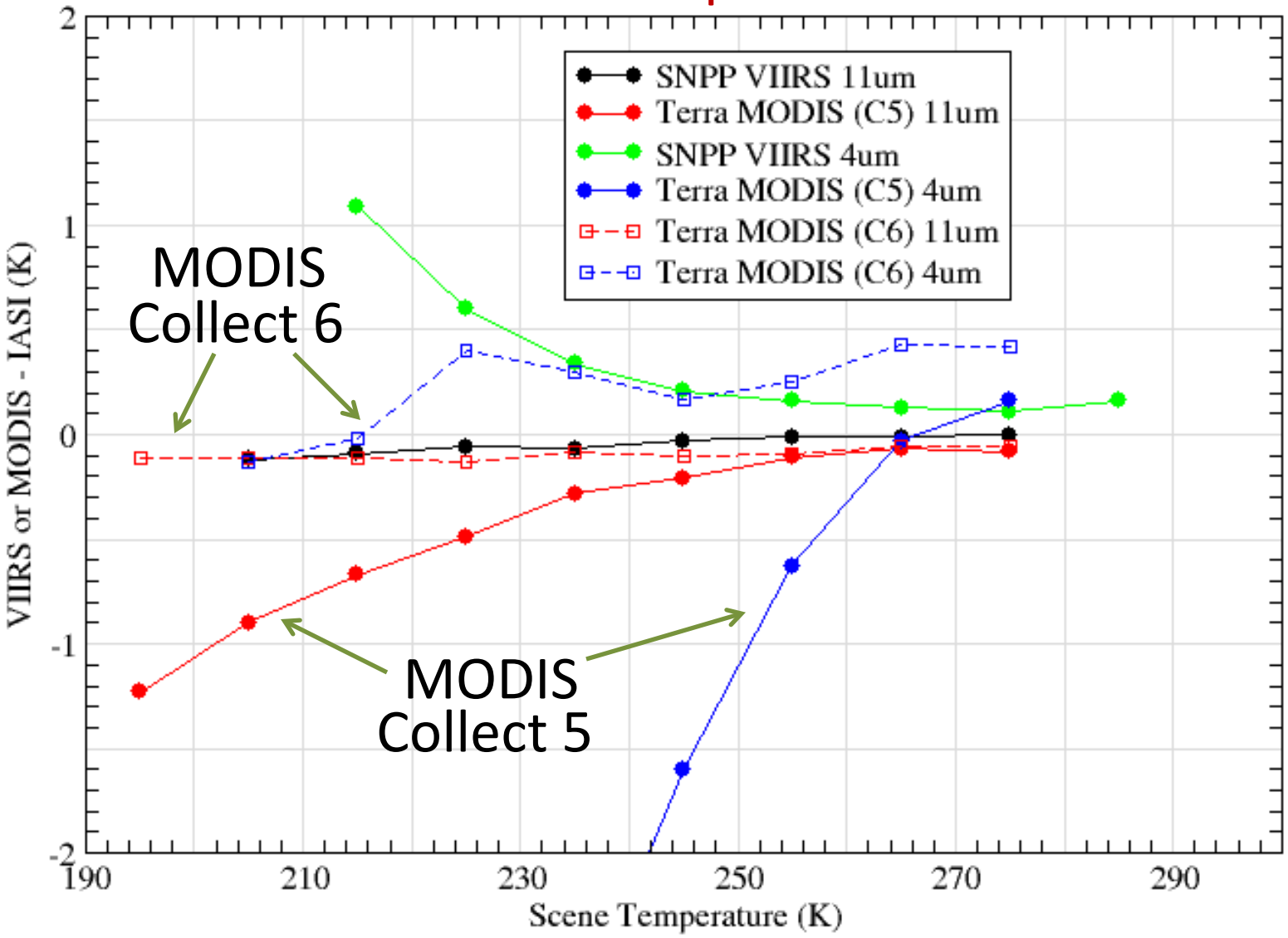
MODIS and VIIRS TEB Comparisons to IASI

Some Perspective!

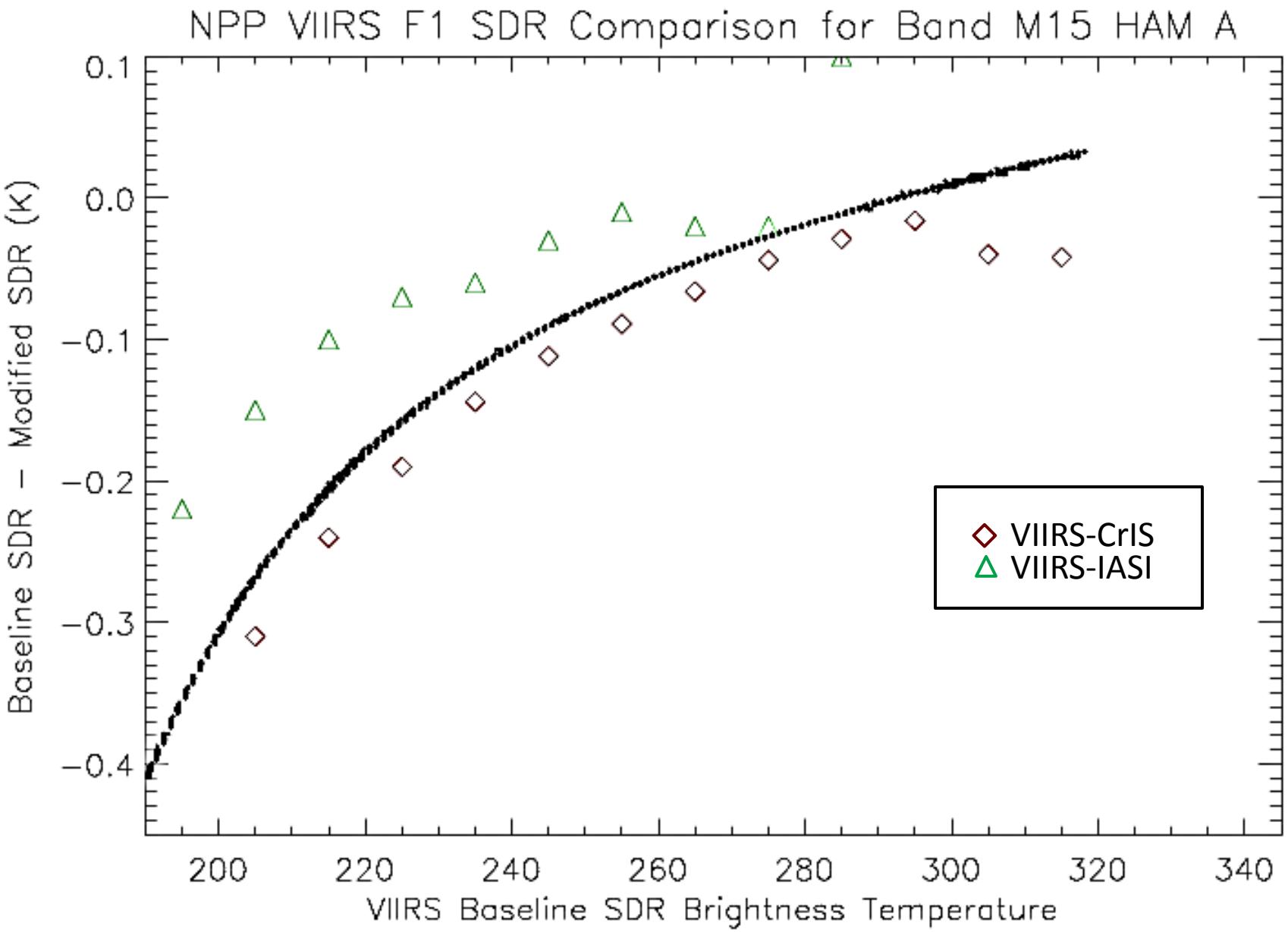


MODIS and VIIRS TEB Comparisons to IASI

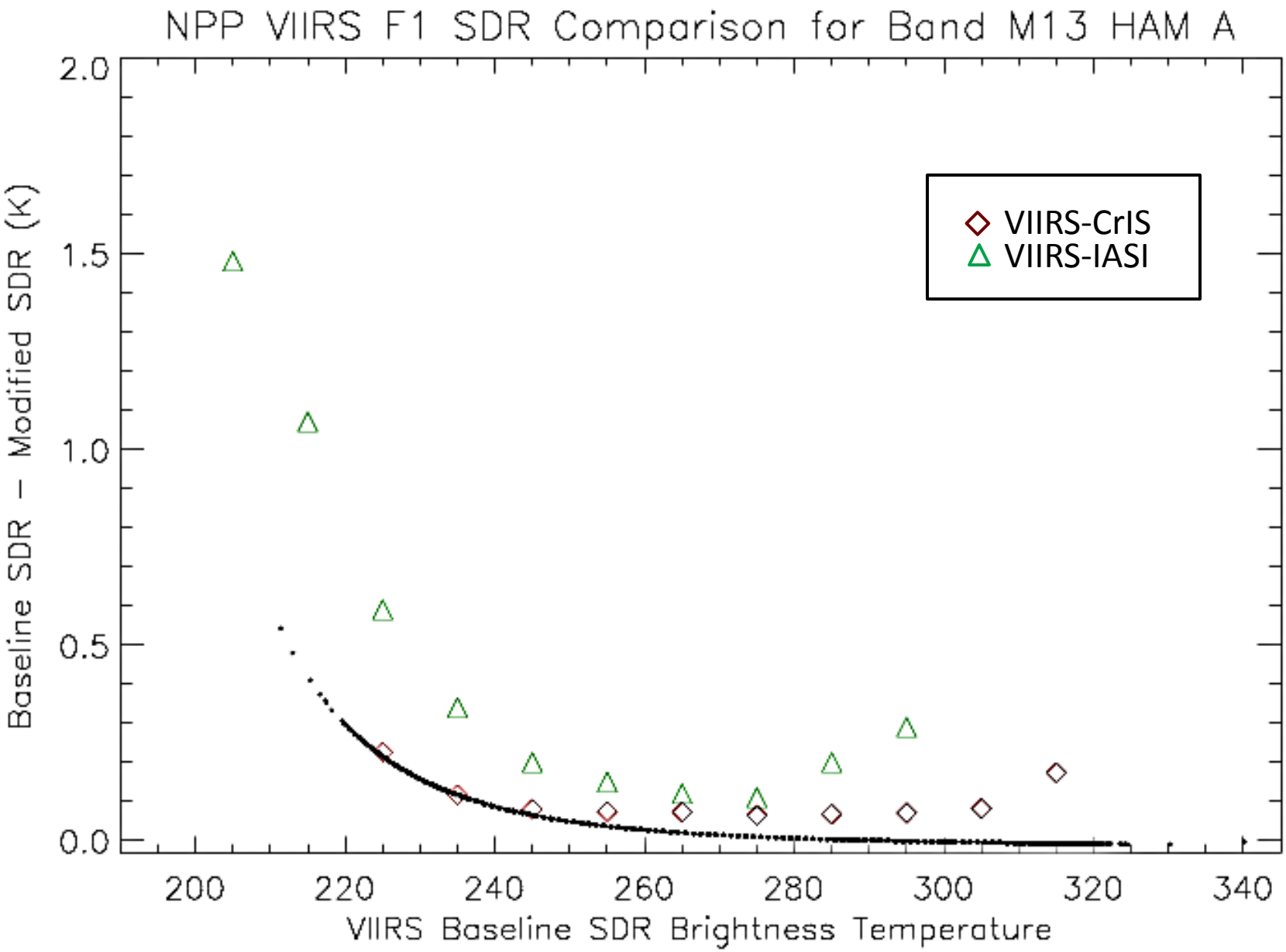
Some Perspective!



VIIRS C_0 Calibration Coefficient Modification



VIIRS C_0 Calibration Coefficient Modification

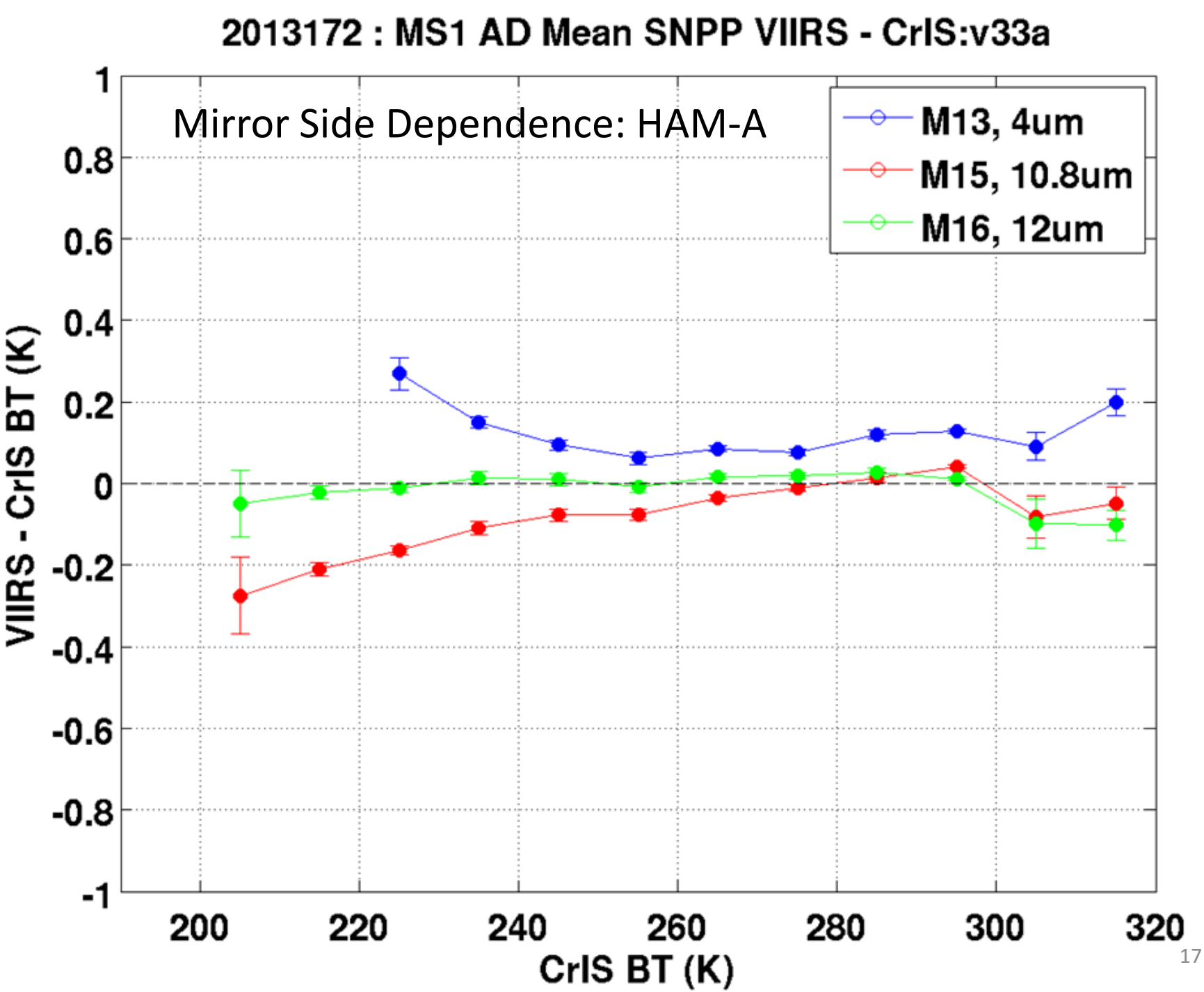


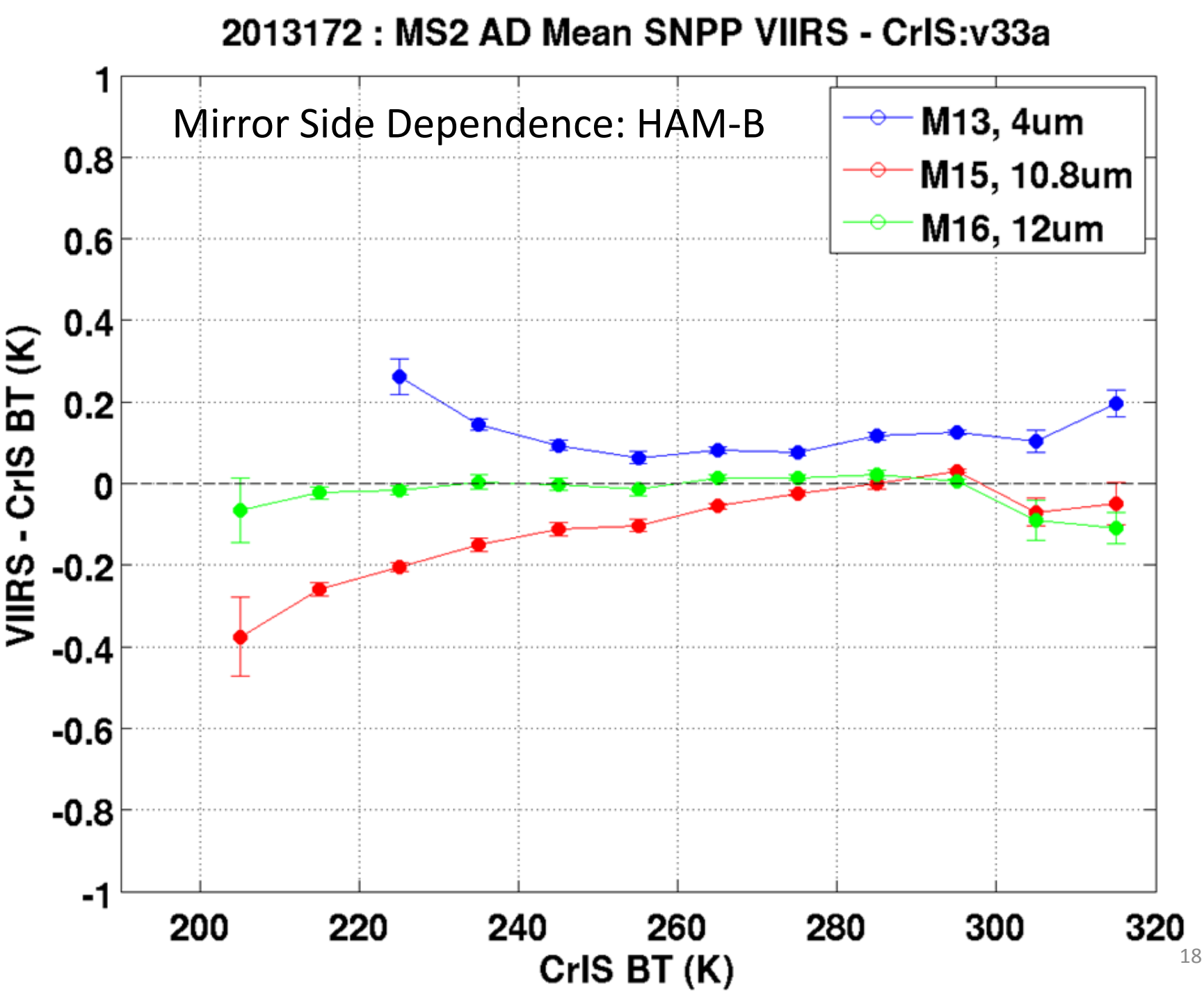
Considerations on C0 Adjustment

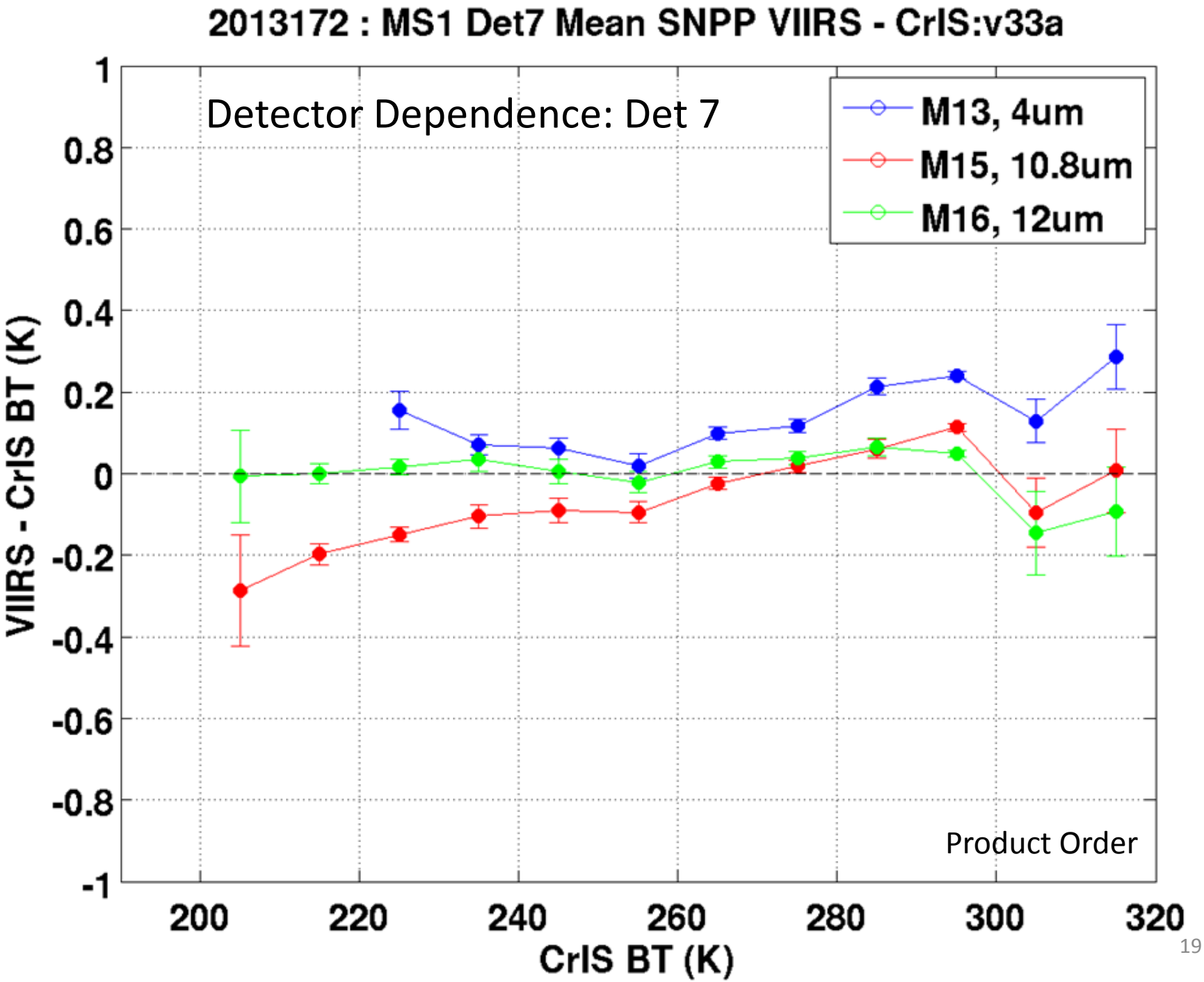
- CrIS, AIRS, Metop-A IASI and Metop-B IASI are all well calibrated systems. But they disagree at cold scenes by ~0.1 – 0.2 K in LWIR and more so in MWIR. Which is “truth”?
- VIIRS currently about as good as C6 MODIS 11um
- 0.25 K accuracy is well within VIIRS specification for LWIR cold scenes.
- On the other hand…..
  - M15 and M16 are commonly used together in science algorithms; consistent relative performance between M15 and M16 would seem beneficial.

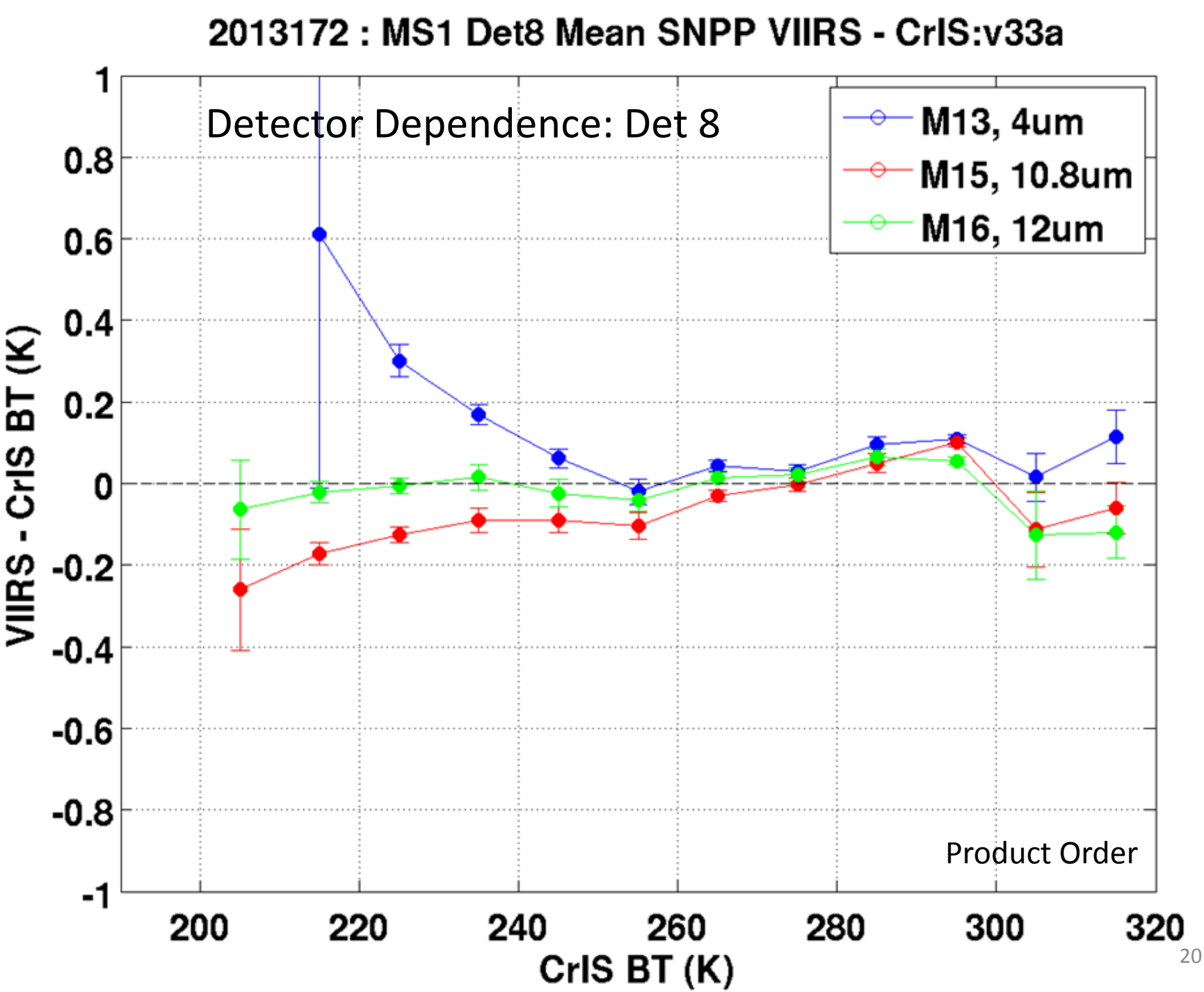
Mirror Side and Detector Striping

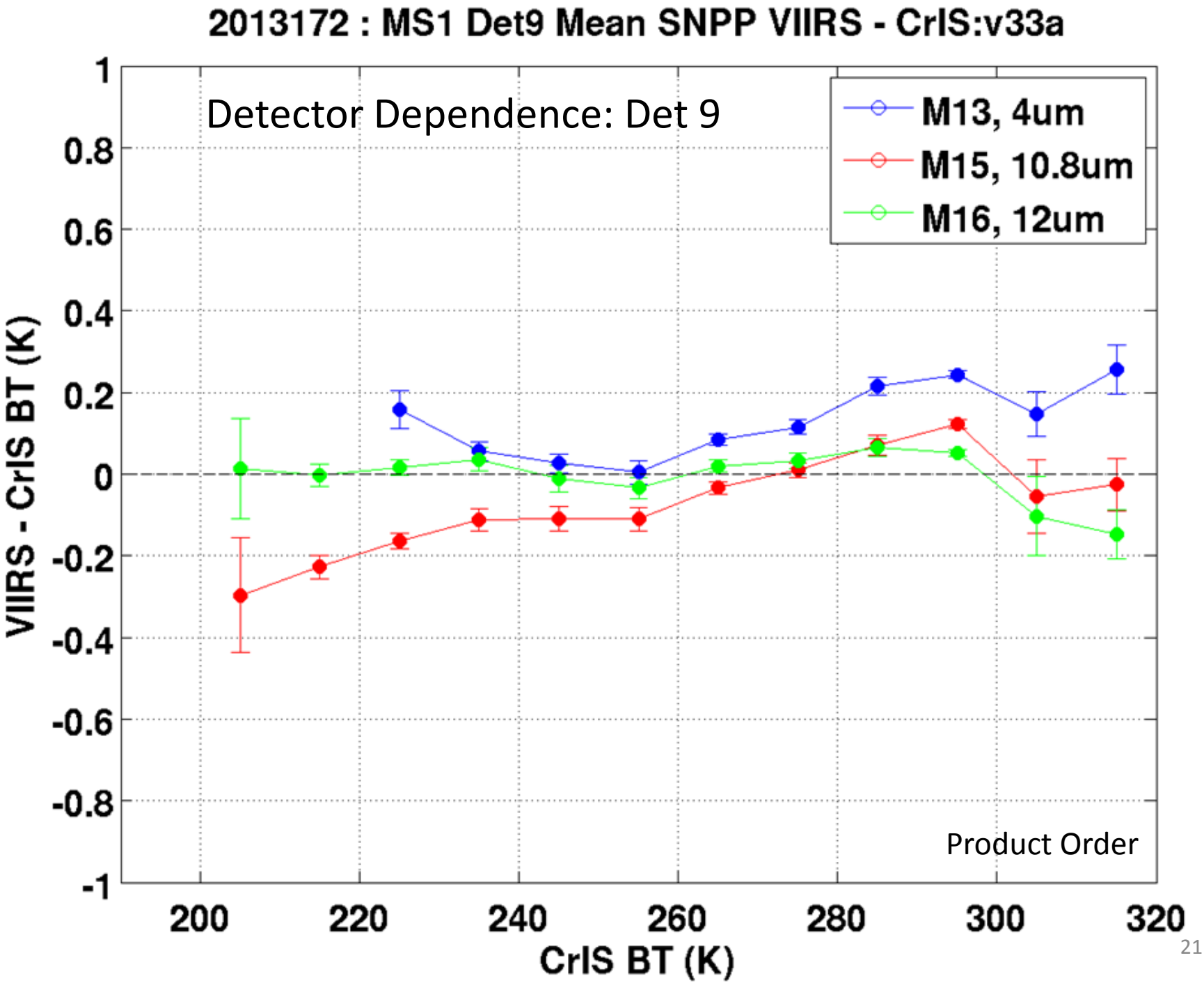
- Using VIIRS-CrIS global day comparisons, stratify the data by mirror side and detector.
- Reveals information on striping in SDR that may be masked by natural variability.
- M13, M15, and M16 examined (insufficient spectral coverage for M12, M14 by CrIS).
- 4 global days tested; similar result each day:
  - Suggestion of small mirror side effect in M15.
  - M13 has distinct even-odd detector pattern.

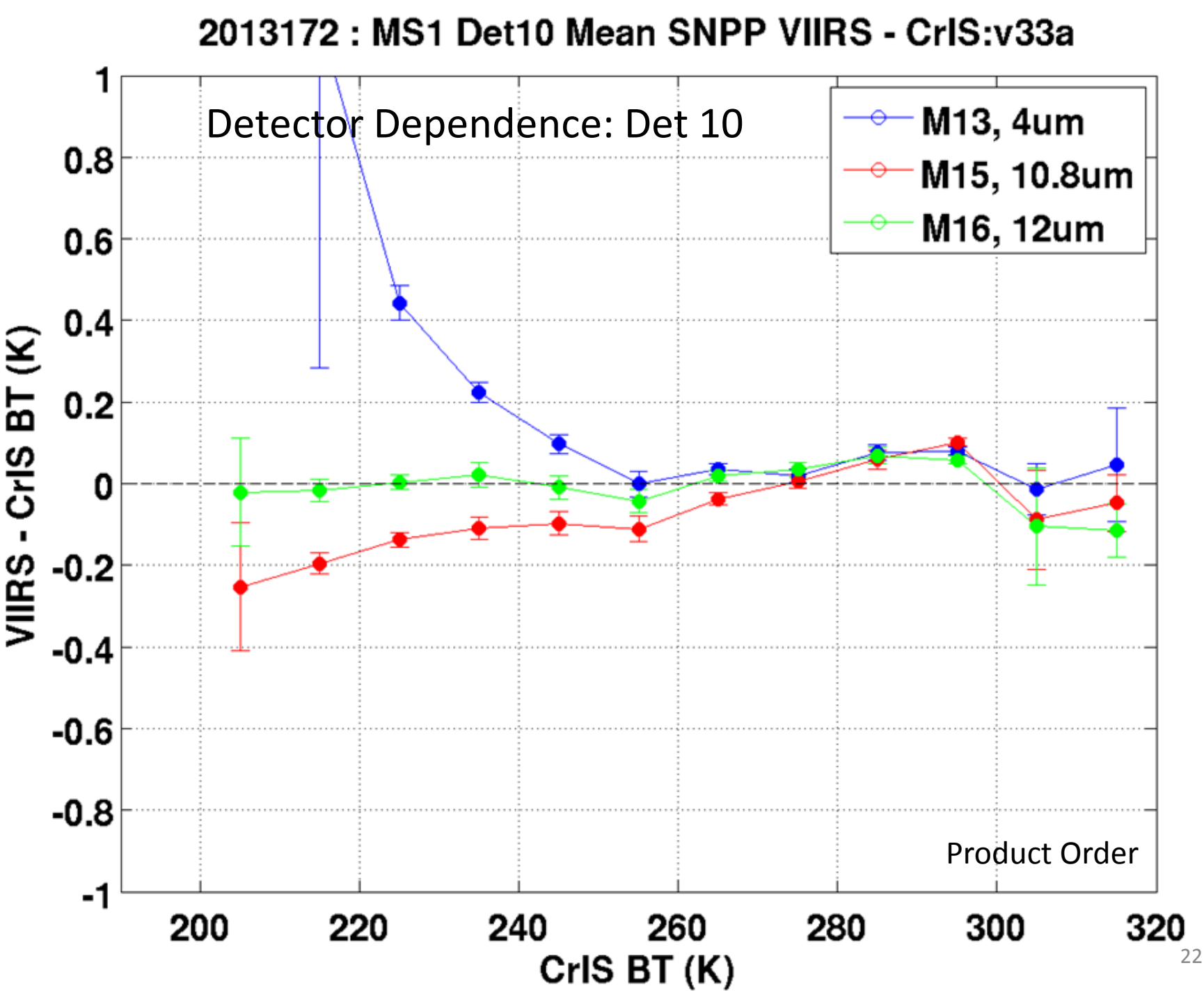

2013172 : MS1 AD Mean SNPP VIIRS - CrIS:v33a
Mirror Side Dependence: HAM-A
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320

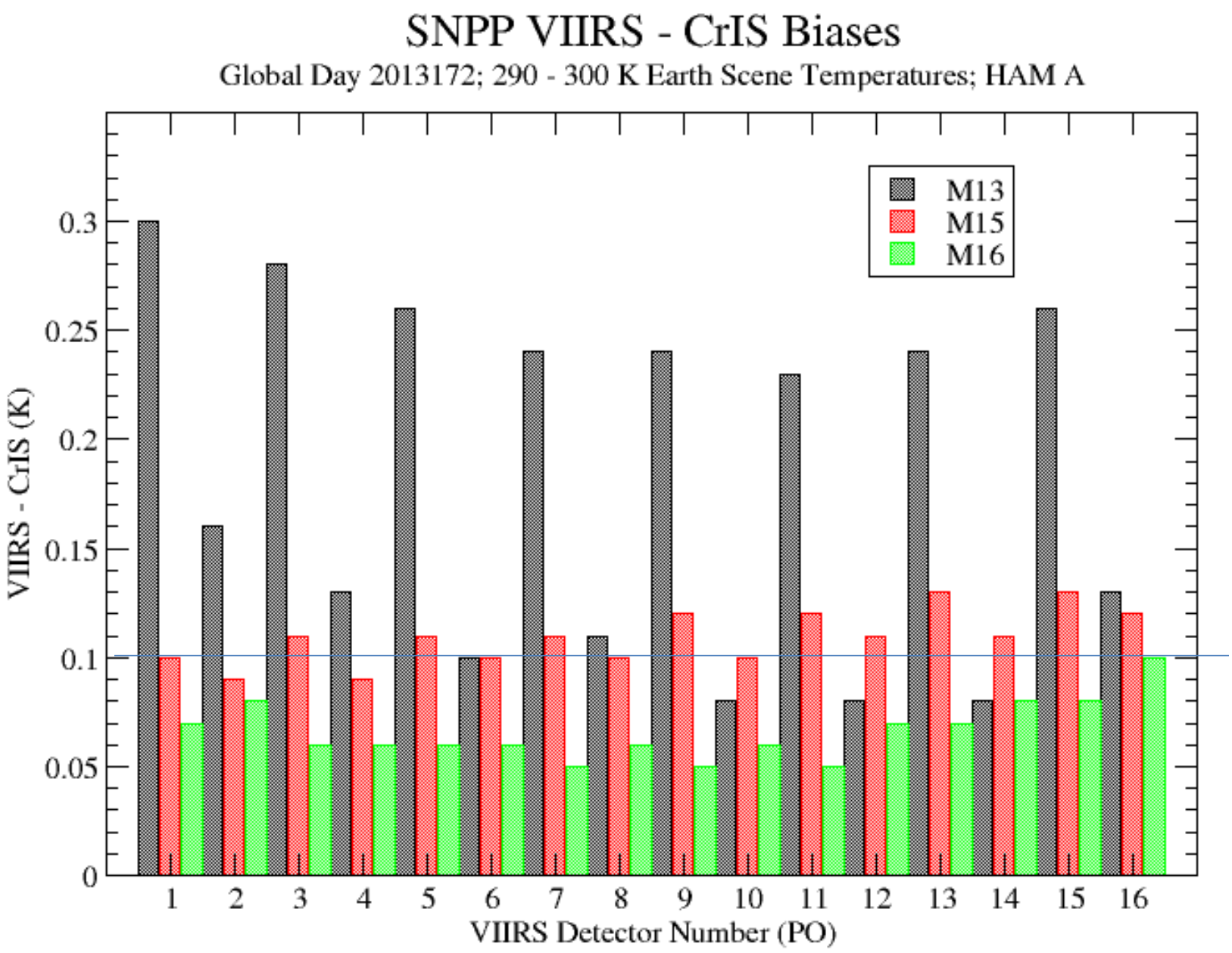

2013172 : MS2 AD Mean SNPP VIIRS - CrIS:v33a
Mirror Side Dependence: HAM-B
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320

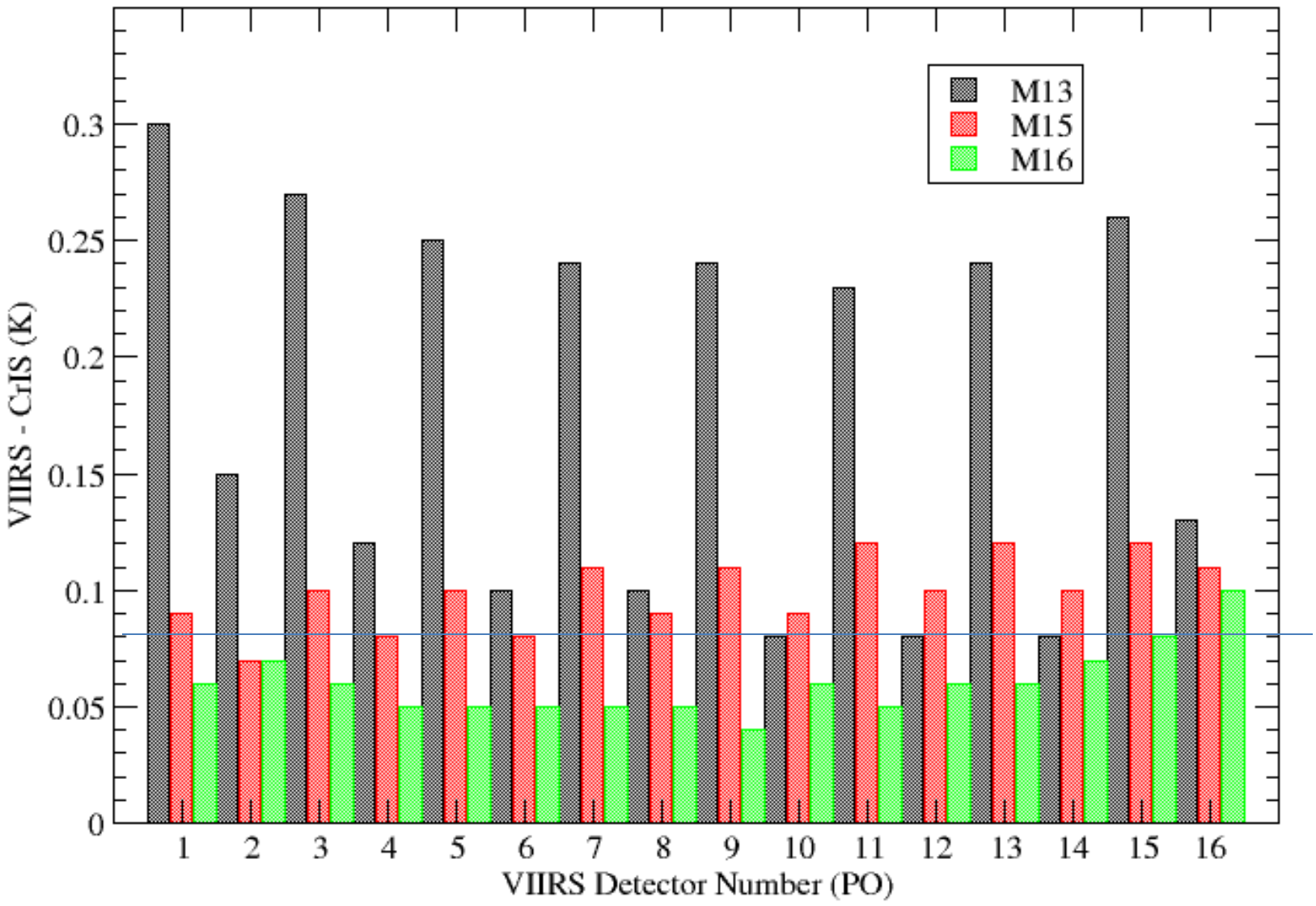

2013172 : MS1 Det7 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 7
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

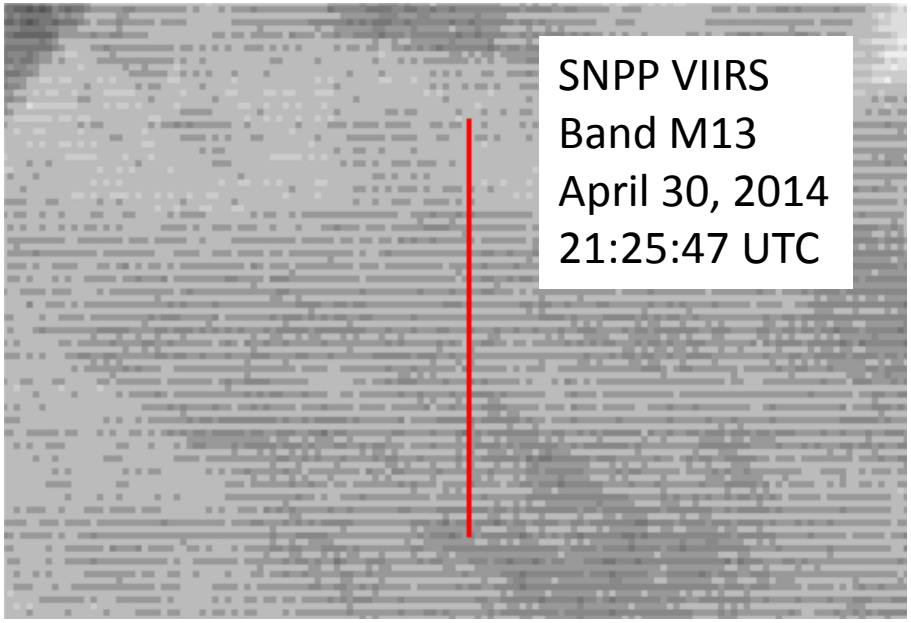

2013172 : MS1 Det8 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 8
M13, 4um
M15, 10.8um
M16, 12um
Product Order
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320

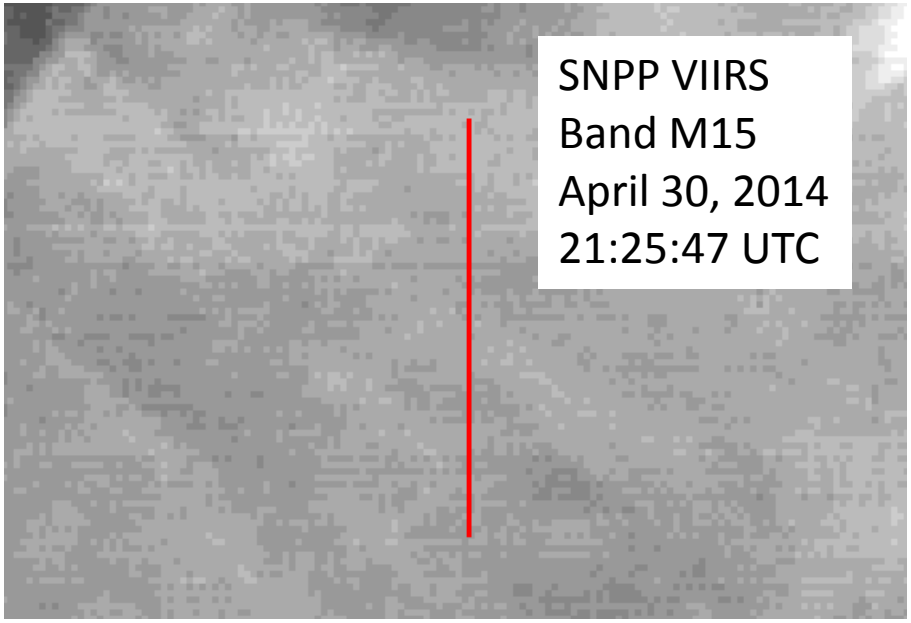

2013172 : MS1 Det9 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 9
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

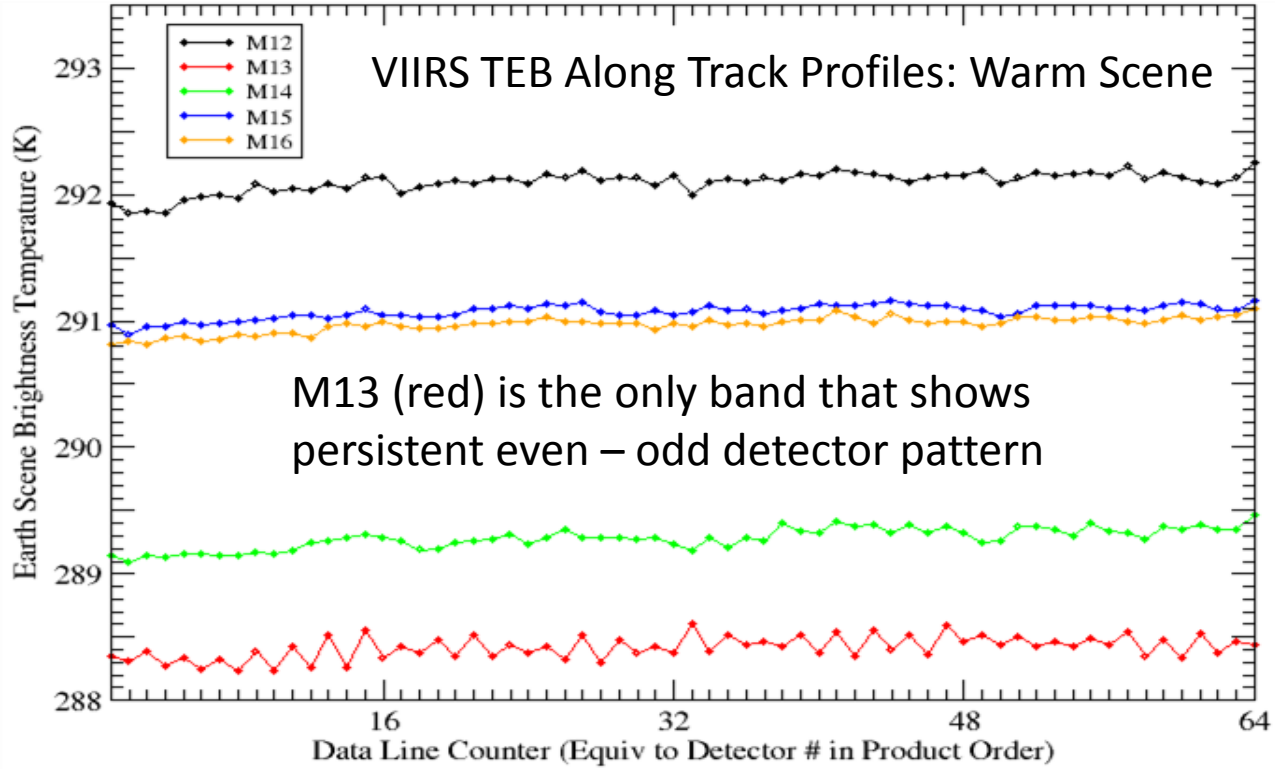

2013172 : MS1 Det10 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 10
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order


SNPP VIIRS - CrIS Biases
Global Day 2013172; 290 - 300 K Earth Scene Temperatures; HAM A
M13
M15
M16
VIIRS - CrIS (K)
0
0.05
0.1
0.15
0.2
0.25
0.3
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
VIIRS Detector Number (PO)


SNPP VIIRS - CrIS Biases
Global Day 2013172; 290 - 300 K Earth Scene Temperatures; HAM B
M13
M15
M16
VIIRS - CrIS (K)
0
0.05
0.1
0.15
0.2
0.25
0.3
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
VIIRS Detector Number (PO)


SNPP VIIRS
Band M13
April 30, 2014
21:25:47 UTC


SNPP VIIRS
Band M15
April 30, 2014
21:25:47 UTC


VIIRS TEB Along Track Profiles: Warm Scene
M12
M13
M14
M15
M16
M13 (red) is the only band that shows
persistent even – odd detector pattern
Earth Scene Brightness Temperature (K)
293
292
291
290
289
288
16
32
48
64
Data Line Counter (Equiv to Detector # in Product Order)

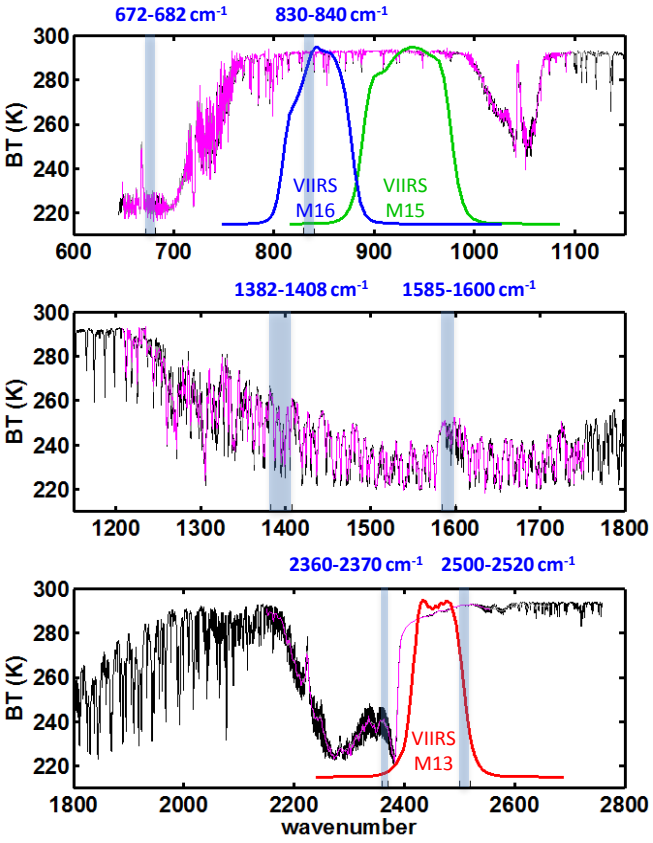
Summary

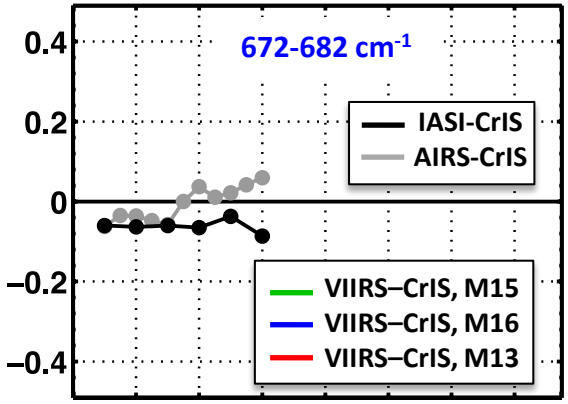
- SNPP VIIRS TEB SDR performing within uncertainty requirements; minimal trends
- Minor adjustment to M15 C0 calibration coefficient will bring M15 and M16 performance closer together, but question on which sensor (AIRS, IASI, CrIS) is “truth”
- Evidence of mirror side striping in M15
- Detector level striping evident in M13 and seems to exist at a very small level in M15 and M16

Backup

Summary of SNO results

for 6 representative spectral regions, and VIIRS/CrIS comparisons:



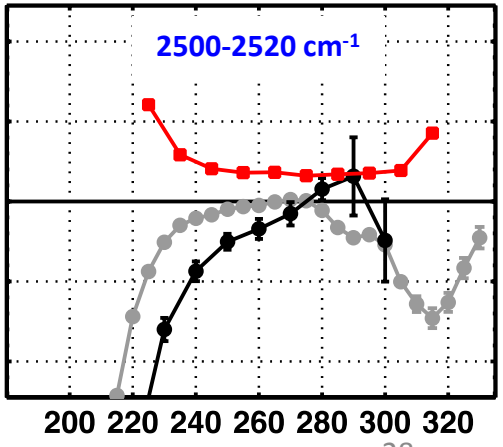


830-840 cm-1

1382-1408 cm-1

1585-1600 cm-1

2360-2370 cm-1

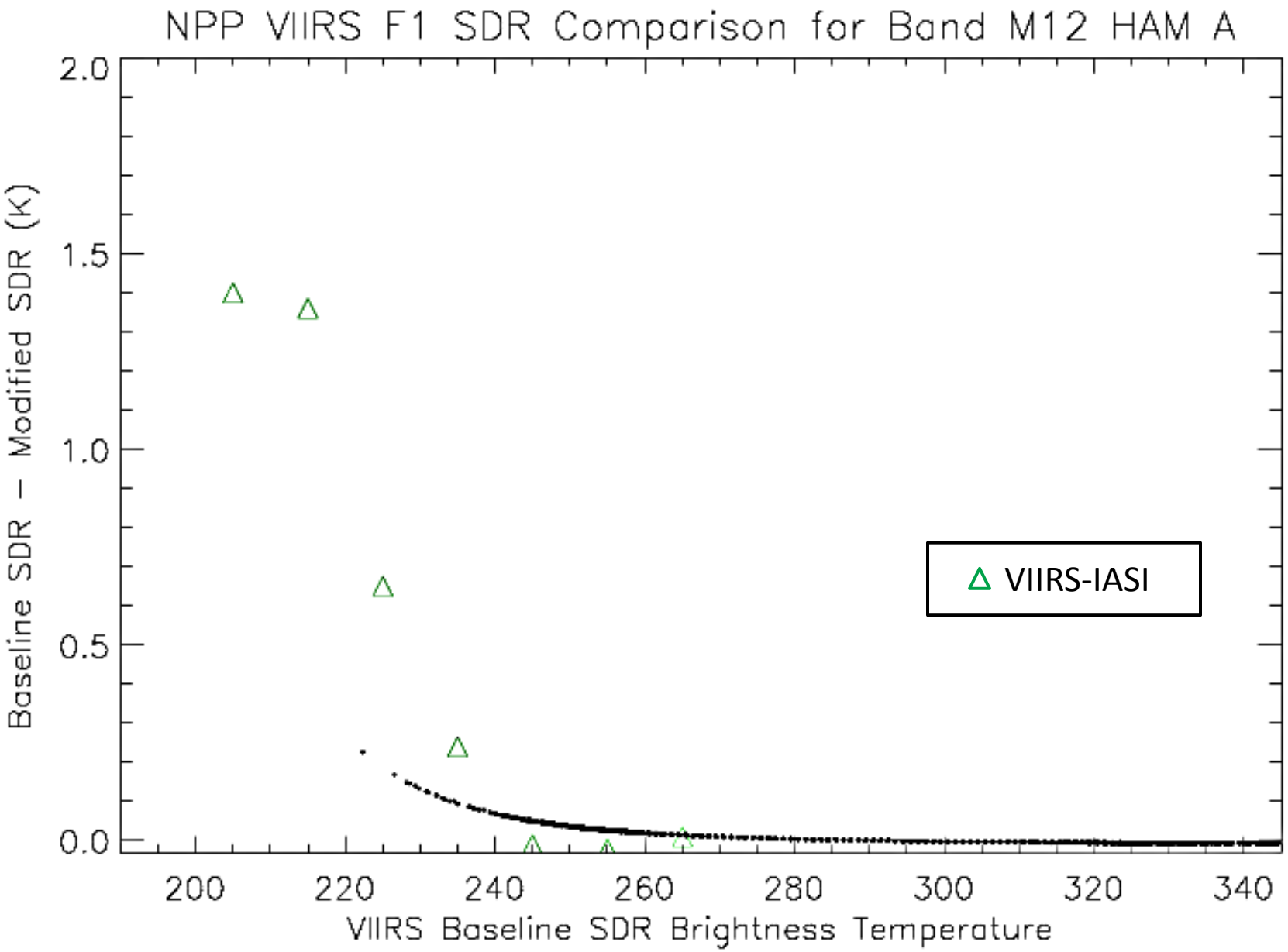


- LW differences display only small dependence on scene BT for both IASI and AIRS SNOs.
- MW differences are relatively independent of scene BT for IASI and for AIRS at 1382-1408 cm^{-1}; Differences for AIRS at 1585-1600 cm^{-1} range from ~+0.3K at 200K to -0.1K at 265K.
- SW differences are relatively flat above ~240K; Below ~230K larger differences between all three sensors are observed.
- Consistent with SNO results shown in L. Strow presentation, and reported by L. Wang et al. at NOAA STAR.

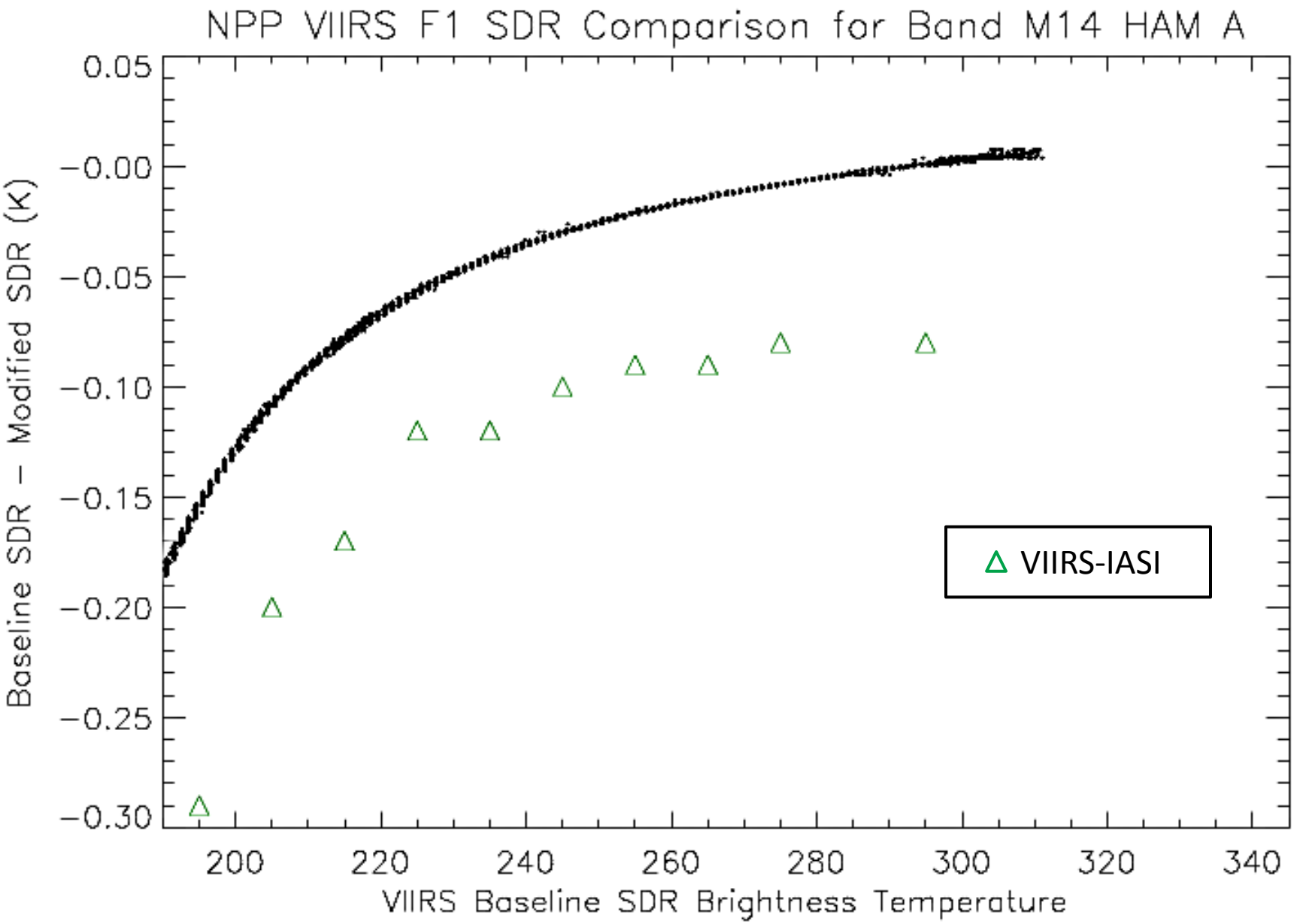
VIIRS C_0 Calibration Coefficient Modification

- ADR7414: TEB calibration coefficient c0 requires modification to reduce striping and improve radiometric accuracy at low scene temperatures
- The zero-th order calibration coefficient c0
  - introduced as an ad hoc parameter…compensating for errors in other retrieval equation parameters or…in the radiometric model.
  - can reduce discrepancies between VIIRS and CrIS and between VIIRS and IASI at low scene temperatures…, and reduce striping in the TEB SDR that is evident in cold uniform scenes.

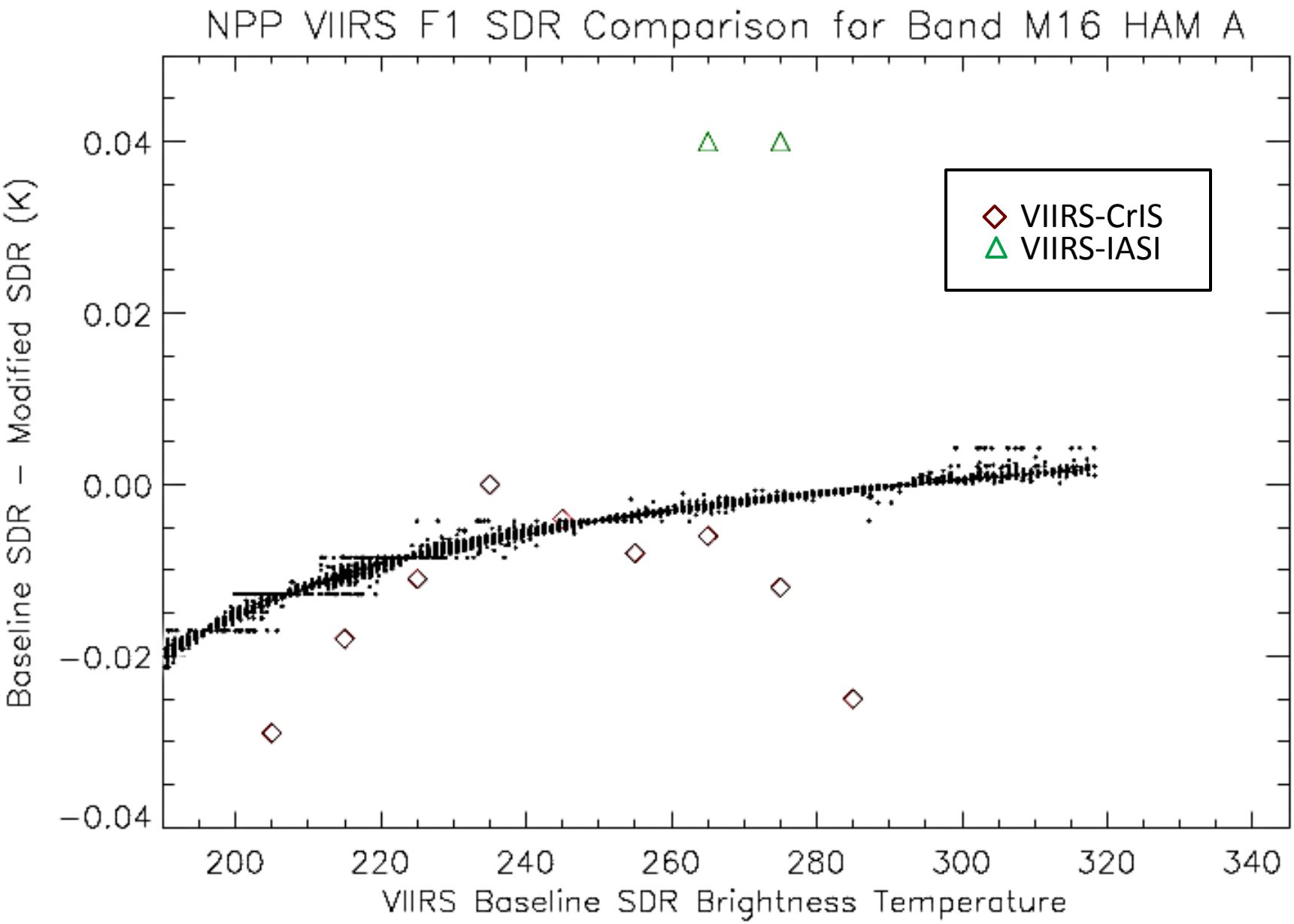
VIIRS C_0 Calibration Coefficient Modification

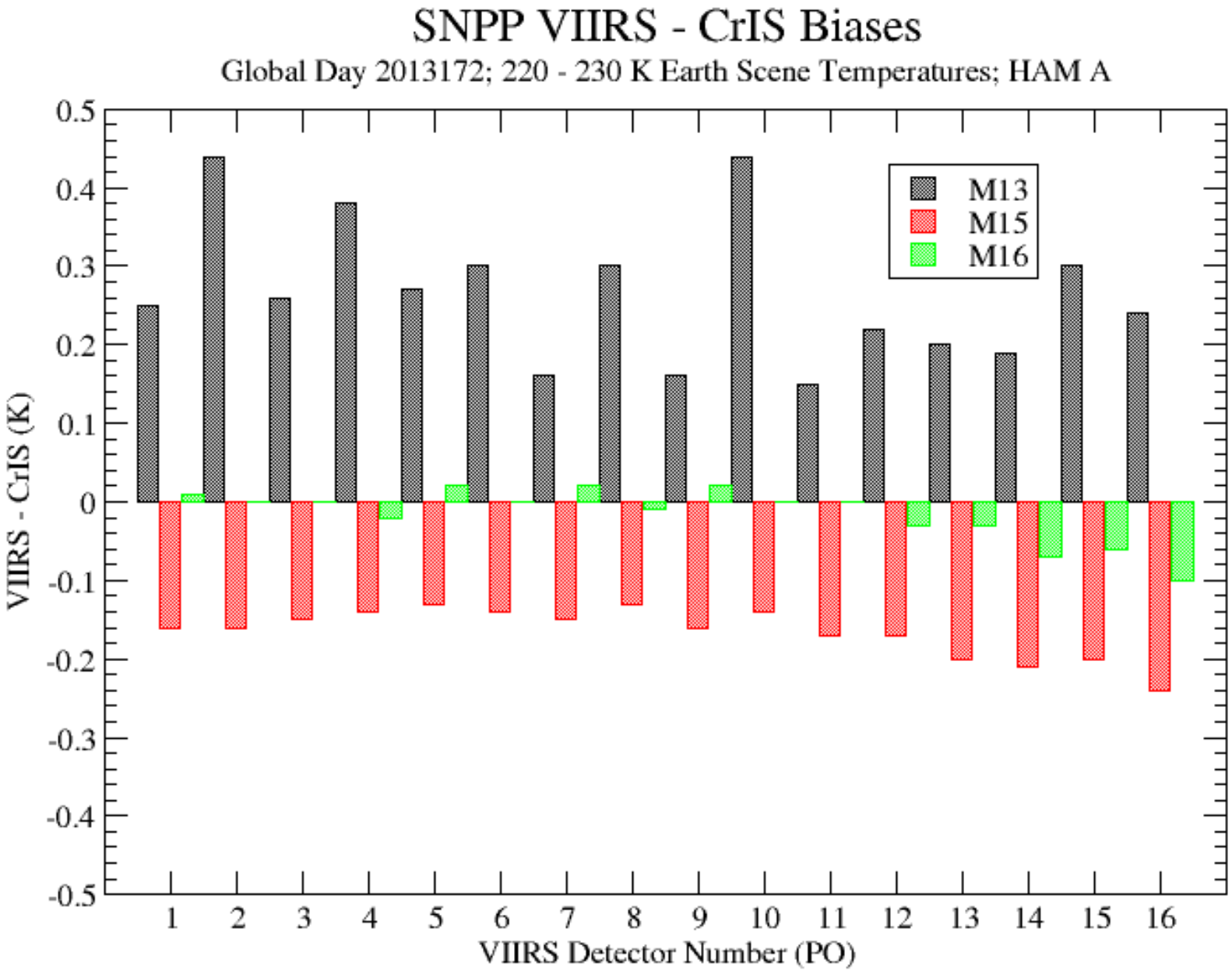


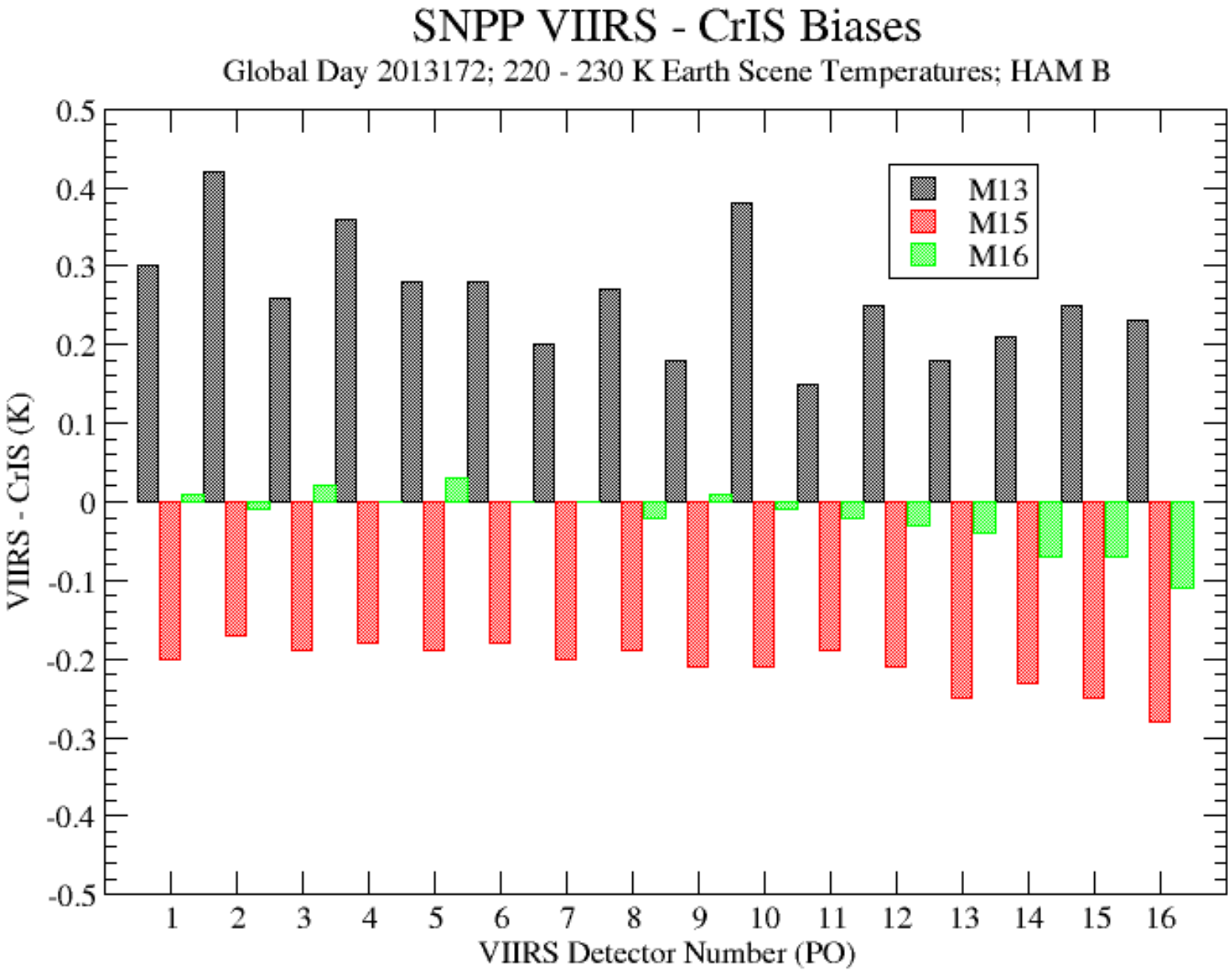
VIIRS C_0 Calibration Coefficient Modification

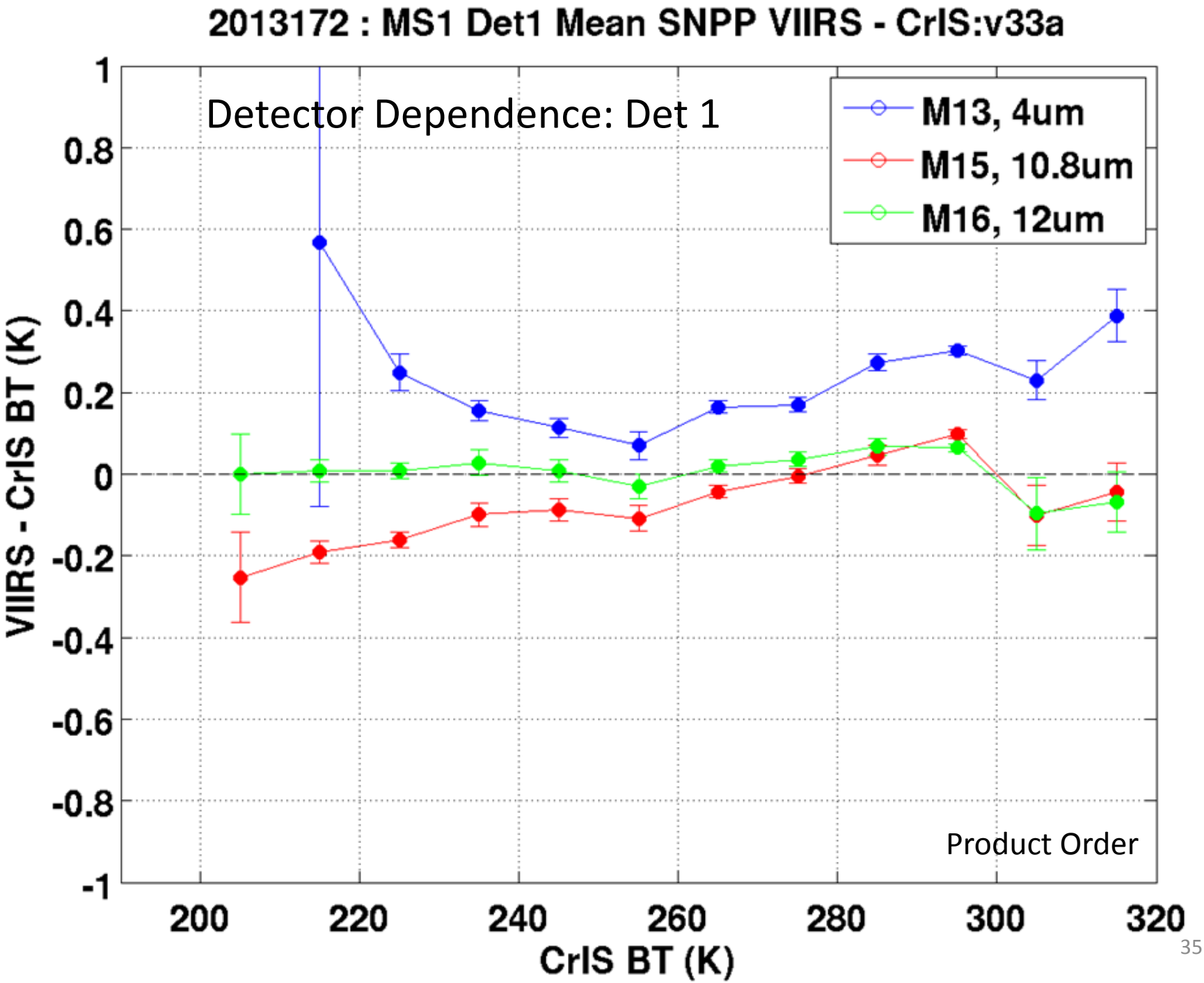


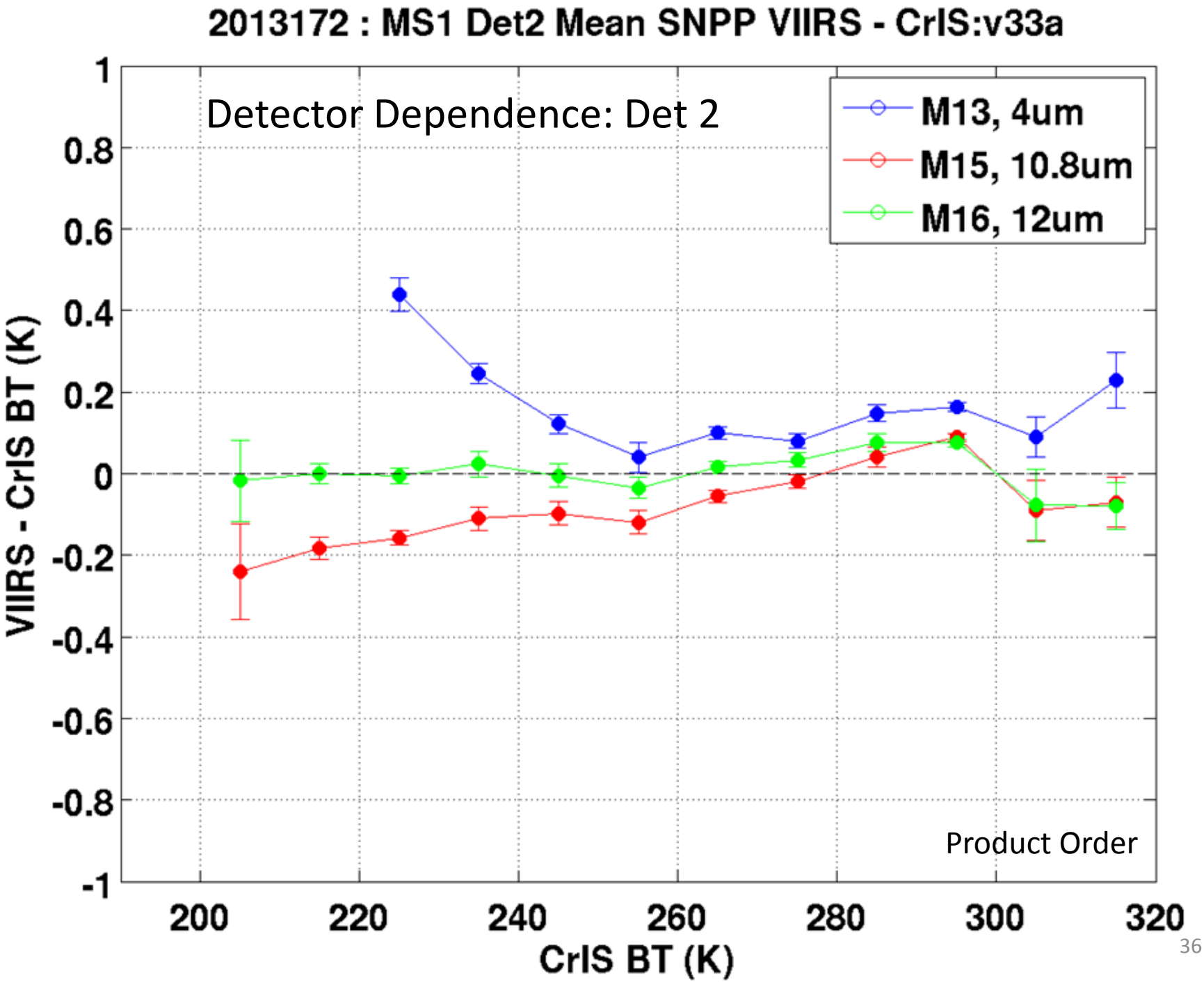
VIIRS C_0 Calibration Coefficient Modification

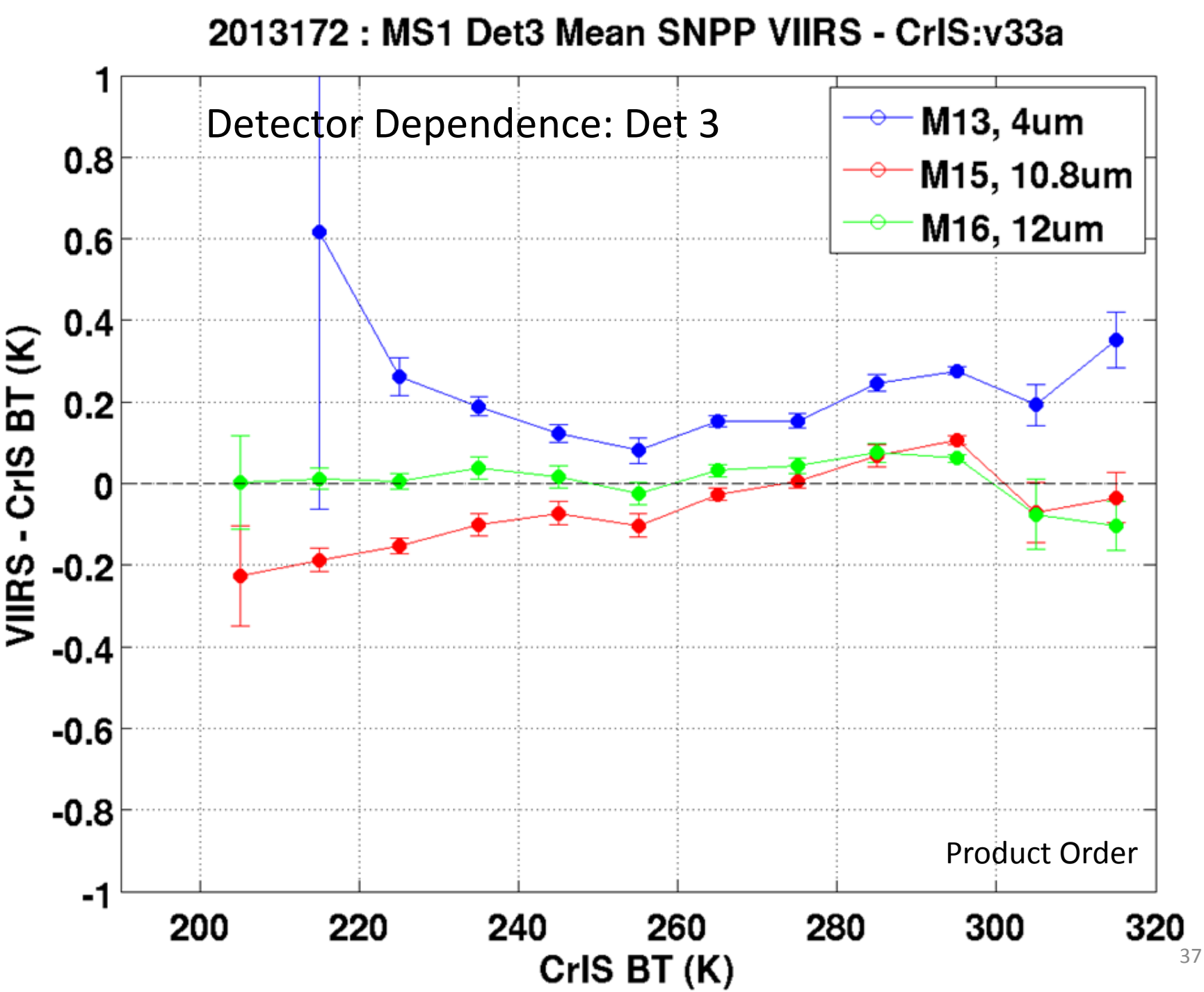


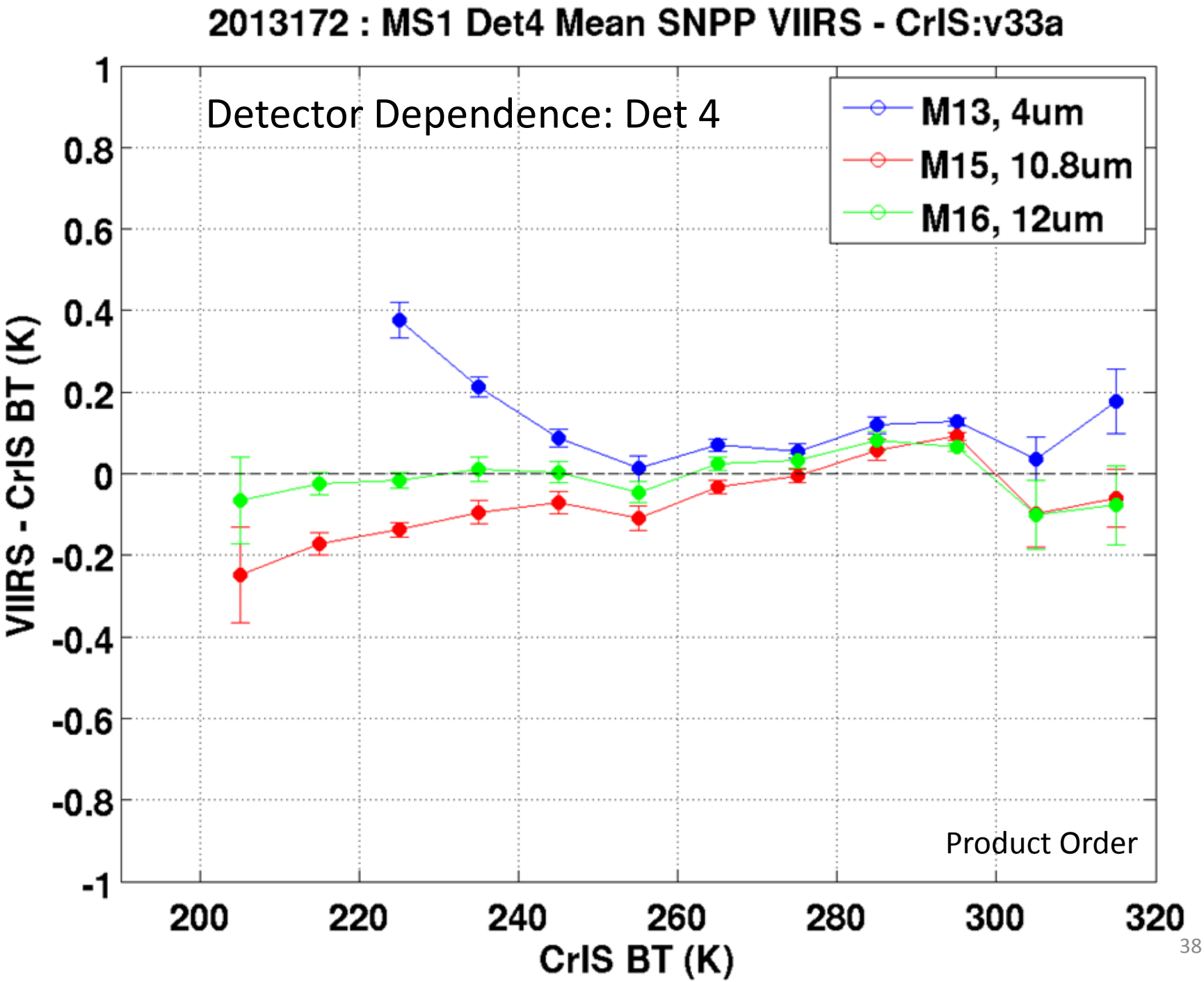

SNPP VIIRS - CrIS Biases
Global Day 2013172; 220 - 230 K Earth Scene Temperatures; HAM A
M13
M15
M16
VIIRS - CrIS (K)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
VIIRS Detector Number (PO)

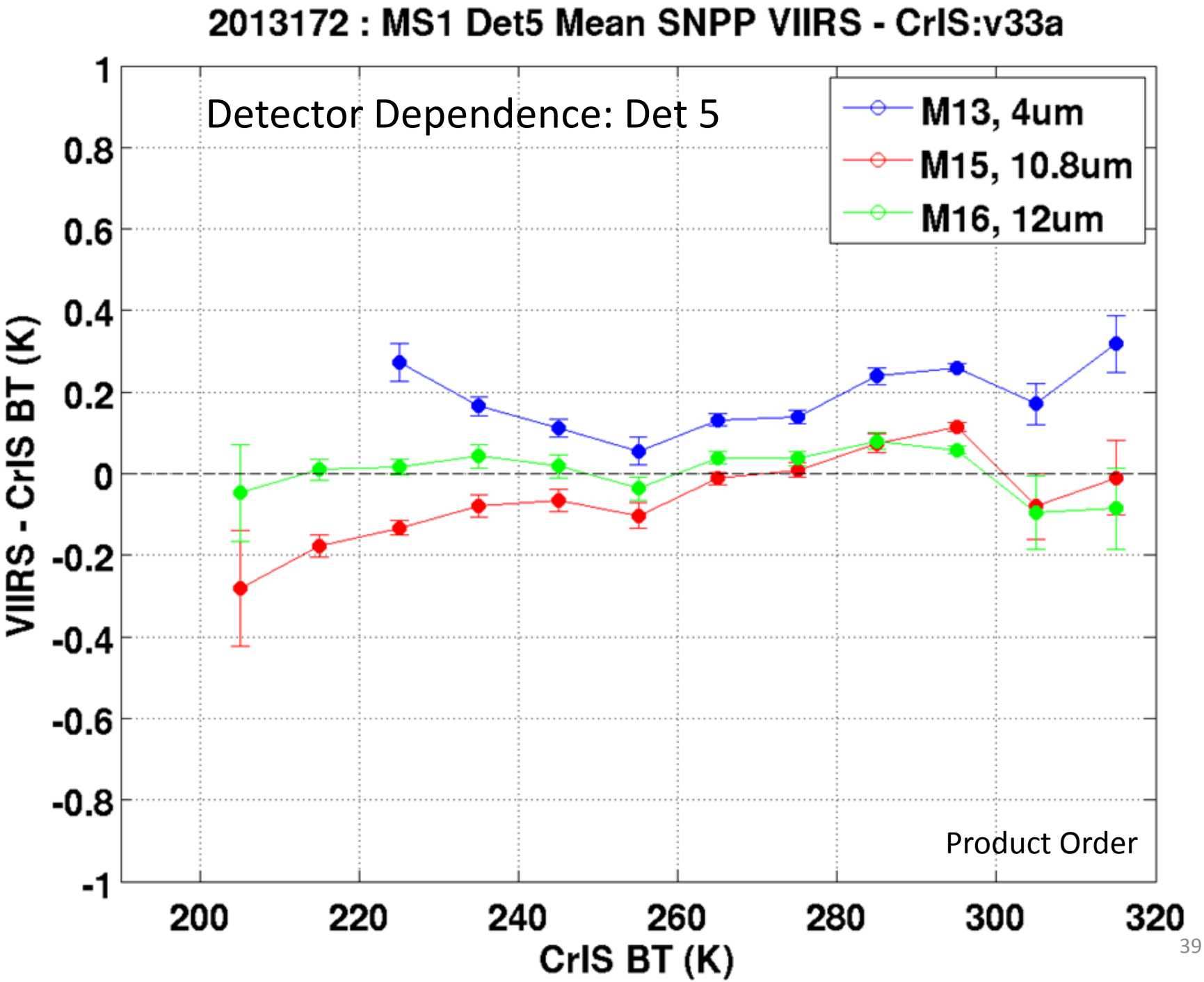

SNPP VIIRS - CrIS Biases
Global Day 2013172; 220 - 230 K Earth Scene Temperatures; HAM B
M13
M15
M16
VIIRS - CrIS (K)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
VIIRS Detector Number (PO)

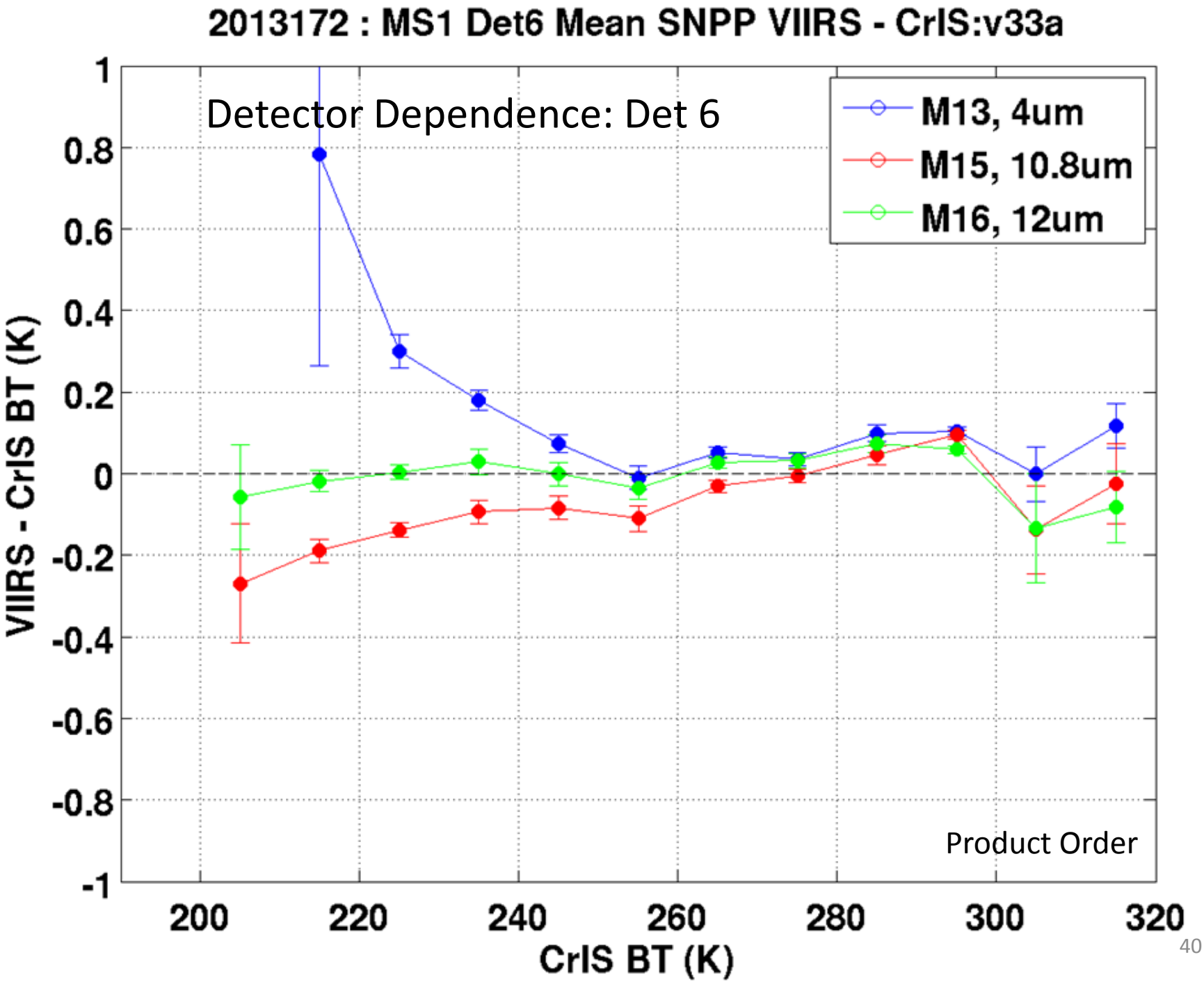

2013172 : MS1 Det1 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 1
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

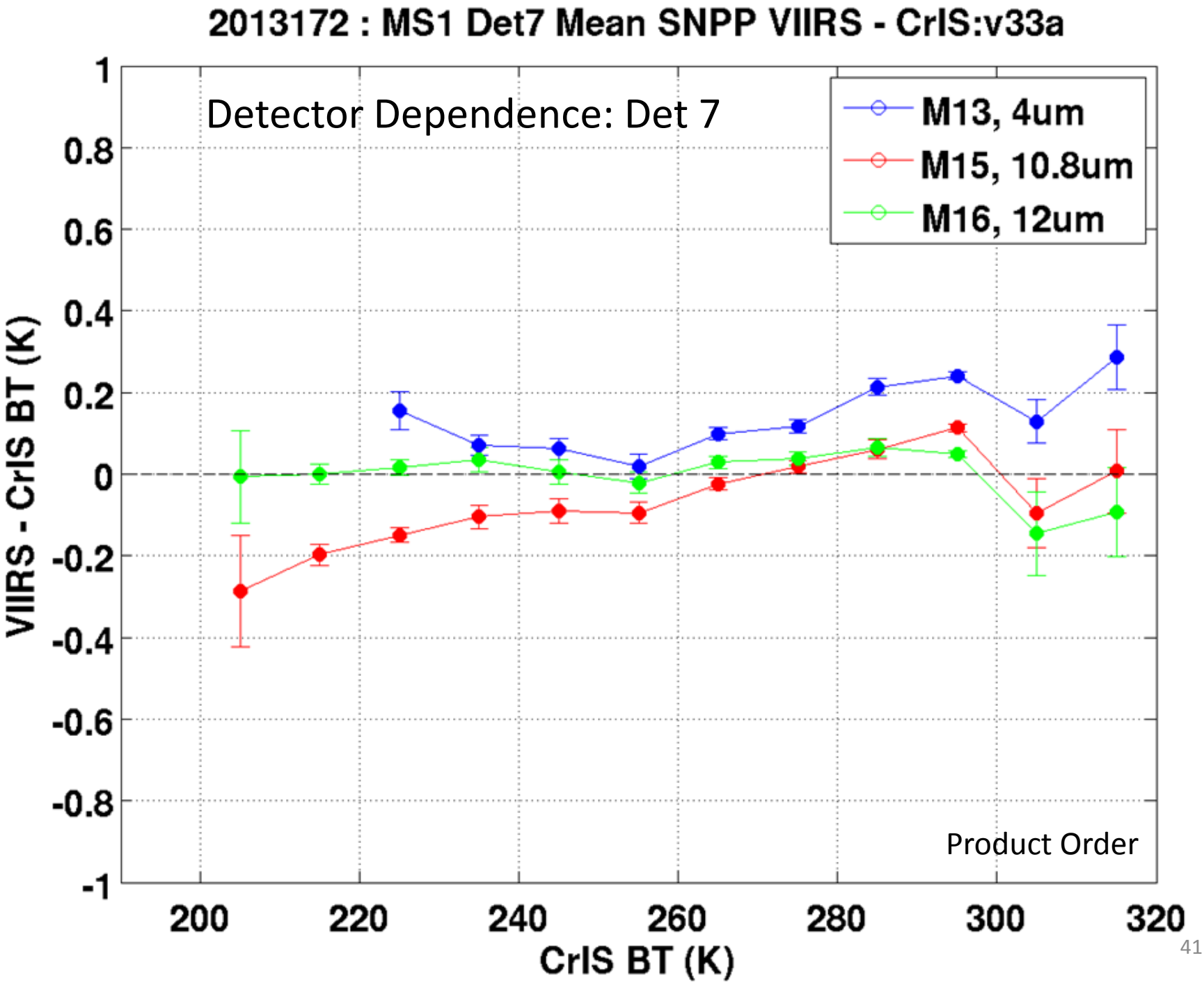

2013172 : MS1 Det2 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 2
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

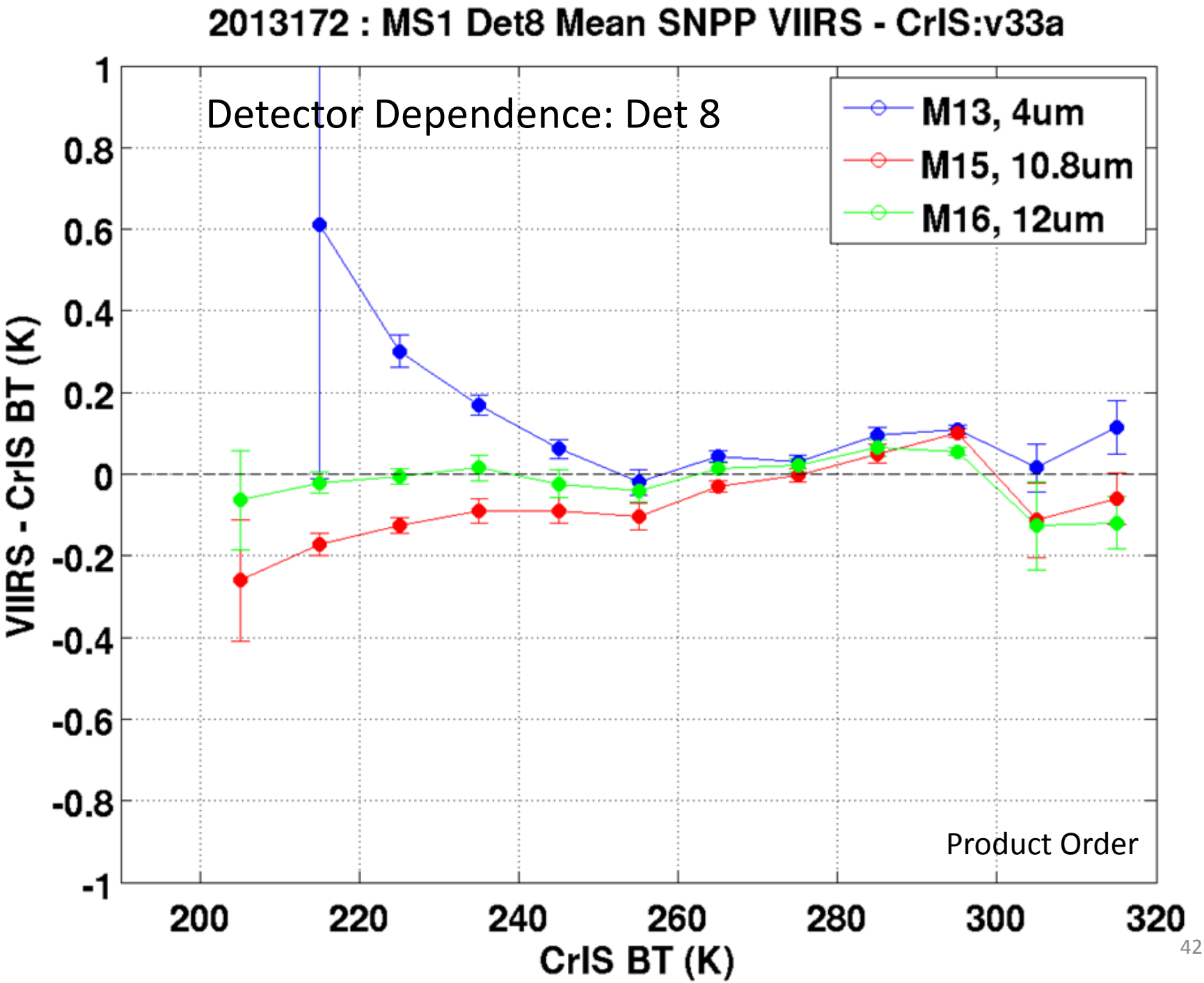

2013172 : MS1 Det3 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 3
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

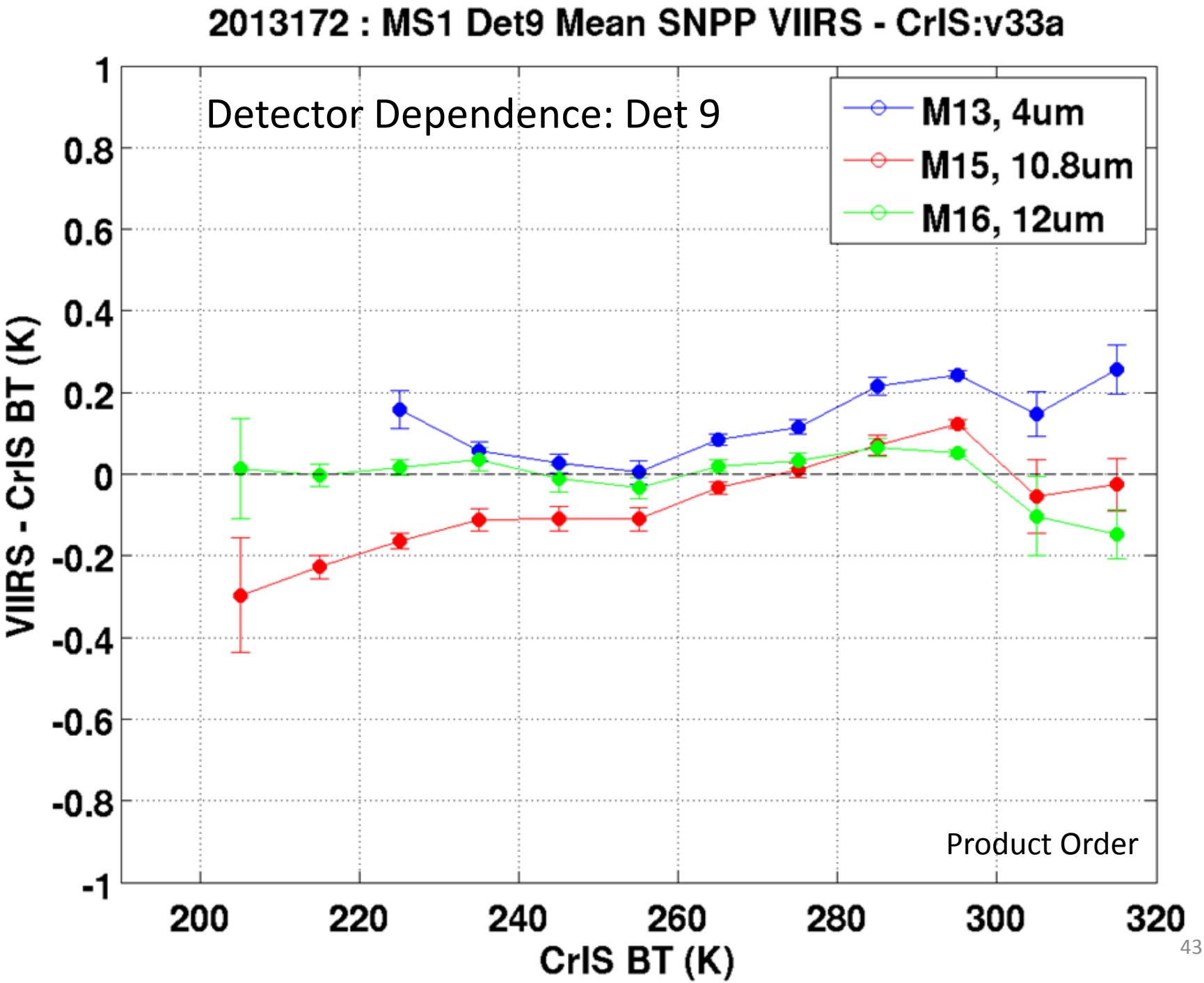

2013172 : MS1 Det4 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 4
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

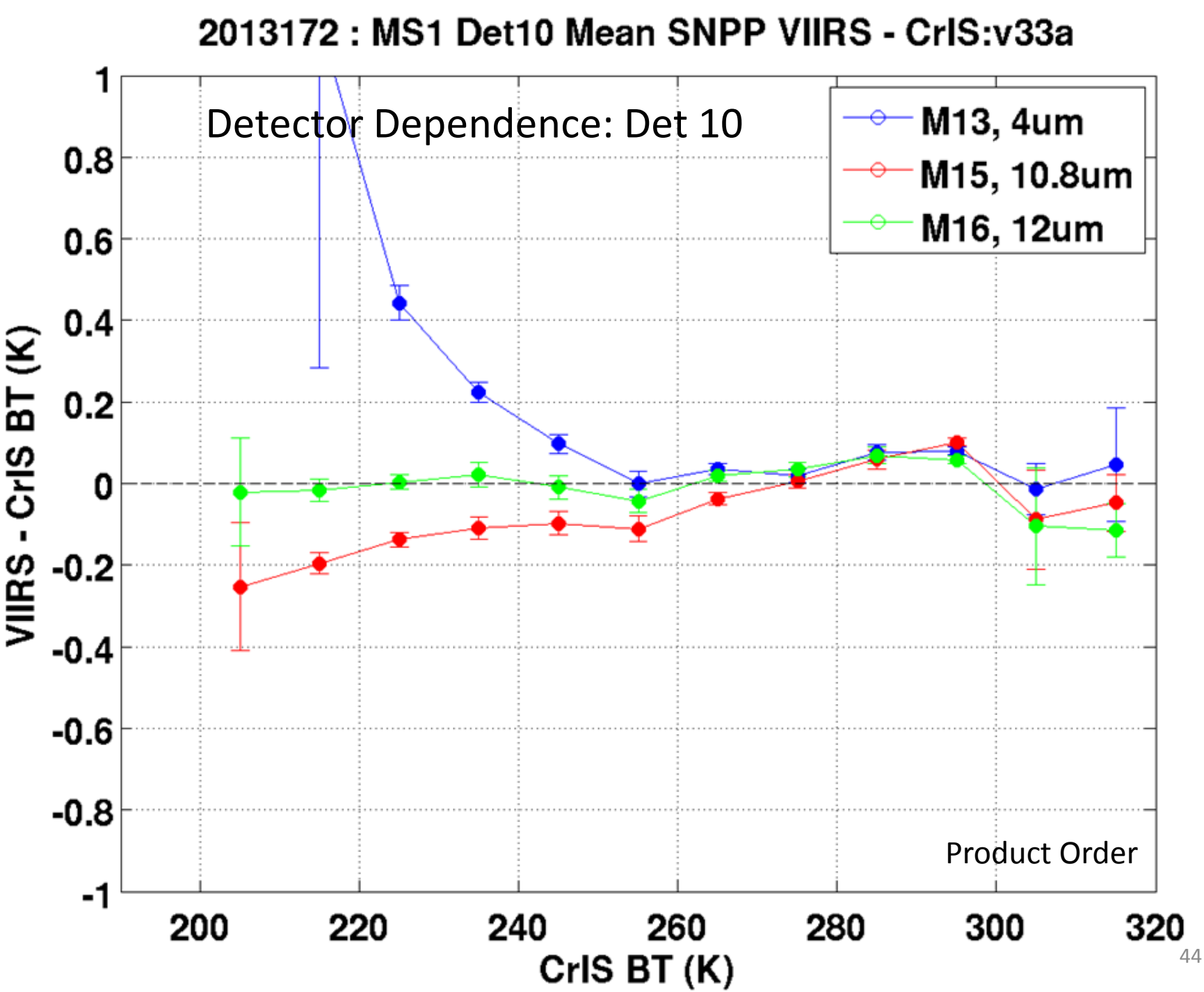

2013172 : MS1 Det5 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 5
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

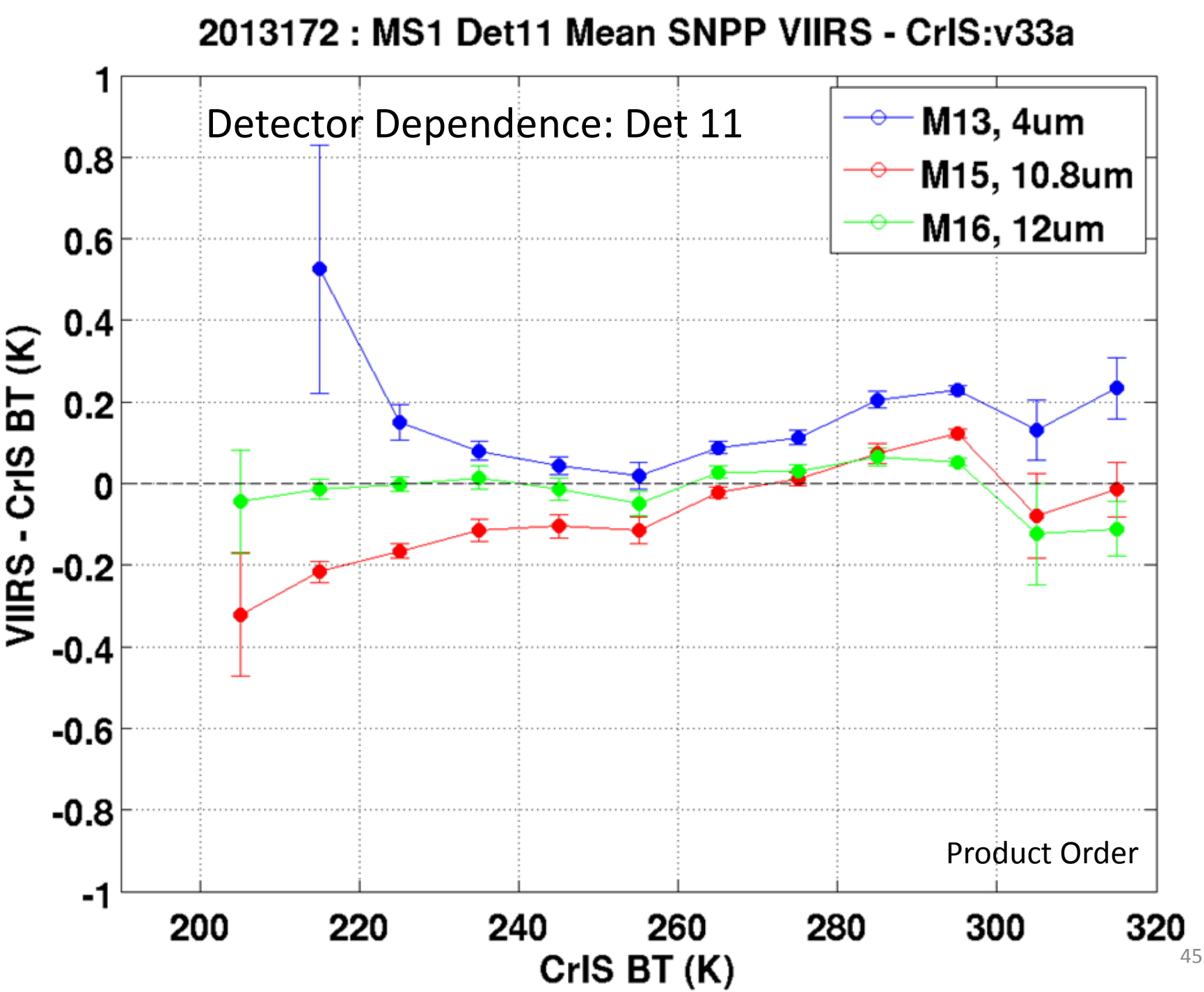

2013172 : MS1 Det6 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 6
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

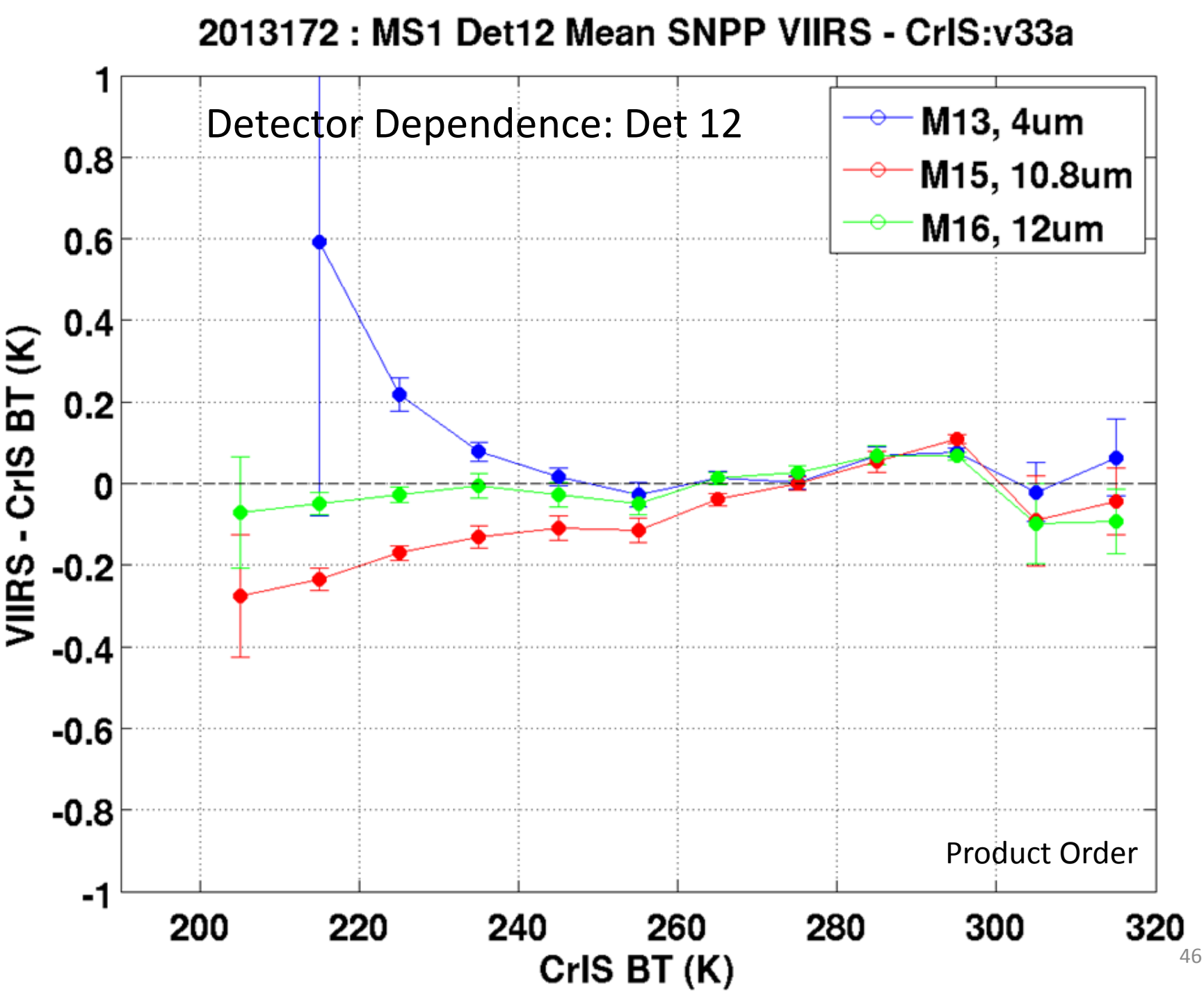

2013172 : MS1 Det7 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 7
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

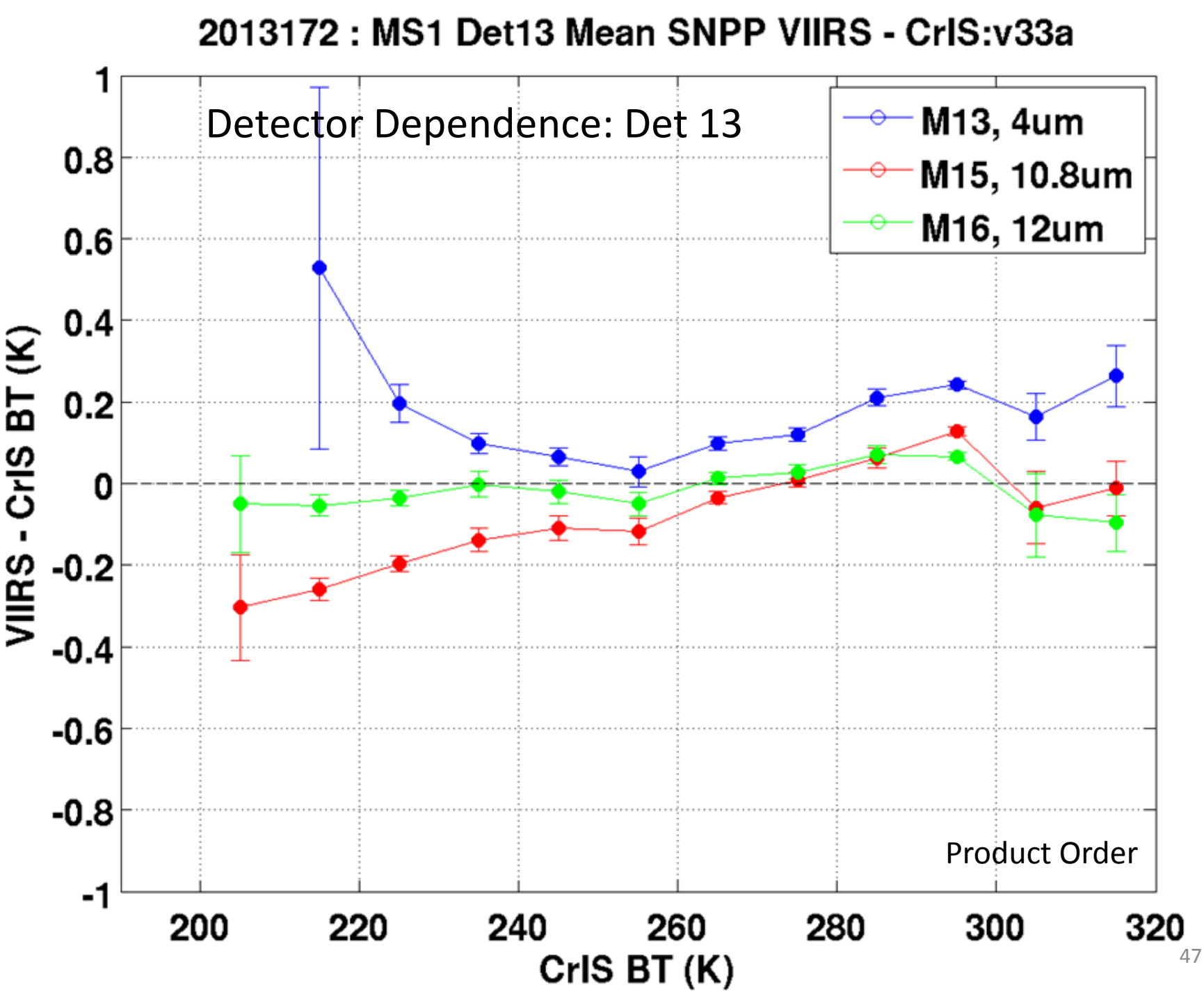

2013172 : MS1 Det8 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 8
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

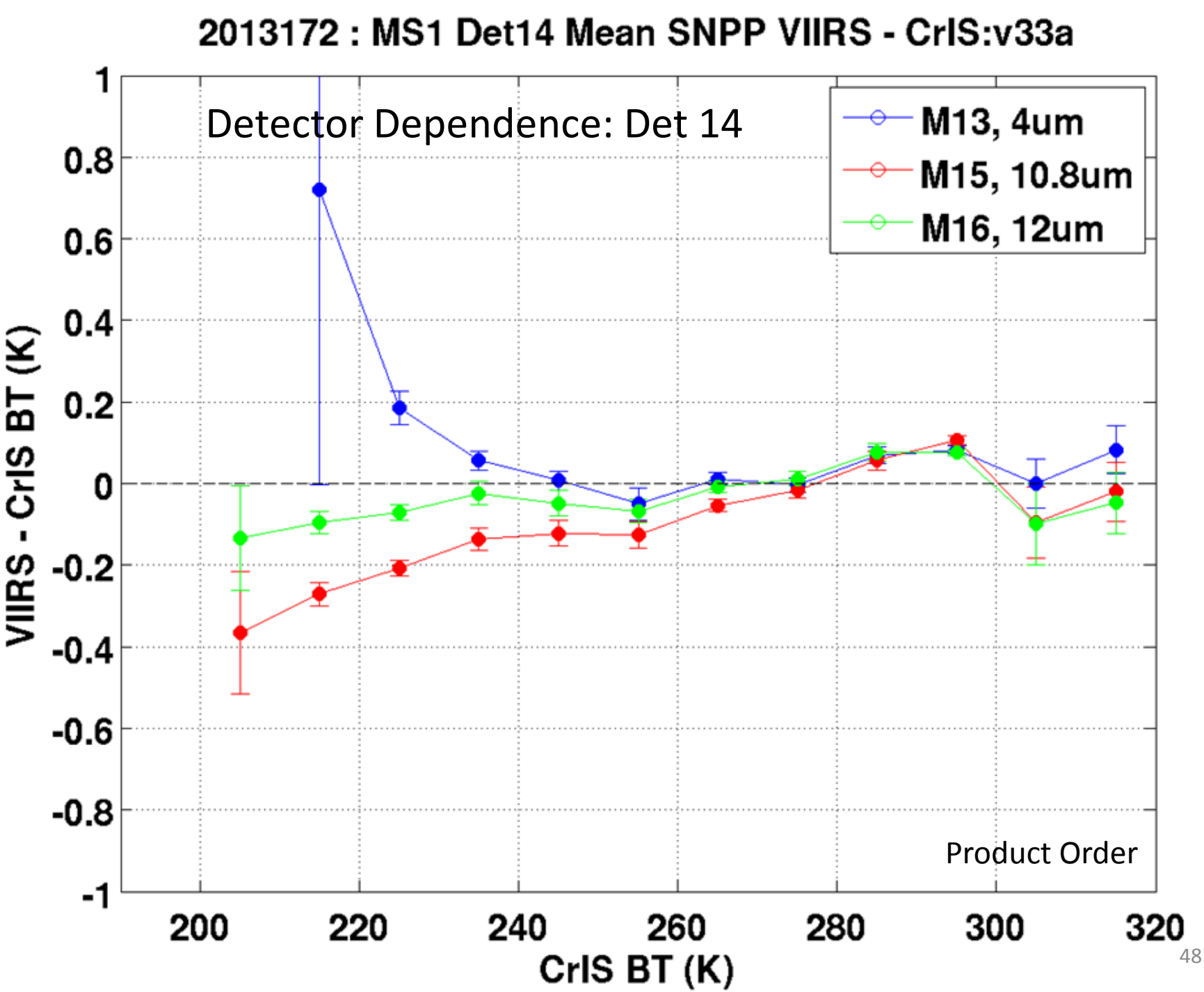

2013172 : MS1 Det9 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 9
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

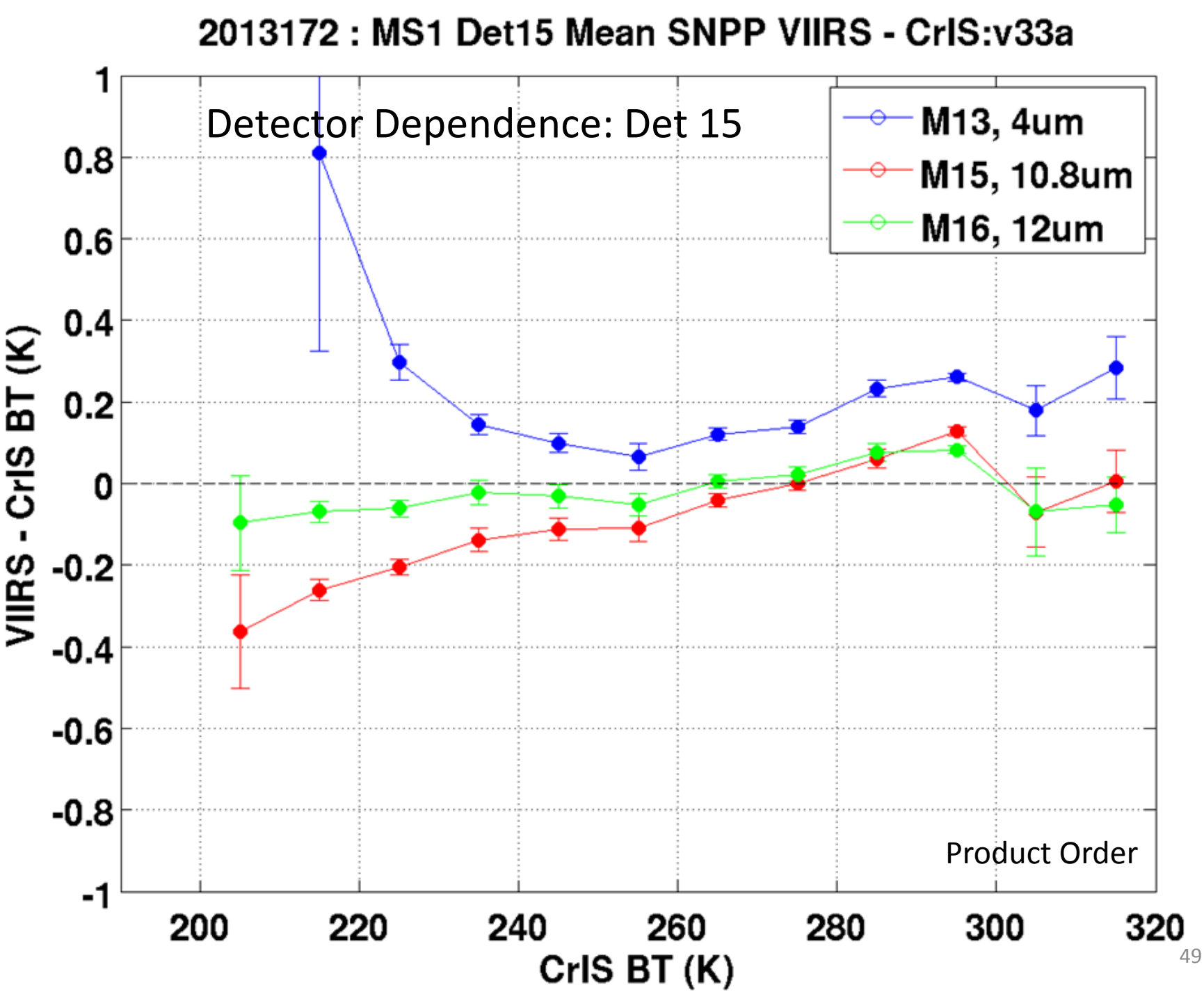

2013172 : MS1 Det10 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 10
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order

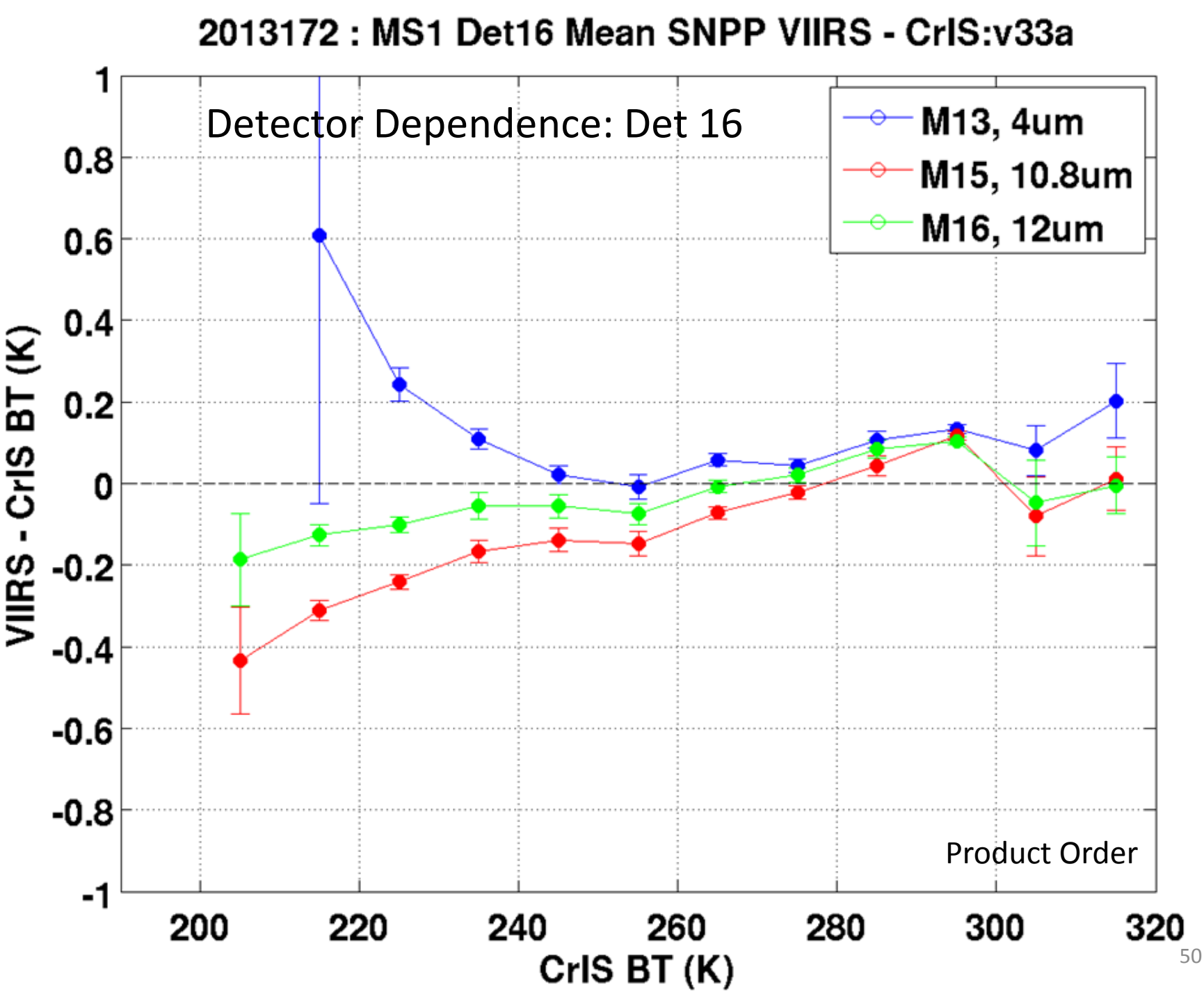

2013172 : MS1 Det11 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 11
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order


2013172 : MS1 Det12 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 12
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order


2013172 : MS1 Det13 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 13
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order


2013172 : MS1 Det14 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 14
M13, 4um
M15, 10.8um
M16, 12um
Product Order
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320


2013172 : MS1 Det15 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 15
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order


2013172 : MS1 Det16 Mean SNPP VIIRS - CrIS:v33a
Detector Dependence: Det 16
M13, 4um
M15, 10.8um
M16, 12um
VIIRS - CrIS BT (K)
CrIS BT (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
200
220
240
260
280
300
320
Product Order