VIIRS TEB Potential Improvements

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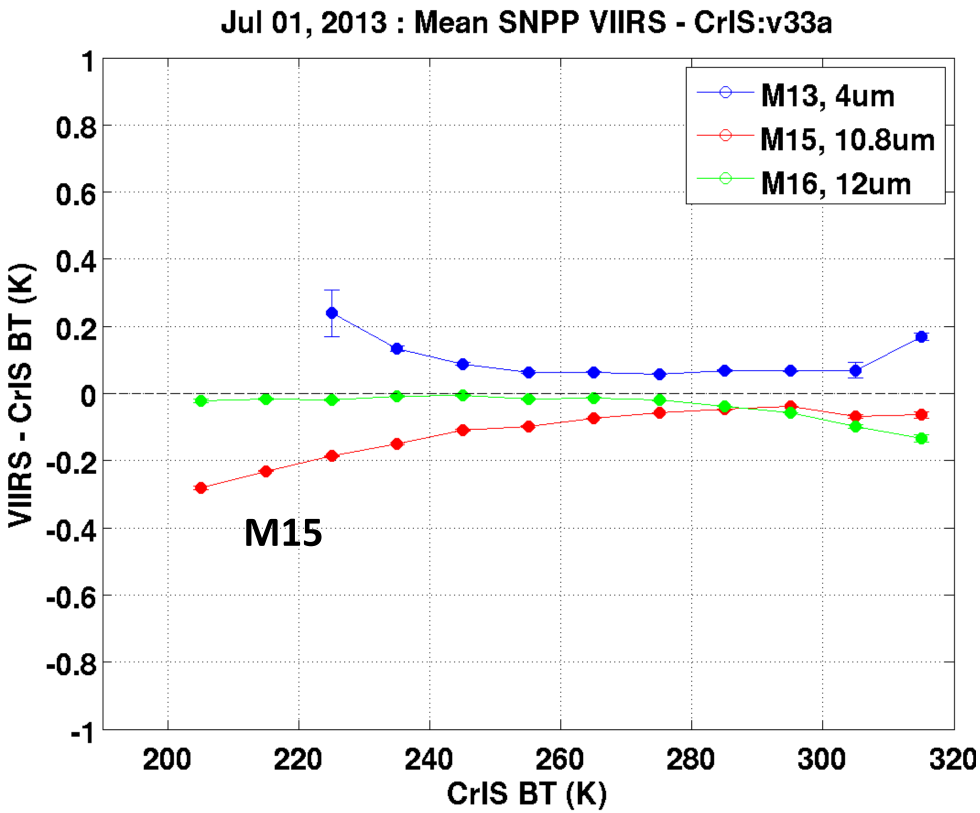
JPSS Annual Science Team Meeting (August 9, 2016)

Outline

- Background
  - Remaining issues with SNPP VIIRS TEB calibration
- Potential Improvements to TEB calibration
  - Review of the Aerospace's method
  - Alternative method
  - Other potential improvements
- Summary

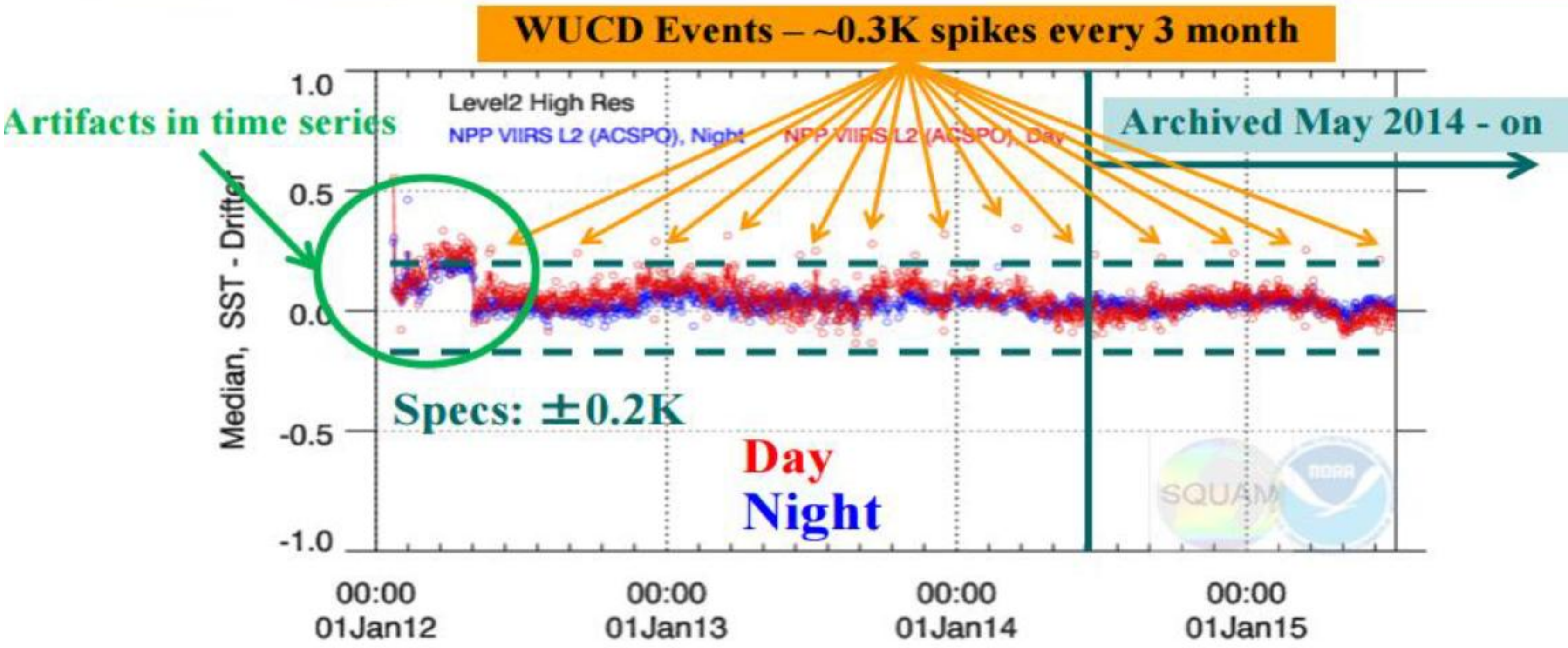
Three Remaining Issues with TEB Calibration



Courtesy of Chris Moeller, 2014 JPSS Annual Science Team Meeting

Issue 1: M15 has a cold bias at low scene temperature (~0.3 K at 200 K)
Issue 2: Constant bias also exist at SST and other temperatures for M15

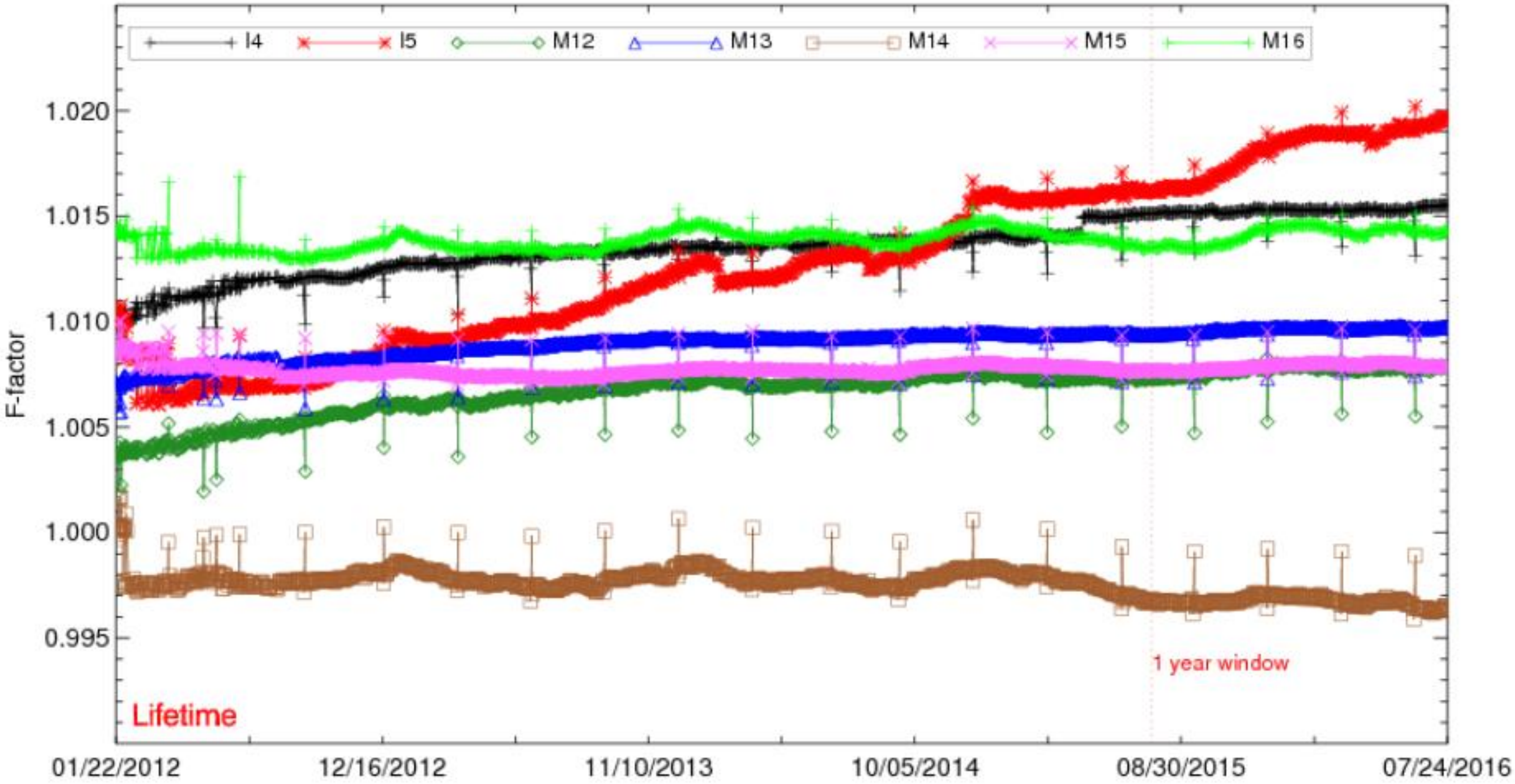
Three Remaining Issues with TEB Calibration



Courtesy of Dr. Ignatov, 2015 JPSS Annual Science Team Meeting

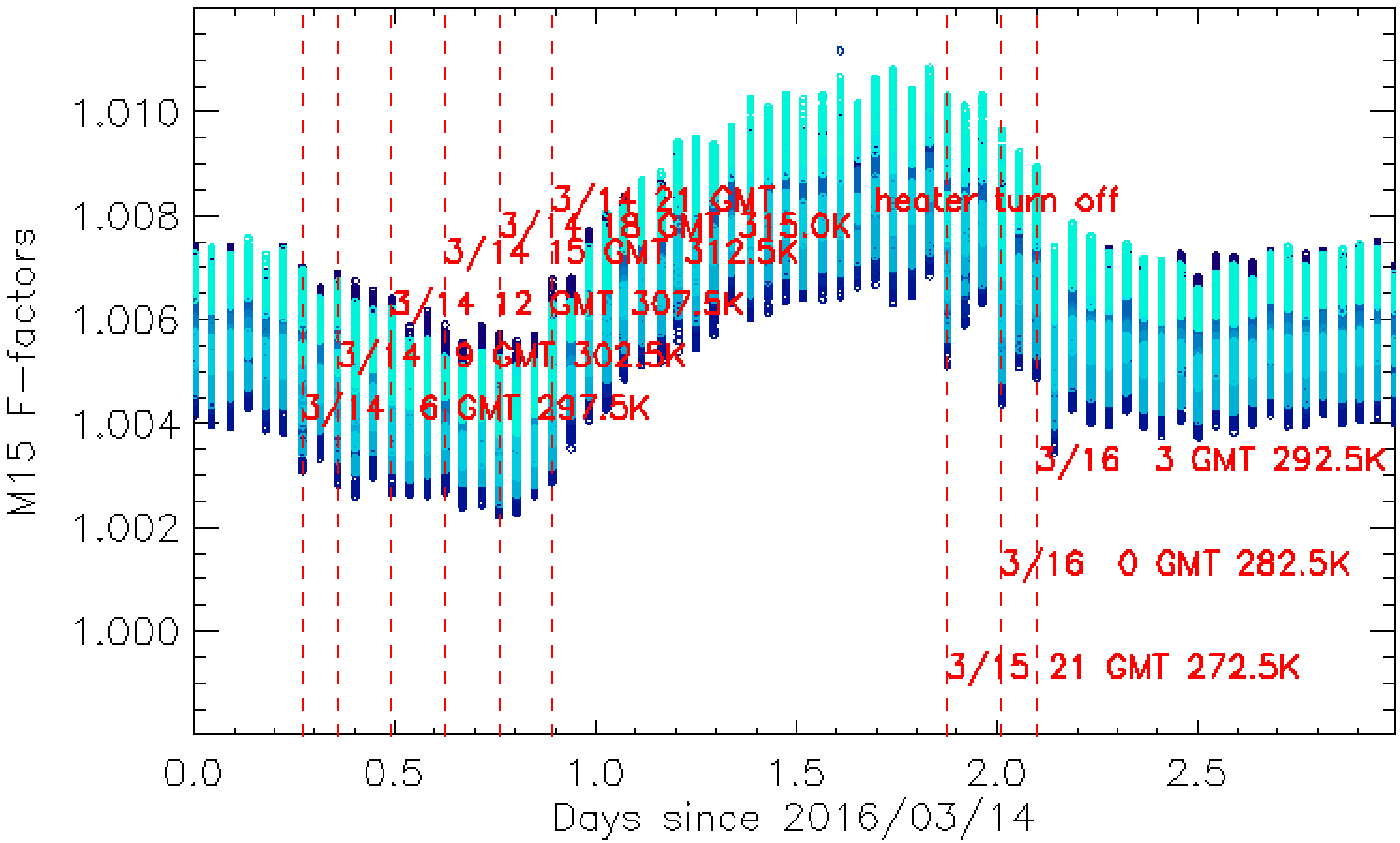
- **VIIRS SST product is generally consistent with drifter measurements, except**
- **Issue 3: "Global warming of ~0.3K" occurs in VIIRS SST every 3 months, due to warm up cool down (WUCD) calibration anomaly.**

STAR ICVS TEB F-Factor Time Series



TEB F-factors behave differently during WUCD compared to during nominal blackbody (BB) temperature setting (292.5 K).

M15 F-factor for March 2016 WUCD Event



M15 F-factors have large warm biases during cool down→ warm bias in scene BT

small cold bias during warm up → small cold bias in scene BT

Overall: warm bias during WUCD

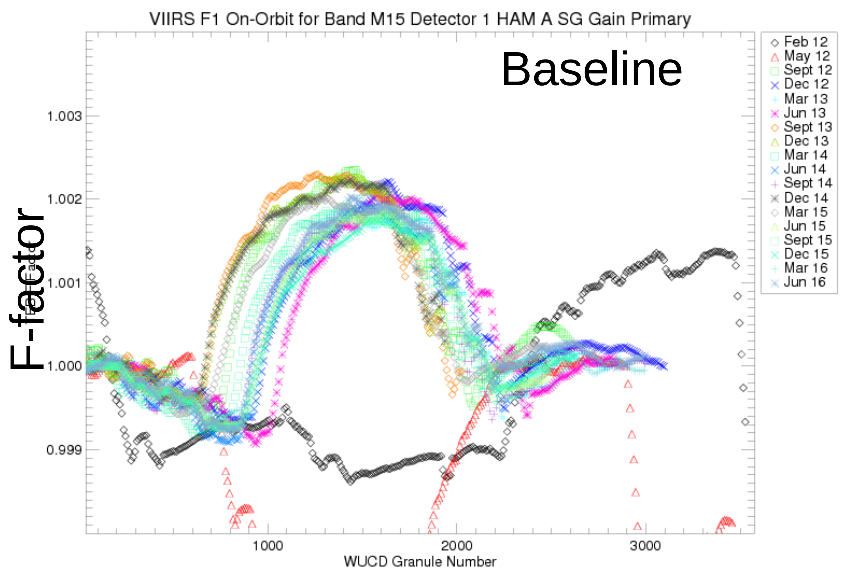
Summary of Aerospace’s Method

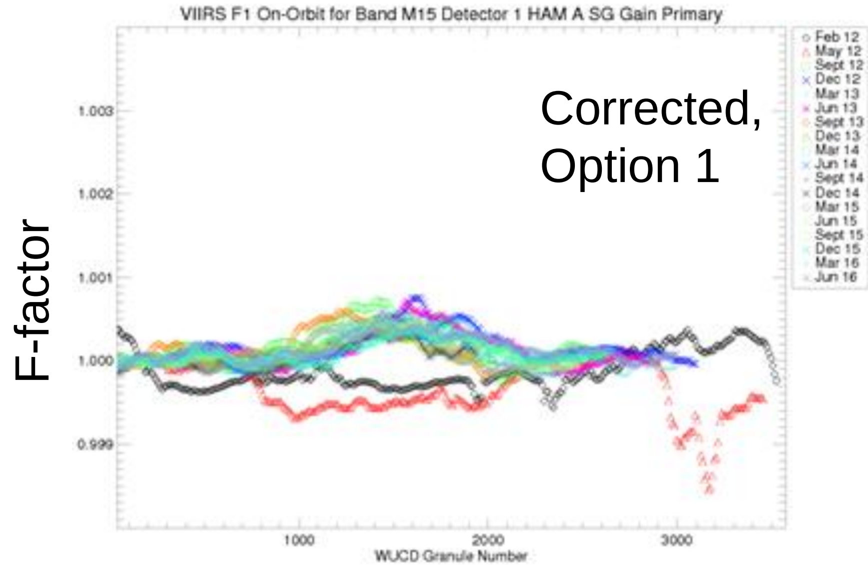
- Aerospace proposed a method to reduce F-factor anomalies and scene temperature biases during WUCD (October 7, 2015, Option 1):
  - OBCBB Response Versus Scan (RVS) was changed to optimized values (band-averaged corrections);
  - Half Angle Mirror (HAM) emitted radiance LUT was modified to better represents true HAM radiance;
  - Only #3 and #6 Blackbody (BB) thermistors were used in radiance calculation;
  - Three TEB calibration LUTs in total were changed, no code change required.
  - The method was applicable to all TEB bands.
- The initial proposed method was further updated to flatten F-factors during WUCD by implementing (August 3, 2016, Option 2) :
  - Detector dependent corrections to OBCBB RVS;
  - Detector dependent modification of HAM emitted radiance LUT and using Emission Versus Scan (EVS) to better represents true HAM radiance;
  - Require changes of 3 LUTs + VIIRS SDR science code change;
  - The updated method can be applied to all TEB bands.

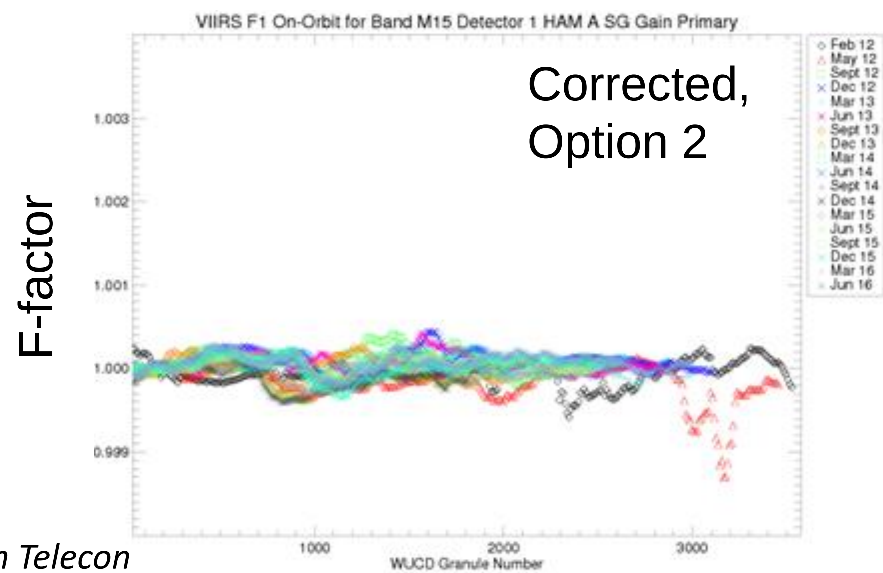
Details of Aerospace’s method are available on GRAVITE Information Portal under VIIRS SDR telecon documentation directory.

Summary of Aerospace's Method
-Band M15 F Factor Trending Over Historical WUCDs

M15, HAM-A, D1







Other detectors/bands show similar patterns
F Factors Smoothed Over Orbits

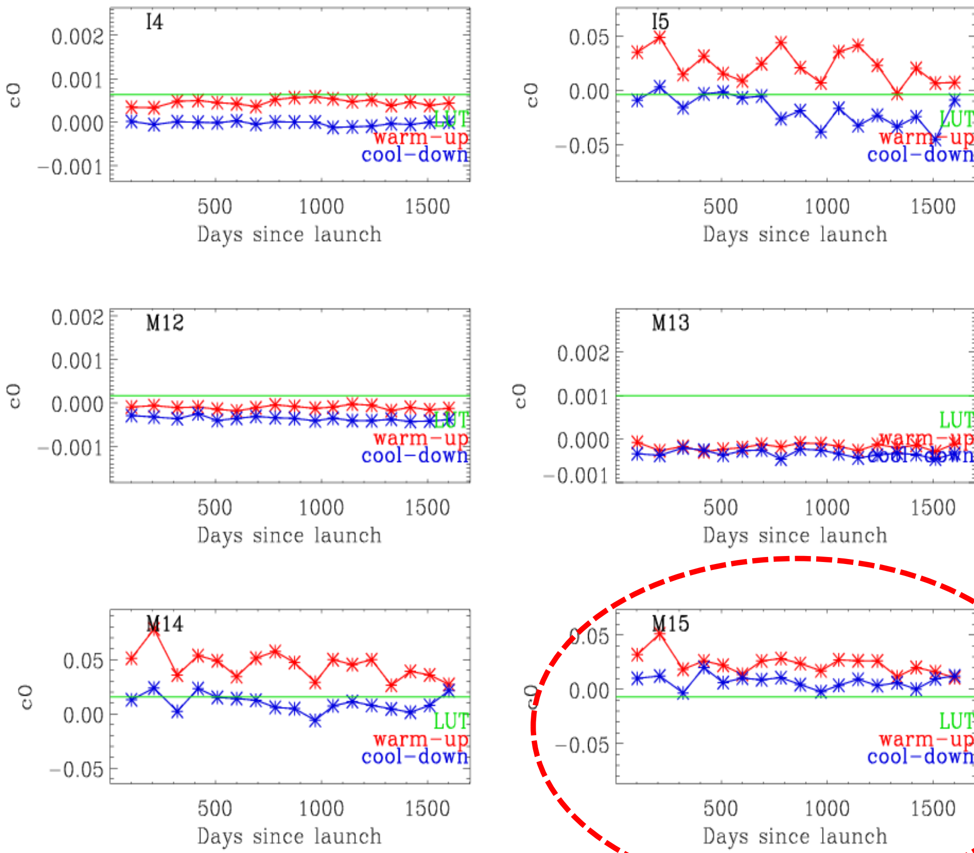
Courtesy of David Moyer, Aerospace, Aug 3, 2016 VIIRS SDR Team Telecon

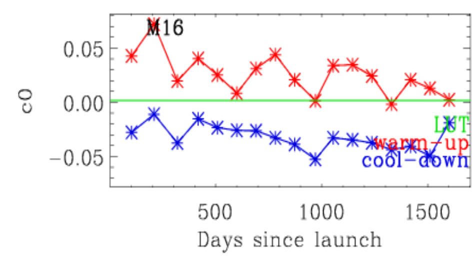
Summary of Aerospace's Method Pros and Cons

- Aerospace's method can effectively reducing F-factor anomalies for all TEB bands and reduce scene BT bias during WUCD at SST temperatures
- It can also reduce M15 constant scene BT bias under nominal BB temperatures
- However, it will increase M15 cold scene bias;
- Three LUTs needed to be modified;
- Code change is require for detector dependent HAM radiance correction (option 2);
- Only use 2 out of 6 BB temperature thermistors.

Alternative Method to Improve TEB Calibration

Prelaunch versus WUCD derived C Coefficients





Courtesy of NASA VCST, June 2016 MODIS/VIIRS Science Team Meeting

- Prelaunch characterized C coefficients are currently used for operational SNPP VIIRS TEB SDR production;
- On orbit instrument environment may be different from prelaunch;
- Larger difference exist between prelaunch and WUCD derived C coefficients in some bands; e.g.

M15 WUCD derived c0s are consistently higher than the prelaunch values, and with opposite sign

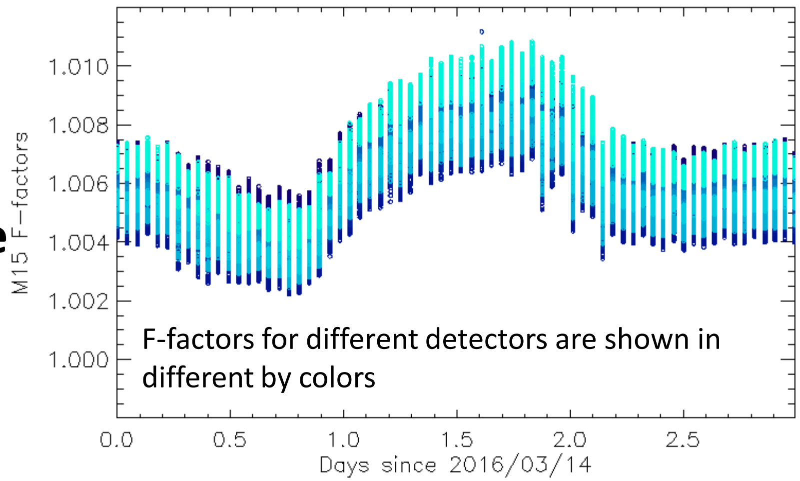
Alternative Method to Improve TEB Calibration Modify C Coefficients

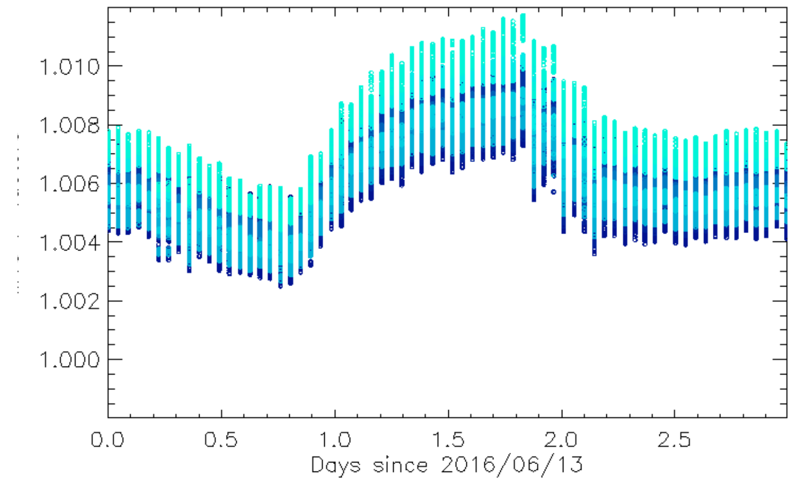
- An alternative method is to explore using WUCD derived C coefficients to address TEB calibration issues.
  - VCST WUCD C coefficients were used as references in this study;
  - One LUT (VIIRS-SDR-DELTA-C-LUT) needs to be modified;
  - Similar method was used for MODIS TEB.
- TEB calibration terms from typical granules with nominal (292.5K), warm (315 K), and cold (272.5 K) BB temperatures at nadir were exacted using ADL and used for:
  - further analyzing the sensitivity of different terms, including C coefficients, on WUCD F-factor anomaly and scene temperature biases;
  - Refining Tele and Tomm dependencies of C coefficients.
- The method was applied to M15 in this study:
  - Band averaged, Tomm dependent modifications were applied to c0, which show large differences between prelaunch and WUCD values;
  - Prelaunch c1 and c2 values are generally consistent those derived by WUCD, therefore unchanged;
  - c2 values are small (on the order of 1E-8), not sensitivity to WUCD anomalies.

M15 F-factors (HAM-A)

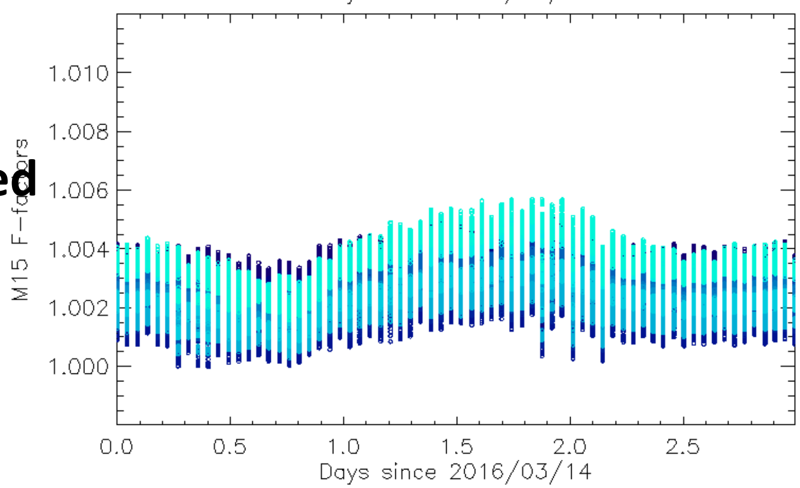
March 2016 WUCD | **June 2016 WUCD**

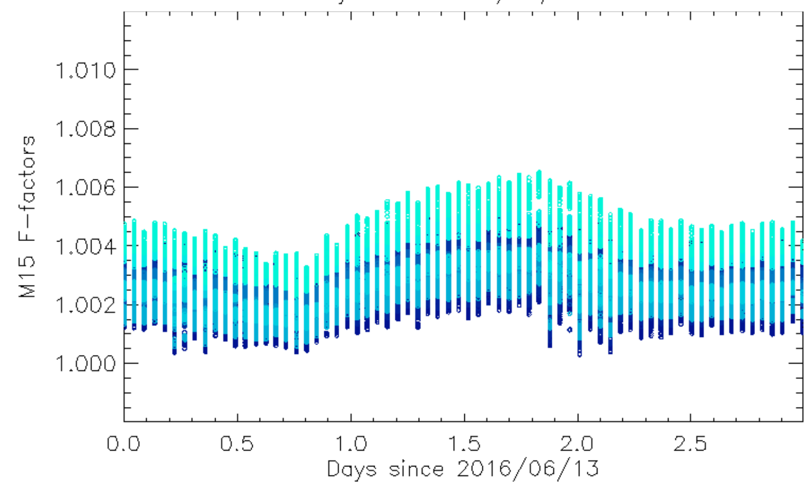
Baseline





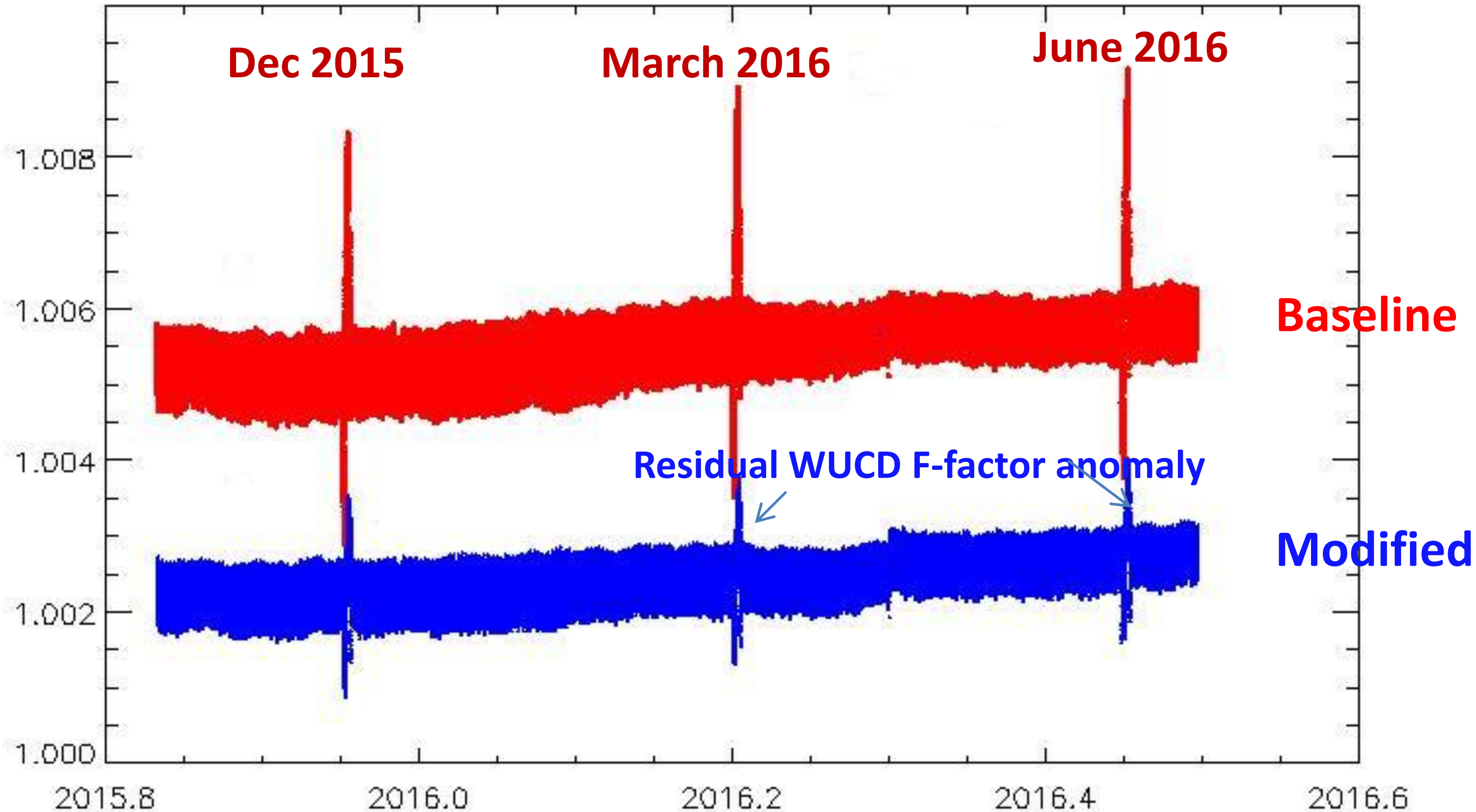
Corrected





After correction, M15 F-factors become more consistent during normal, warm, and cold BB temperatures. HAM-B shows similar patterns.

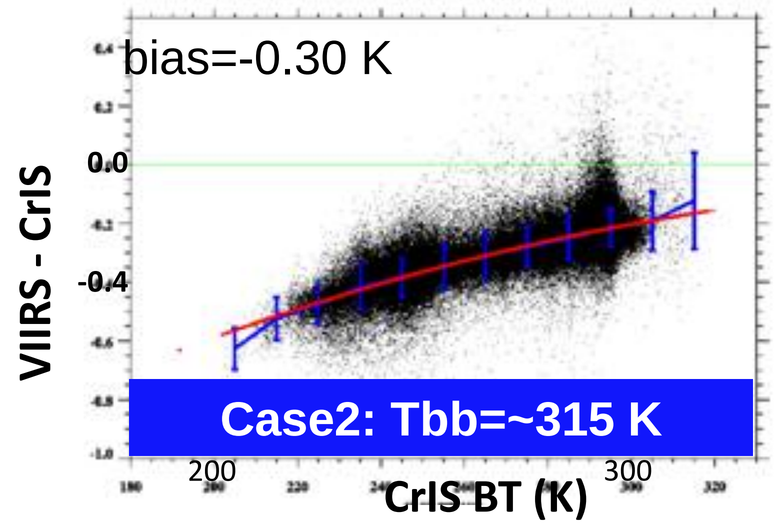
Band-Averaged F-factor Time Series for M15 (November 2015 - June 2016)

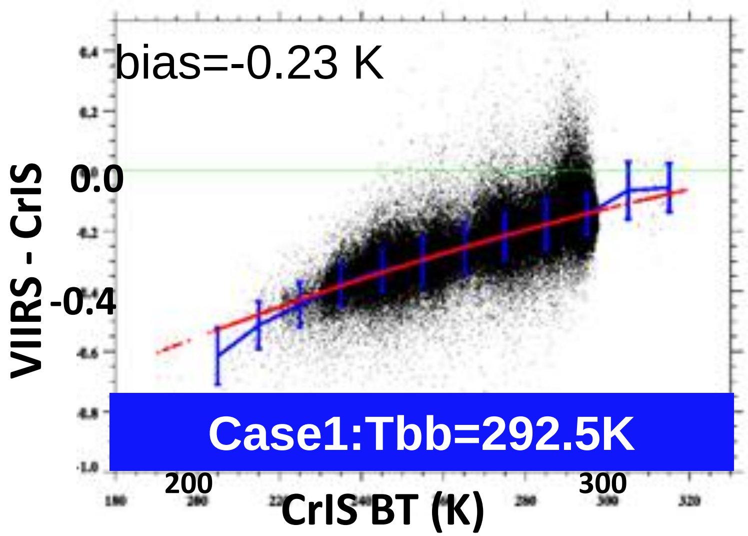


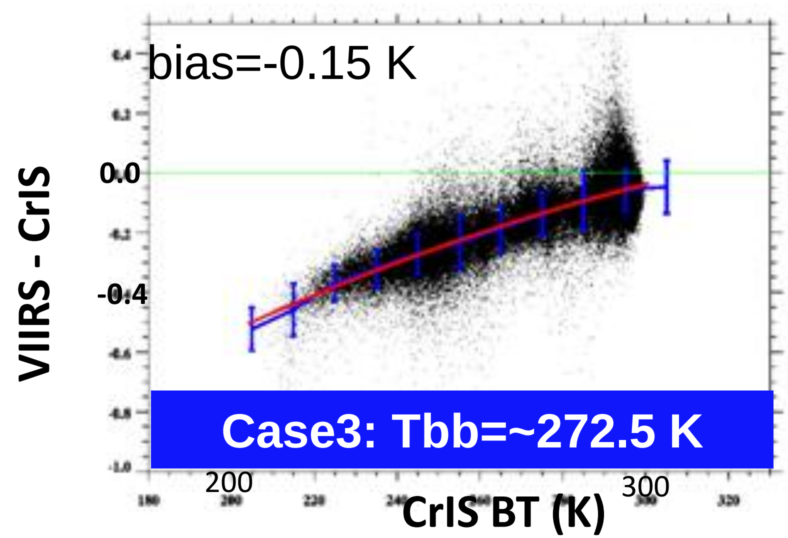
- WUCD F-factor anomalies are significantly reduced after applying the modified c0 values.
- c0 values, esp its Tomm dependency, can be refined to further reduce the anomalies.

Three Types of M15 BT biases Based on Comparisons with CrIS (Baseline)

1. **Cold scene bias**
   Larger bias under cold scene temperatures
2. **Constant bias**
   VIIRS M15 and CrIS BTs differ by ~0.2 K on average during nominal BB temperatures
3. **WUCD biases**
   1. Cold bias during warm up
   2. Warm bias during cool down



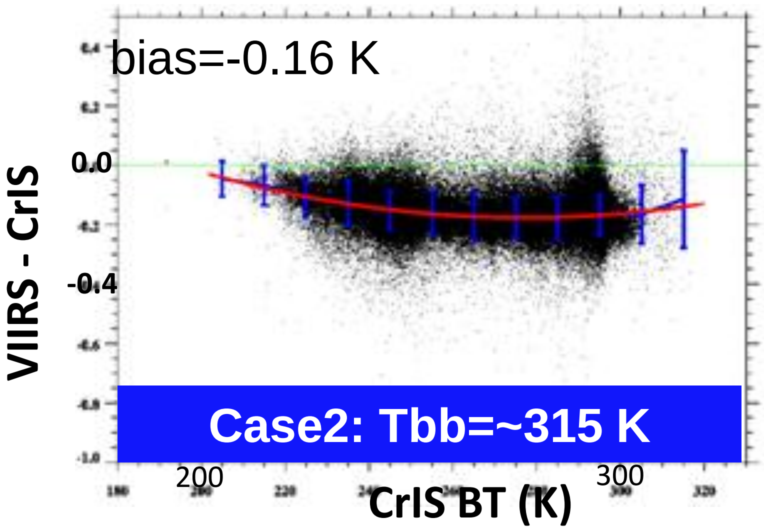


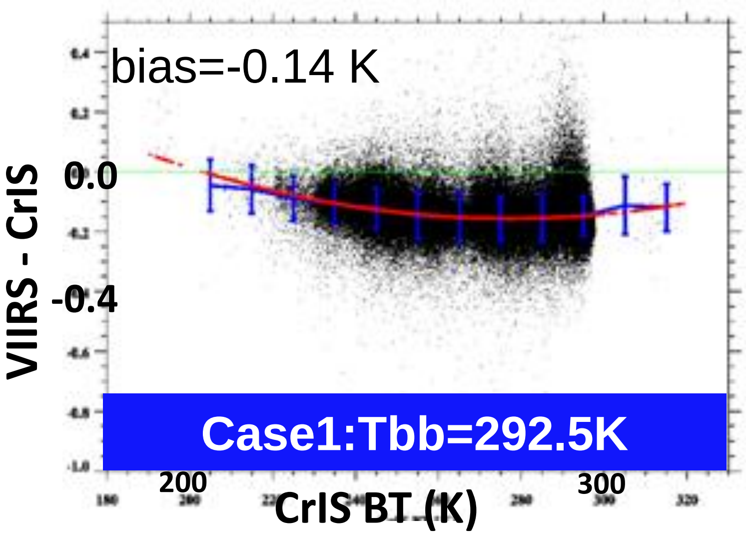


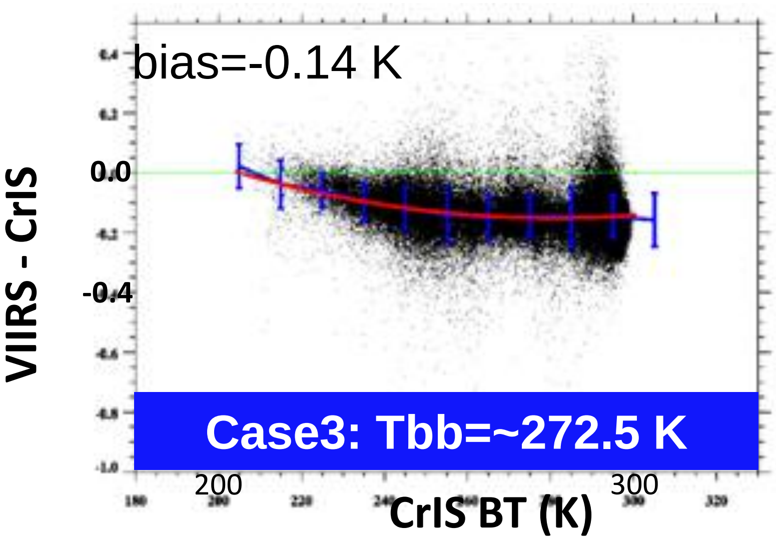
Courtesy of Likun Wang (STAR CrIS SDR Team), each plot was generated using 2 hours of data

Three Types of M15 BT biases Based on Comparisons with CrIS (Updated)

1. **Cold scene bias was almost removed;**
2. **Constant bias was reduced by ~0.1 K;**
3. **WUCD biases removed:**
   Remaining constant biases are close to each other under different BB temperature settings.







Courtesy of Likun Wang (STAR CrIS SDR Team)

Other Potential Improvement: TEB calibration Equation

- **Current VIIRS TEB Calibration Equations:**

$$F = \frac{\mathrm{RVS}(\theta_{obc}) \cdot \left\{ \left(1 - \frac{1}{\mathrm{RVS}(\theta_{obc})}\right) \cdot \frac{\left\{\left(1 - \overline{\rho_{rta}(\lambda)}\right) \cdot \overline{L(T_{rta}, \lambda)} - \overline{L(T_{ham}, \lambda)}\right\}}{\overline{\rho_{rta}(\lambda)}} + \overline{\varepsilon_{obc}(\lambda)} \cdot \overline{L(T_{obc}, \lambda)} + \overline{L_{obc\_rfl}(T_{sh}, T_{cav}, T_{tele}, \lambda)} \right\}}{\sum_{j=0}^{2} c_j \cdot dn_{obc}{}^{j}}$$

$$\overline{L_{ap}}(\theta, B) = \frac{F \cdot \sum_{i=0}^{2} c_i \cdot dn^i - (\mathrm{RVS}(\theta, B) - 1) \cdot \frac{\left\{\left(1 - \overline{\rho_{rta}(\lambda)}\right) \cdot \overline{L(T_{rta}, \lambda)} - \overline{L(T_{ham}, \lambda)}\right\}}{\overline{\rho_{rta}(\lambda)}}}{\mathrm{RVS}(\theta, B)}$$

F-factor scales c0,c1, c2 equally on orbit

- **MODIS-equivalent TEB Calibration Equations:**

$$c_1^{'} = \frac{RVS(\theta_{obc}) \cdot \left\{ \left(1 - \frac{1}{\mathrm{RVS}(\theta_{obc})}\right) \cdot \frac{\left\{\left(1 - \overline{\rho_{rta}(\lambda)}\right) \cdot \overline{L(T_{rta}, \lambda)} - \overline{L(T_{ham}, \lambda)}\right\}}{\overline{\rho_{rta}(\lambda)}} + \overline{\varepsilon_{obc}(\lambda)} \cdot \overline{L(T_{obc}, \lambda)} + \overline{L_{obc\_rfl}(T_{sh}, T_{cav}, T_{tele}, \lambda)} \right\} - c_0 - c_2 \cdot dn^2_{obc}}{dn_{obc}}$$

$$\overline{L_{ap}}(\theta, B) = \frac{c_0 + c_1^{'} \cdot dn + c_2 \cdot dn^2 - (\mathrm{RVS}(\theta, B) - 1) \cdot \frac{\left\{\left(1 - \overline{\rho_{rta}(\lambda)}\right) \cdot \overline{L(T_{rta}, \lambda)} - \overline{L(T_{ham}, \lambda)}\right\}}{\overline{\rho_{rta}(\lambda)}}}{\mathrm{RVS}(\theta, B)}$$

Only c1 is derived for each scan on orbit, no scaling of c0 and c2
This requires further study

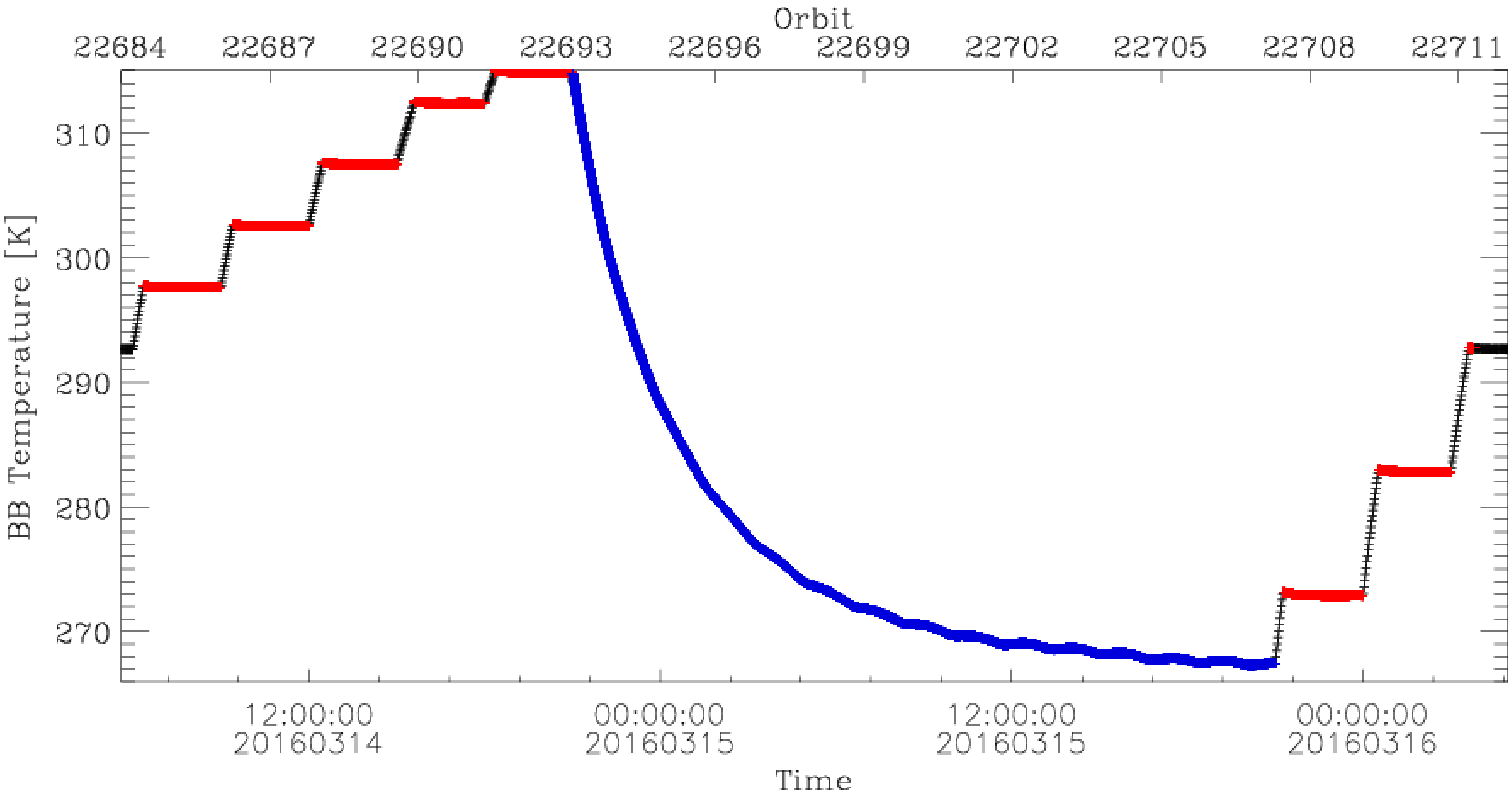
Summary

- The VIIRS SDR teams have been working diligently to address remaining issues in TEB calibration;
- The Aerospace's method was reviewed;
- An new method was proposed, preliminary results are promising:
  - Based on WUCD derived C coefficients and sensitivity analysis;
  - Only change one LUT, no other change is needed;
  - Effectively reducing 3 types of M15 scene BT biases:

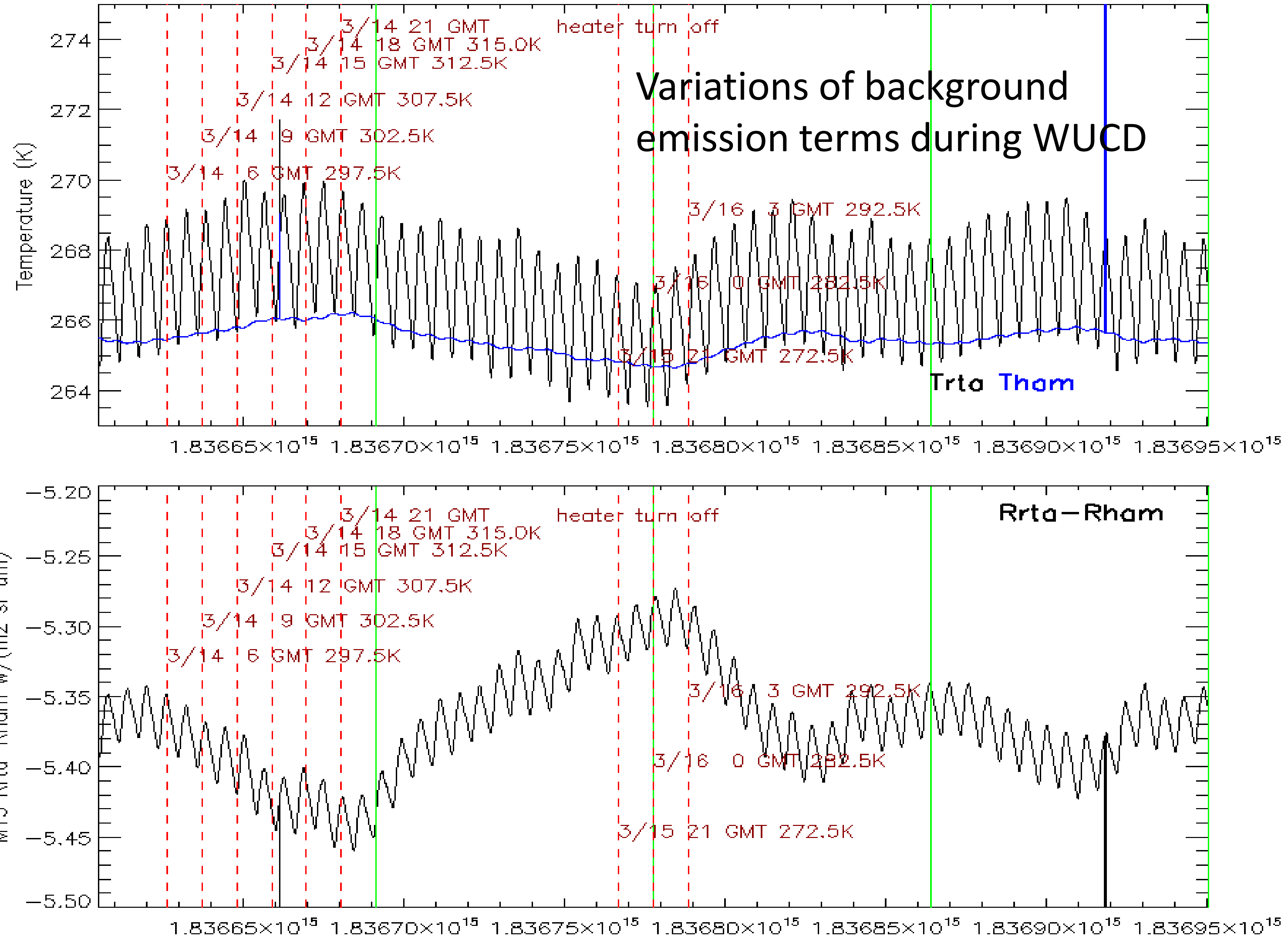
    1)Cold scene bias; 2)Constant bias; 3) WUCD bias.
- Next step:
  - Further refine the new method and apply it to all TEB bands
  - Conduct more impact studies for all methods;
  - Continue to explore other potential solutions.

Backups

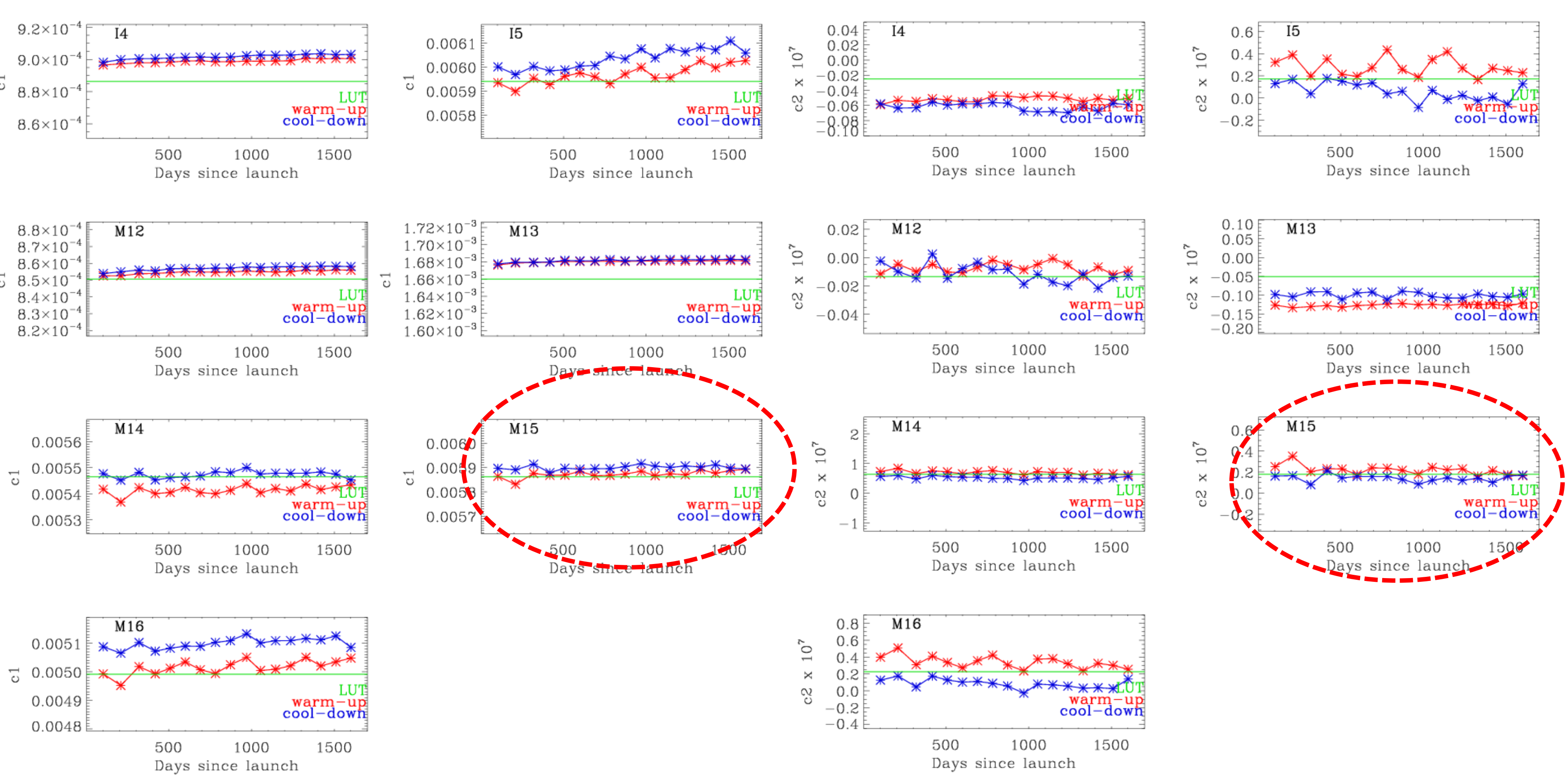
March 14-16 WUCD Event



Courtesy of NASA VCST, June 2016 MODIS/VIIRS Science Team Meeting


Variations of background emission terms during WUCD
Temperature (K)
274
272
270
268
266
264
3/14 21 GMT
heater turn off
3/14 18 GMT 315.0K
3/14 15 GMT 312.5K
3/14 12 GMT 307.5K
3/14 9 GMT 302.5K
3/14 6 GMT 297.5K
3/16 3 GMT 292.5K
3/16 0 GMT 282.5K
3/15 21 GMT 272.5K
Trta Tham
1.83665×10^15 1.83670×10^15 1.83675×10^15 1.83680×10^15 1.83685×10^15 1.83690×10^15 1.83695×10^15
−5.20
−5.25
−5.30
−5.35
−5.40
−5.45
−5.50
Rrta−Rham
3/14 21 GMT
heater turn off
3/14 18 GMT 315.0K
3/14 15 GMT 312.5K
3/14 12 GMT 307.5K
3/14 9 GMT 302.5K
3/14 6 GMT 297.5K
3/16 3 GMT 292.5K
3/16 0 GMT 282.5K
3/15 21 GMT 272.5K
1.83665×10^15 1.83670×10^15 1.83675×10^15 1.83680×10^15 1.83685×10^15 1.83690×10^15 1.83695×10^15

NASA VCST WUCD c1 and c2



Courtesy of NASA VCST, June 2016 MODIS/VIIRS Science Team Meeting