MIT LL Cal/Val Tasks

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NPP ATMS SDR Product Review

13 January 2012

Overview

Finished or Work in Progress Tasks

- Functional Evaluation (SEV-3)
- RF shelf to CP temp. (TUN-2)
- Optimal Space View Selection (TUN-1)
- Radiometric Sensitivity (VER-1)
- Dynamic Range (SEV-6)
- Scan Angle (SEV-7)
- Temperature Stabilization (SEV-8)
- Roll Maneuvers (TUN4-6)

Upcoming Tasks

- Center Frequency Stability (SEV-9)
- Resampling Evaluation (VER-3)
- SDR Comparisons with RAOB and NWP (VER-7 & 8)
- SDR Correction Factors (TUN-7)

Functional Evaluation

- **Objective: To evaluate that the sensor is operating as expected**
- **OPSCON Tasks: SEV-3, SEV-8, & TUN-2**
- **Resource: NGES RE-13676 “ATMS In-Flight Activation and Checkout Plan” (14Apr2006)**
- **Exit Criterion:**
  - **H&S and Passive telemetry are within operational limits**
  - **Internal Calibration Target (ICT) is within acceptable temperature range**
  - **Video channel tests indicates acceptable noise levels**
  - **Timing and synchronization is within acceptable levels**

ATMS Telemetry (TUN-2)

- **Objective: Verify the SDR algorithm LUT than converts the RF shelf temperature to an appropriate cold plate temperature.**

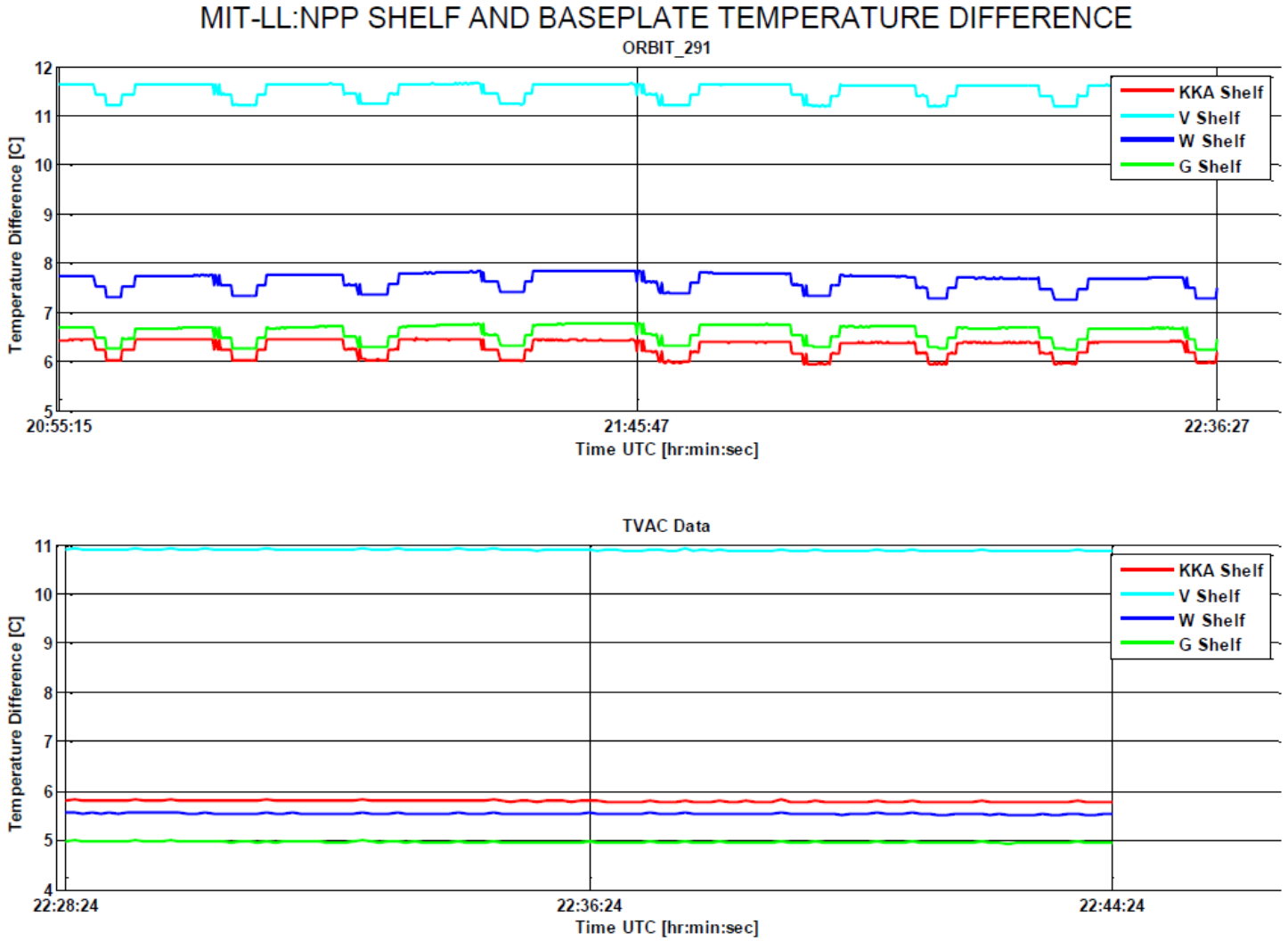
- **This LUT is used to determine the nonlinearity correction factor based on the present RF shelf temperature.**

Temperature Conversion Table

Cold Plate		-10 C	5 C	20 C
KKA Shelf	Ch. 1-2	-4	11	26
V Shelf	Ch. 3-15	2	16	31
W Shelf	Ch. 16	-4	11	25
G Shelf	Ch. 17-22	-5	10	25

- **Results: As expected, there is a different thermal gradient inside ATMS, but the table would remain the same and the NLC would be interpolated to the on-orbit shelf temperature.**

Preliminary Temperature Gradients



Internal Calibration Target

- **Goal:** Investigate potential solar heating (~0.05 K KAV and ~0.15 K WG) of the ATMS Internal Calibration Target (ICT) that the various teams identified immediately after launch.

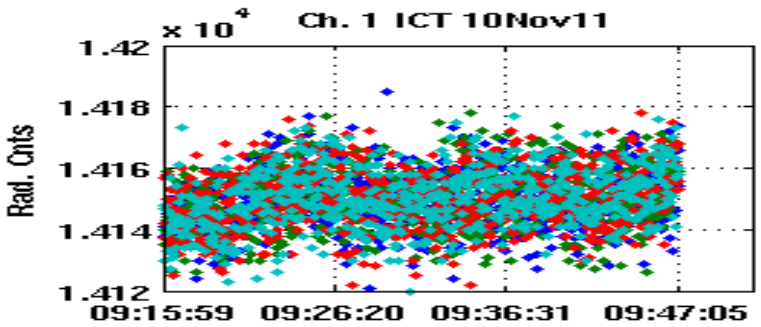
- **Expected result:** If the ICT temperature is increasing, there will be a corresponding increase in ICT radiometric counts

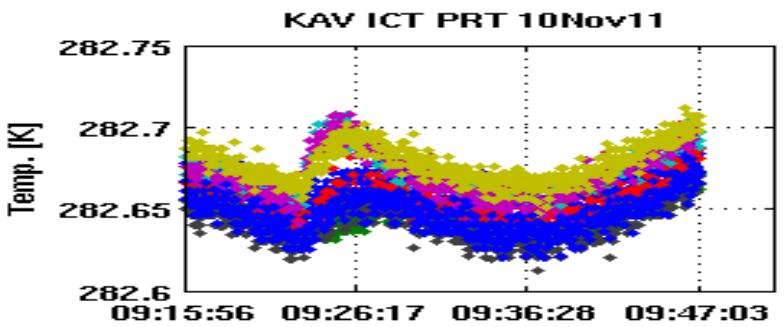
- NGES has delivered to the ATMS SDR team a detailed presentation (and EOC report will follow) confirming solar intrusion as the most likely root cause

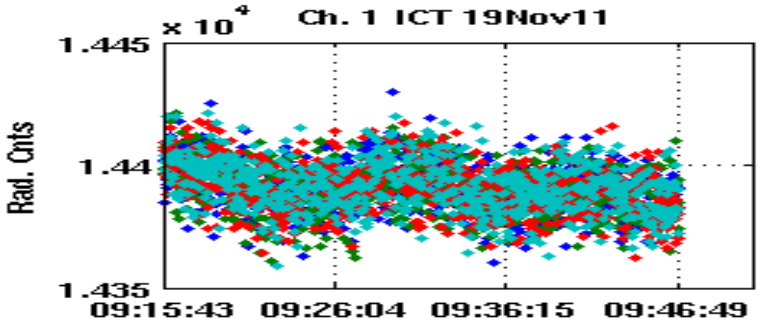
- **Results:**
  - A slight increase in radiometric ICT counts can be seen during ICT thermal heating indicating a real heating and not a voltage anomaly
  - The thermal heating is typically much smaller than most channel's NEDT
  - The thermal heating of the ICT has been consistent since activation
  - No noticeable effect from BUS and SPA PS voltage changes

- **Next Steps:**
  - More complete radiometric analysis of four ICT measurements
  - Optimal PRT weighting based on PRT placement and solar intrusion

KAV Target


Ch. 1 ICT 10Nov11
x 10^4
Rad. Cnts
1.42
1.418
1.416
1.414
1.412
09:15:59
09:26:20
09:36:31
09:47:05


KAV ICT PRT 10Nov11
Temp. [K]
282.75
282.7
282.65
282.6
09:15:56
09:26:17
09:36:28
09:47:03


Ch. 1 ICT 19Nov11
x 10^4
Rad. Cnts
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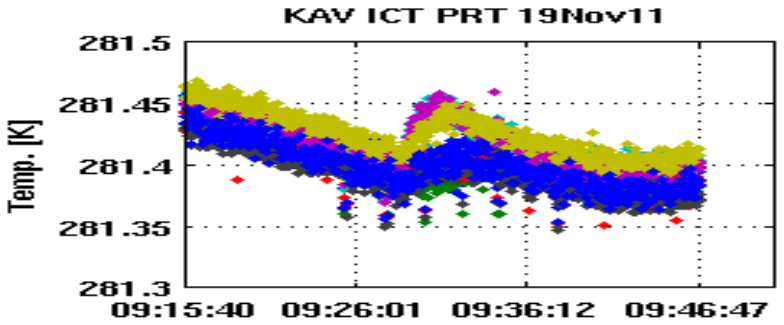
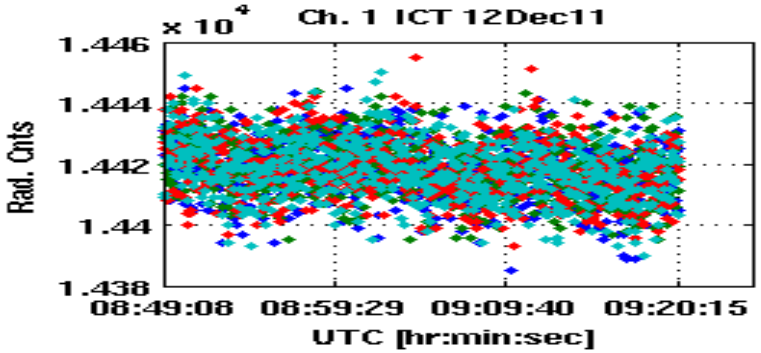
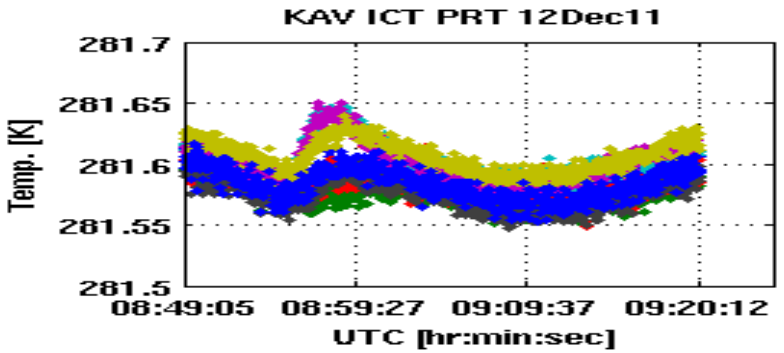
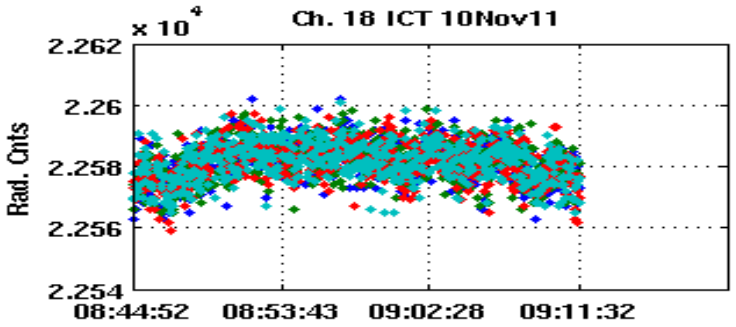
1.44
1.435
09:15:43
09:26:04
09:36:15
09:46:49

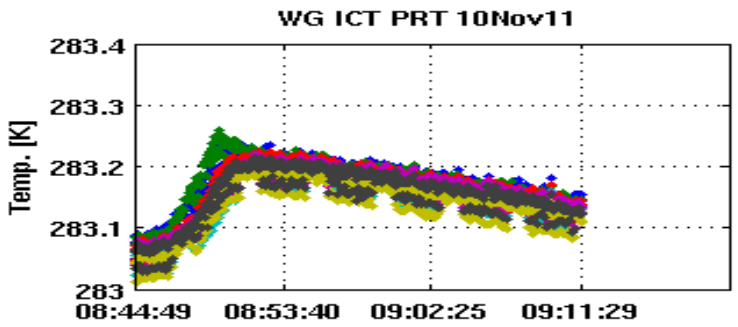

KAV ICT PRT 19Nov11
Temp. [K]
281.5
281.45
281.4
281.35
281.3
09:15:40
09:26:01
09:36:12
09:46:47

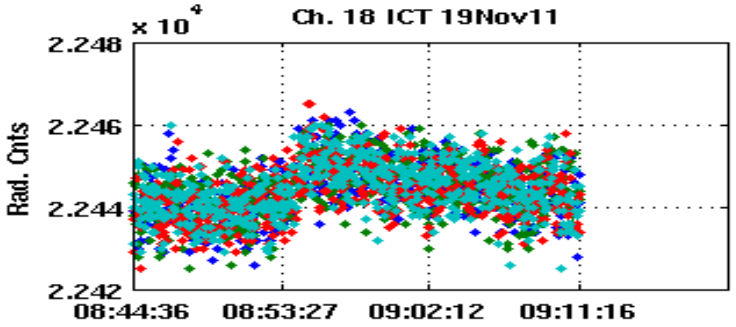

Ch. 1 ICT 12Dec11
x 10^4
Rad. Cnts
1.446
1.444
1.442
1.44
1.438
08:49:08
08:59:29
09:09:40
09:20:15
UTC [hr:min:sec]

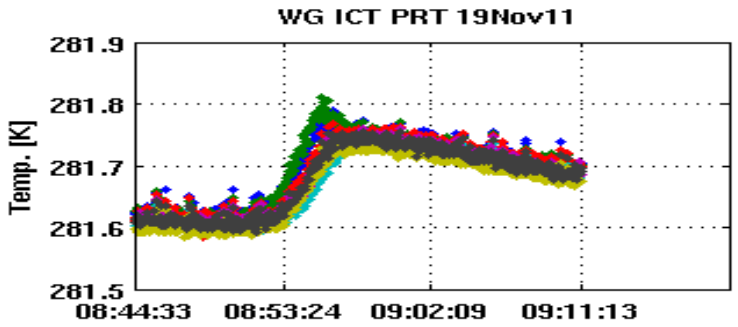

KAV ICT PRT 12Dec11
Temp. [K]
281.7
281.65
281.6
281.55
281.5
08:49:05
08:59:27
09:09:37
09:20:12
UTC [hr:min:sec]

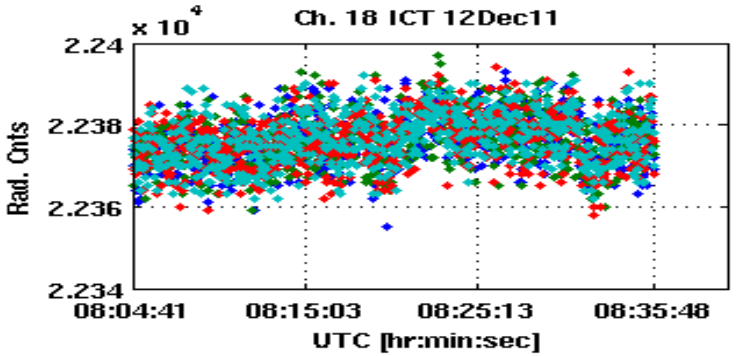
WG Target


Ch. 18 ICT 10Nov11
x 10^4
Rad. Cnts
2.262
2.26
2.258
2.256
2.254
08:44:52
08:53:43
09:02:28
09:11:32


WG ICT PRT 10Nov11
Temp. [K]
283.4
283.3
283.2
283.1
283
08:44:49
08:53:40
09:02:25
09:11:29


Ch. 18 ICT 19Nov11
x 10^4
Rad. Cnts
2.248
2.246
2.244
2.242
08:44:36
08:53:27
09:02:12
09:11:16


WG ICT PRT 19Nov11
Temp. [K]
281.9
281.8
281.7
281.6
281.5
08:44:33
08:53:24
09:02:09
09:11:13


Ch. 18 ICT 12Dec11
x 10^4
Rad. Cnts
2.24
2.238
2.236
2.234
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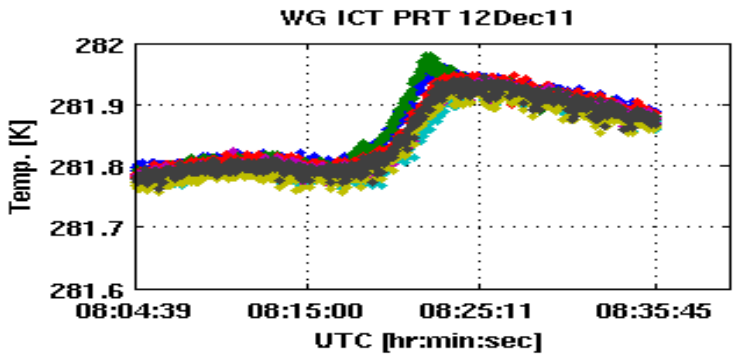
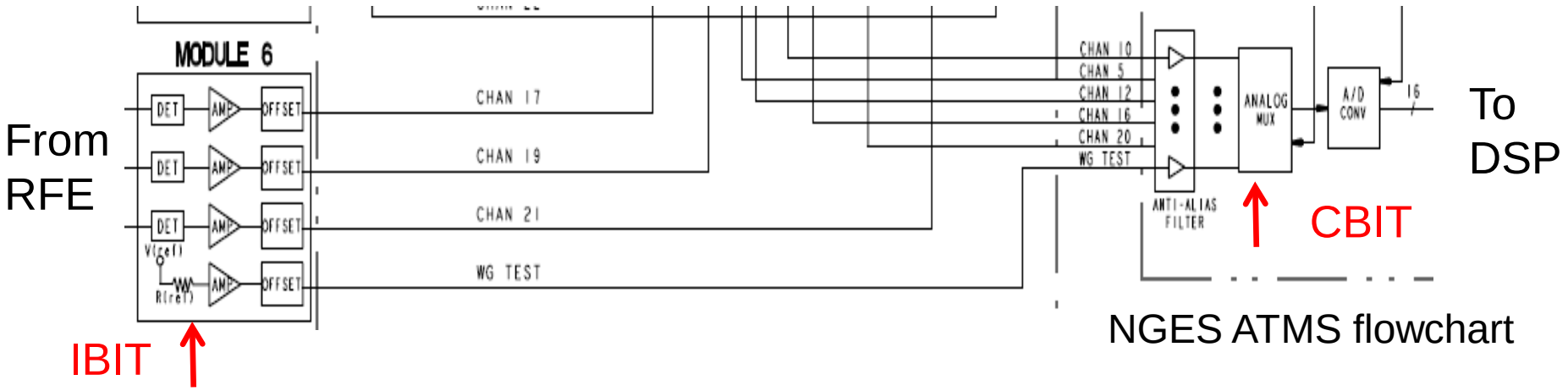
08:15:03
08:25:13
08:35:48
UTC [hr:min:sec]


WG ICT PRT 12Dec11
Temp. [K]
282
281.9
281.8
281.7
281.6
08:04:39
08:15:00
08:25:11
08:35:45
UTC [hr:min:sec]

Video Signal Test

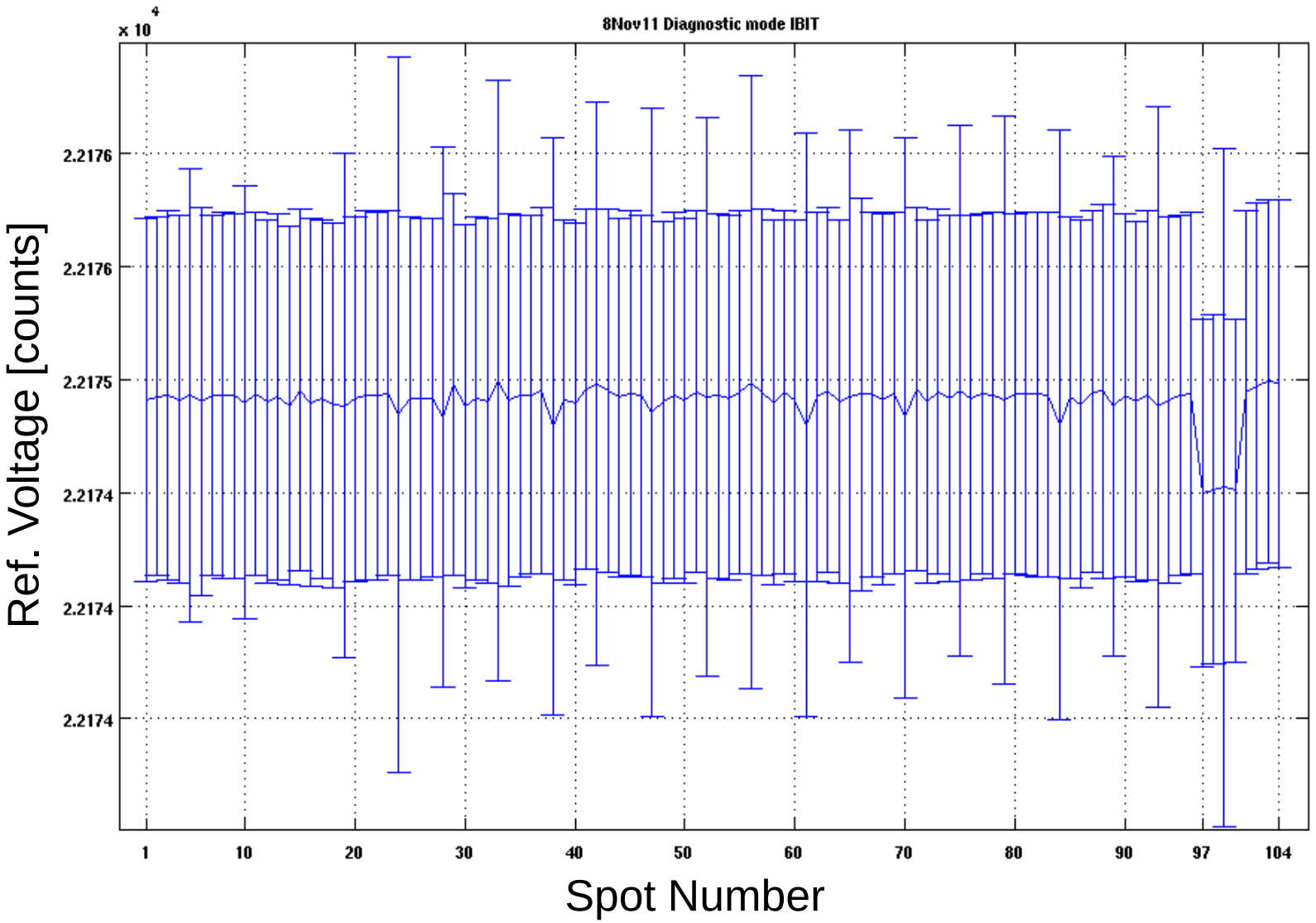
- **Objective: monitor the video signals for potential noise**

- **Two mechanisms:**
  1) **Continuous Build-In Test (CBIT) of a reference voltage injected into a multiplexer/ADC**
  2) **Initiated Built-In Test (IBIT) of a reference voltage injected after the RF detector (further "upstream" than the multiplexer/ADC in the flowchart)**



- **Results: No interference found at this point**

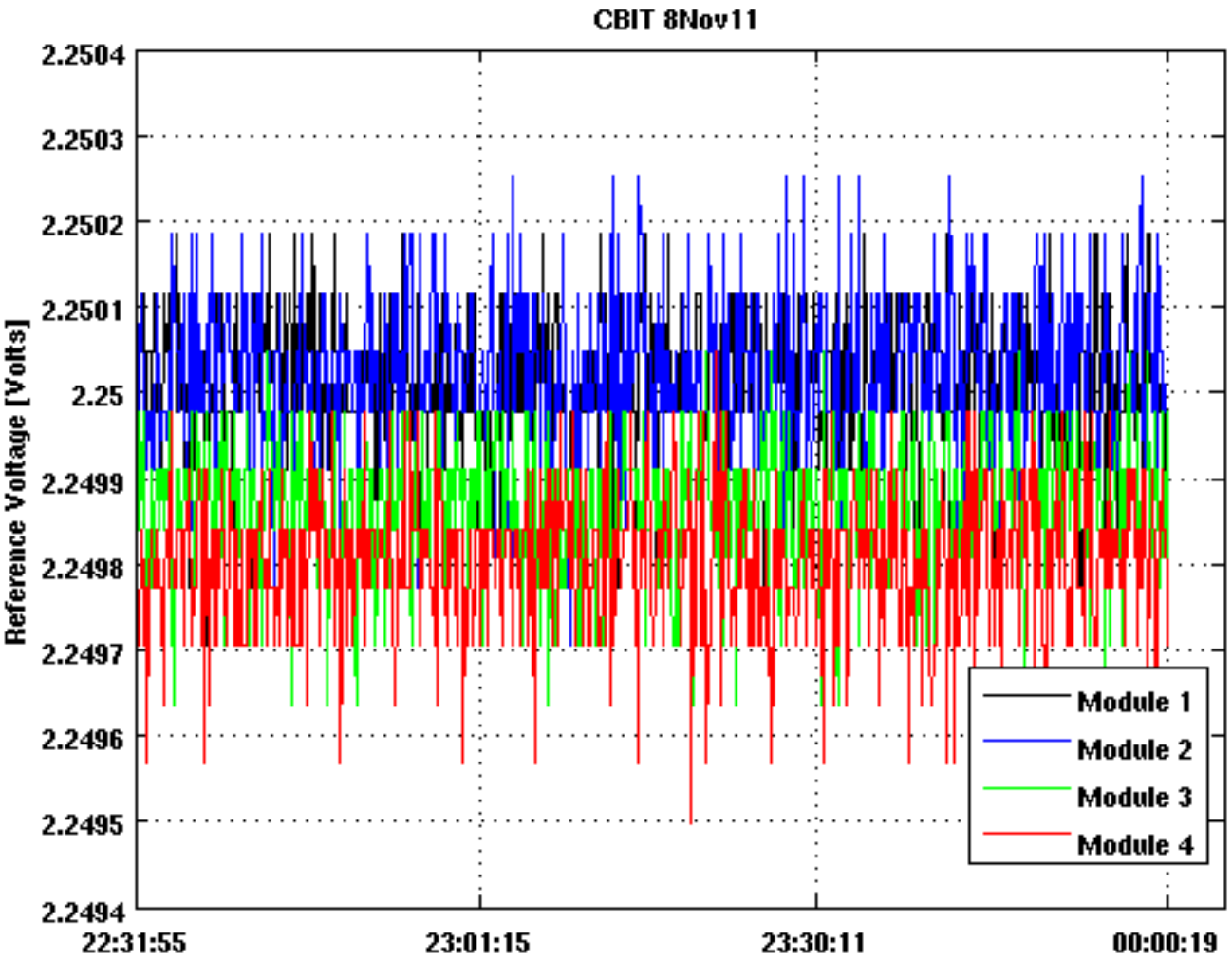
Video Signal Tests: IBIT



Counts at SVS position are slightly lower, but waiting for NGES report

Doesn't seem statistically significant

Video Signal test: CBIT



- Reference Voltage is 2.25 V
- Yellow limits are 1.8 to 2.7 V
- Modules cover all channels and IBIT
- Monitored by NGES and STAR

Timing and Synchronization

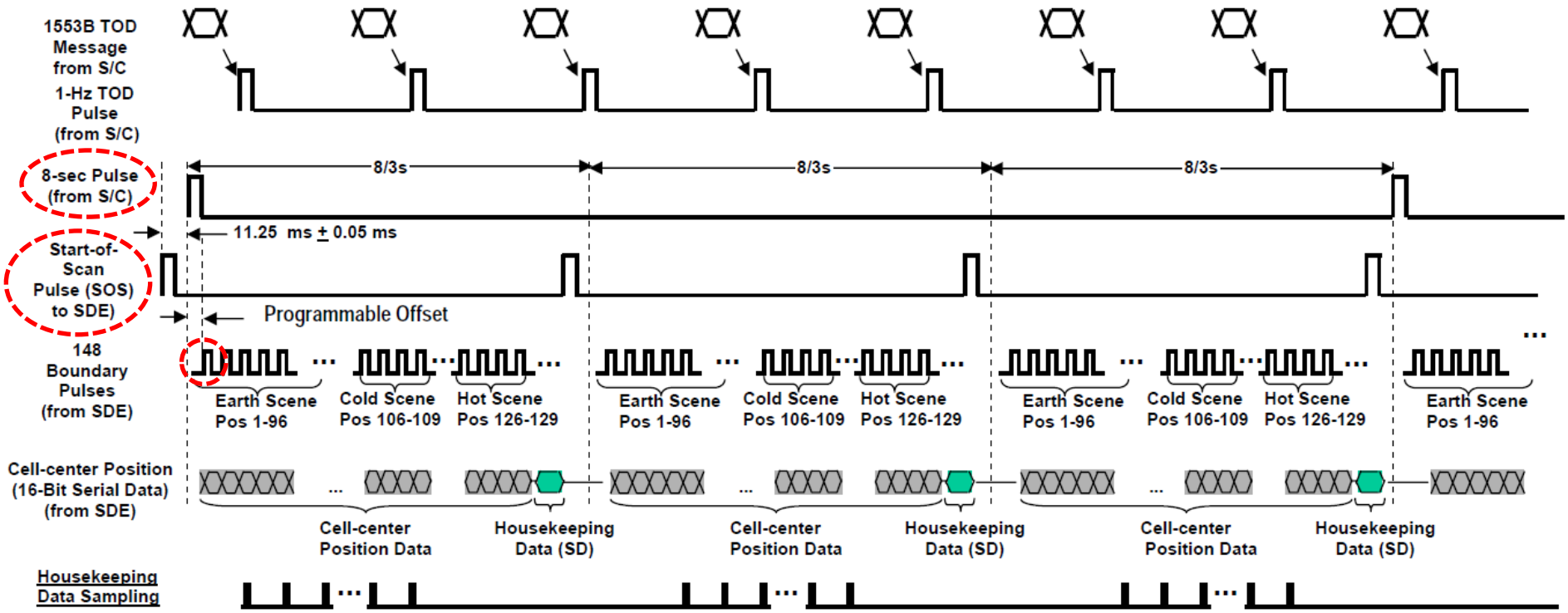
- **Objective: Check the timing of the synchronization of the ATMS scan pattern with the S/C synchronization pulse**

- **In diagnostic mode, the diagnostic packets has the Start of Scan and Scan Sync timestamps, which are compared with the timestamp of the first EV (BP1) spot to see if they match the ATMS timing diagram in the PFM Calibration Data Book**

- **NGES ATMS In-Flight Activation and Checkout Plan states "the BP1 time should be equal to Start of Scan Time + 11.25 ms within a tolerance of <= 5 ms."**

- **Results:**
  - **If you take into account that the BP1 timestamp is at the end of the data collection, the average difference is ~ 14 uS.**
  - **The average difference between the Start of Scan and Scan Sync timestamps is 11.183 ms (noted to be 11.25 ± 0.05 ms)**

ATMS Timing Diagram



Report 14029B
March 19, 2007

Figure 5-2 ATMS Beam Position with Respect to 8-Second Synchronization Pulse

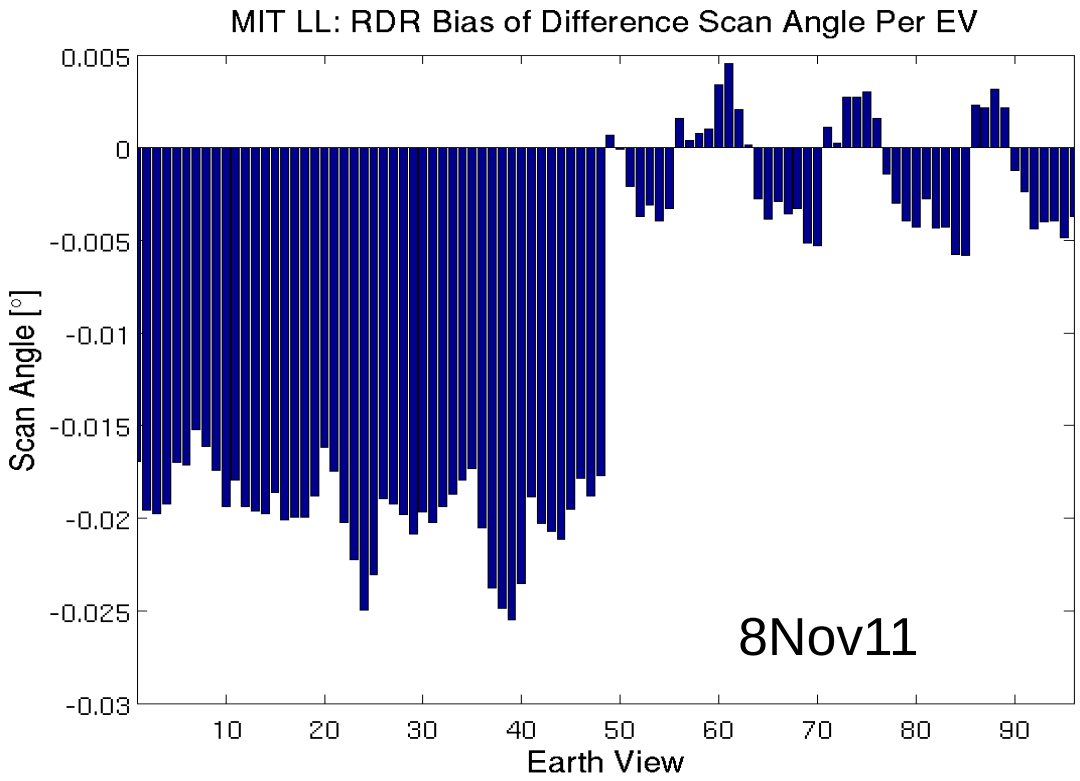
The timing of the beam position samples relative to the 8-second synchronization pulse is illustrated in Figure 5-2. The delay between the synchronization pulse and the start of the beam position 1 sample is set by a programmable (uploadable) offset. The PFM default offset is zero.

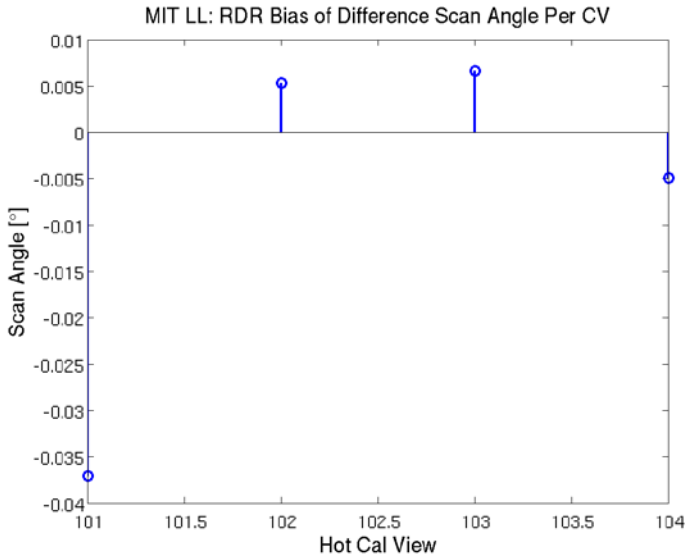
Performance Evaluation

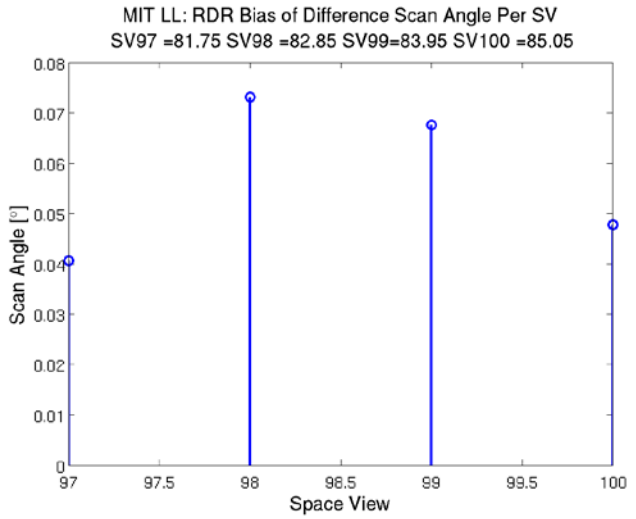
- **Objective: To evaluate that the sensor is operating as expected**
- **Tasks: TUN-1, SEV-6, SEV-7, VER-1**
- **Resources:**
  - **NGES RE-13676 "ATMS In-Flight Activation and Checkout Plan" (14Apr2006)**
  - **ATMS SDR Validation Operations Concept (OPSCON) and Cal/Val Task Description (24May2011)**
- **Exit Criterion:**
  - **Scan angles are within operational limits**
  - **Dynamic range is within specification**
  - **Selection of the best Space View Sector**
  - **Radiometric sensitivity meets requirements**

Scan Drive: Scan Angle Error

- NGES EV requirements: ± 0.035 deg.
- NGES SV and ICT req.: ± 2.25 deg.
- RE-13676 (14Apr2006)
- Data analyzed were within limits



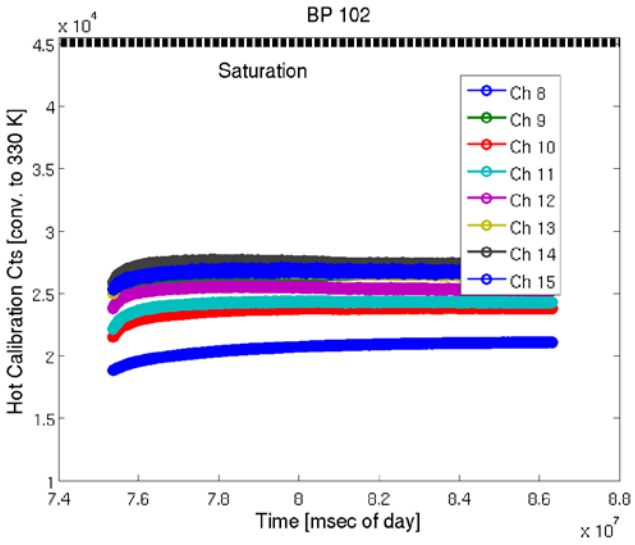


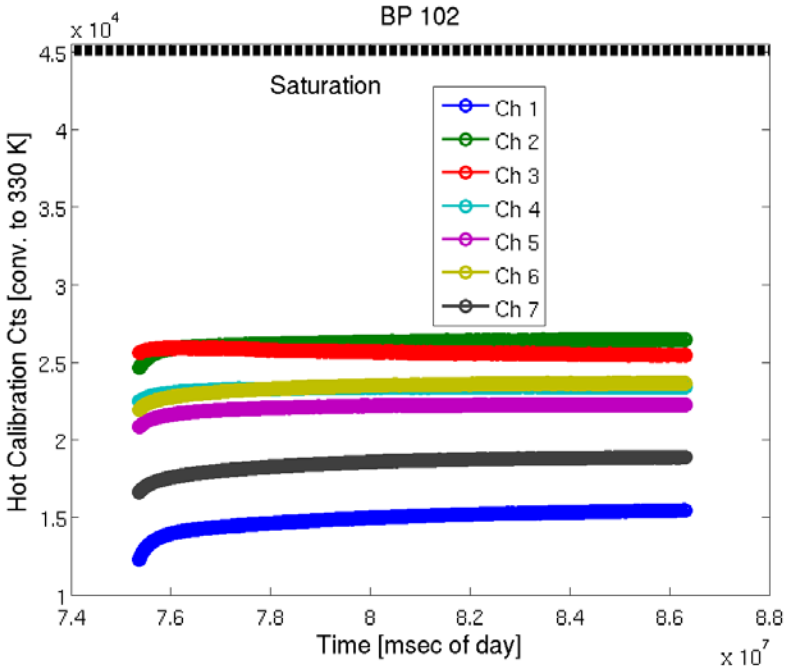


A/D Converter: Dynamic Range

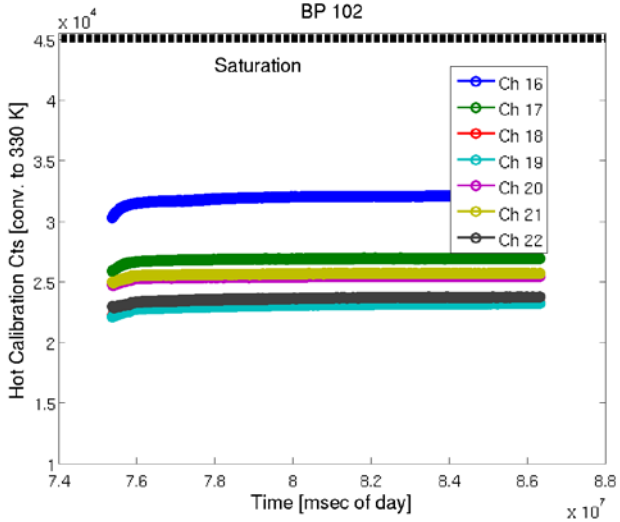
- **Objective:** To verify that the radiometric counts do not exceed specified limit of 45,150 to be within the allowable range of the A/D converter

- **Results:** Counts were extrapolated to 330 K and still maintained a large overhead margin





8Nov11



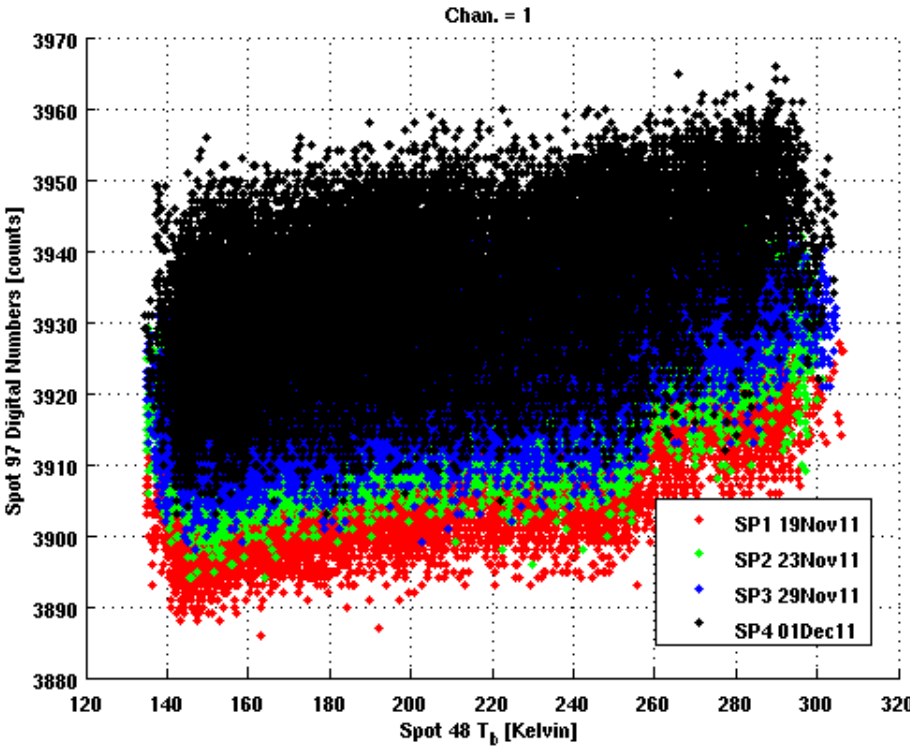
Optimal SVS Selection

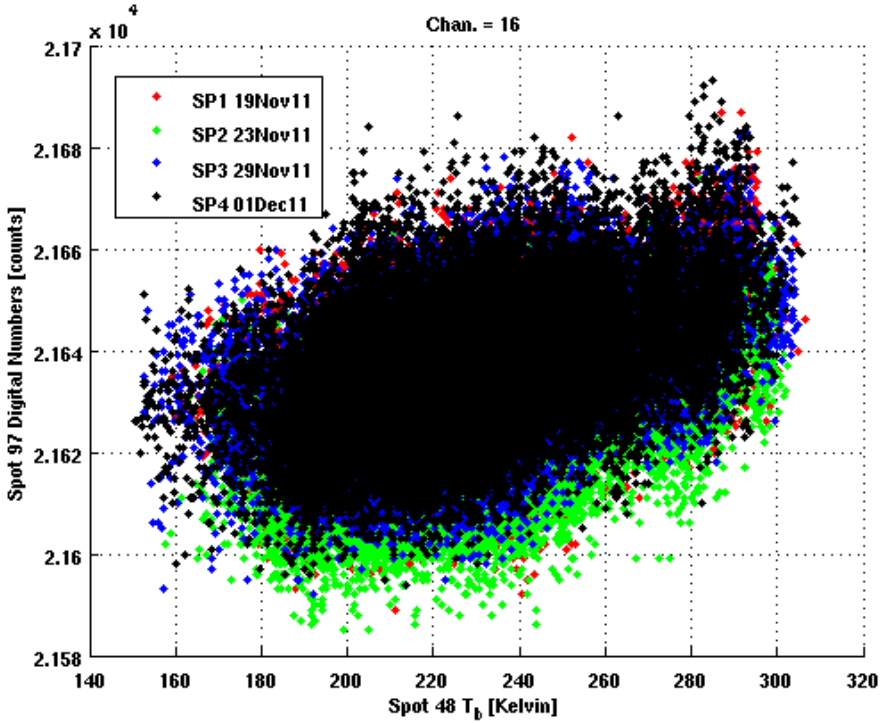
- **Goal:** Evaluate the ATMS SP (i.e., Space View Sectors) for the least amount of contamination due to spacecraft and Earth

- **Technique:** Compare the EV brightness temperatures (i.e., radiance) with SVS counts for correlation through scatter plots, time series plots, and periodograms

- **Results:**
  - Analysis indicates a correlation between the SVS counts and the EV brightness temperature for quasi V-polarized window channels (may have some correlation at the quasi H-pol. V-band window channel)
  - All four SVS showed correlation, but none were statistically significant enough to warrant naming one optimal
  - SVS 1 was chosen due to antenna range measurements and that the EV contamination was estimated to be higher than S/C contamination (NGES PFM Data Calibration Book) for SVS1 analysis

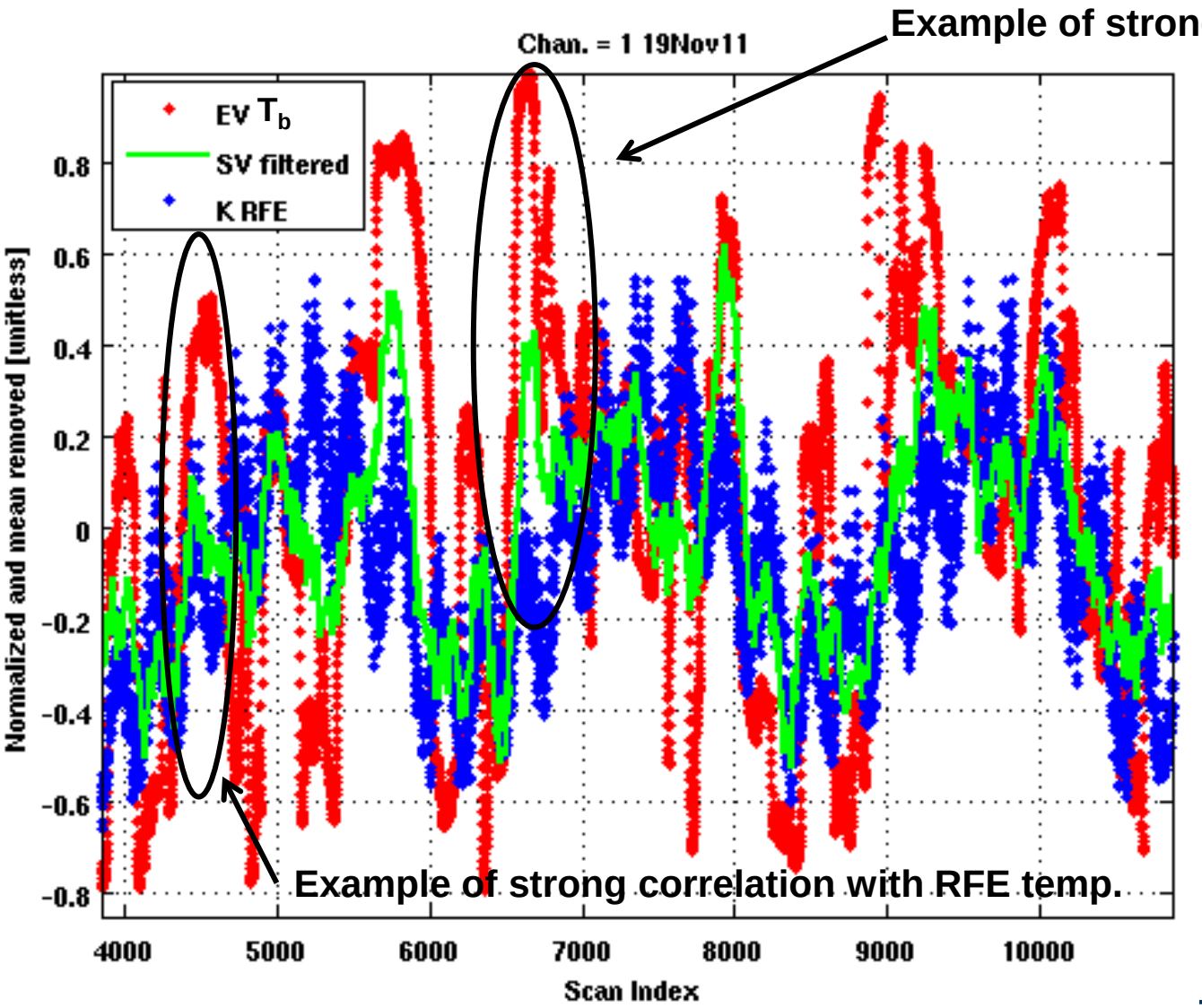
Scatter Plots: SV Spot 97 Cnts vs EV 48 Tb





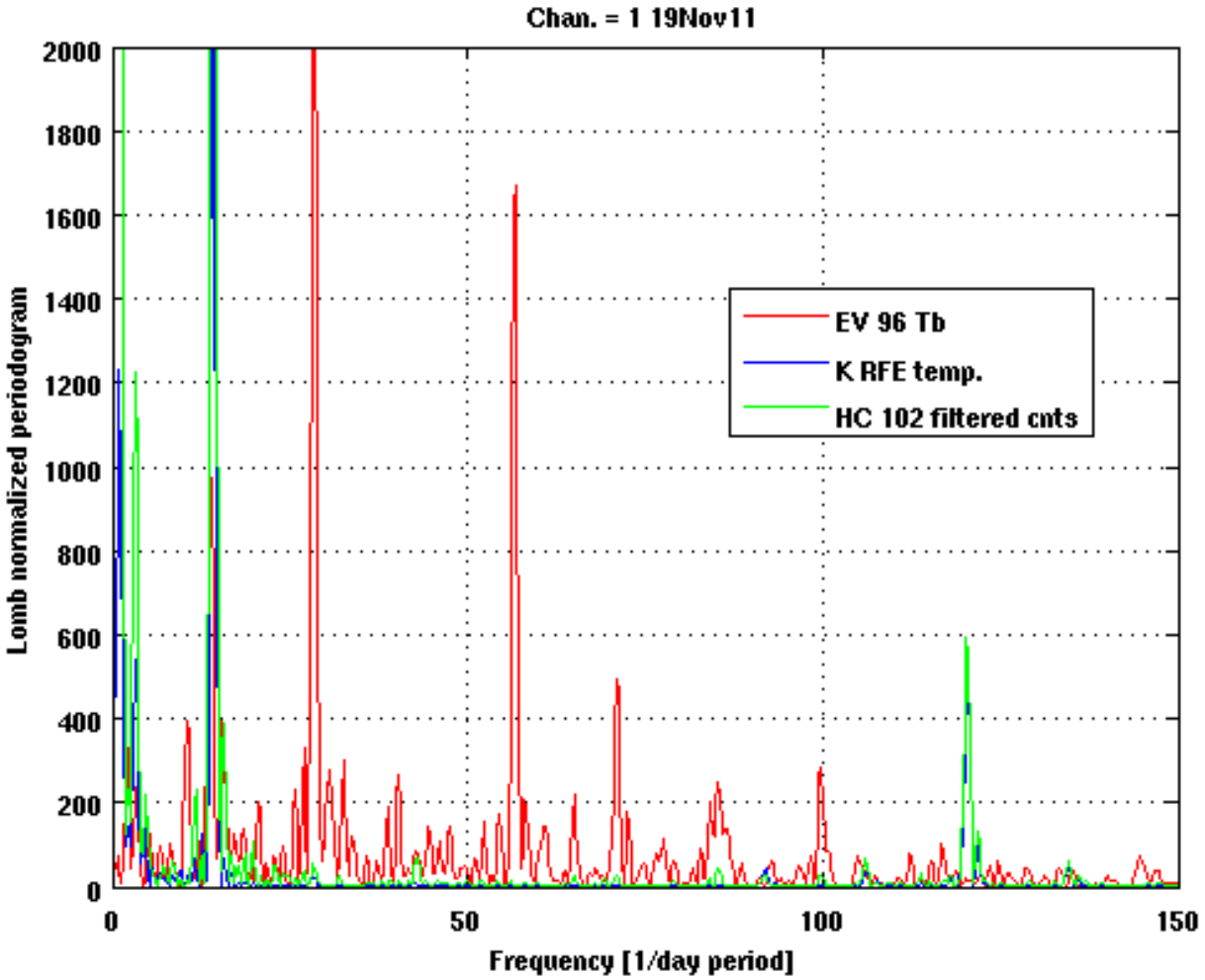
- Plots above indicate a correlation between EV Tb and SV counts
- Disclosure: Tb calibrated using all 8 calibration measurement (4 SV & 4 HC)
- Channels affected seem to be the quasi-V polarized channels (Ch. 1, 2, & 16)
- May be some correlation in V-band window channel (Ch. 3).
- Spot 100 of the SVS had similar response
- Correlation coefficient about the same for all SVS spot 97 (between 0.4 to 0.55)

Time Series: Three Orbits



- Normalized
- Mean removed
- Entire day 19Nov11
- EV Spot 96 Tb
- Filtered SV 97 counts
- K RFE HK temp.
- Channel 1 K band

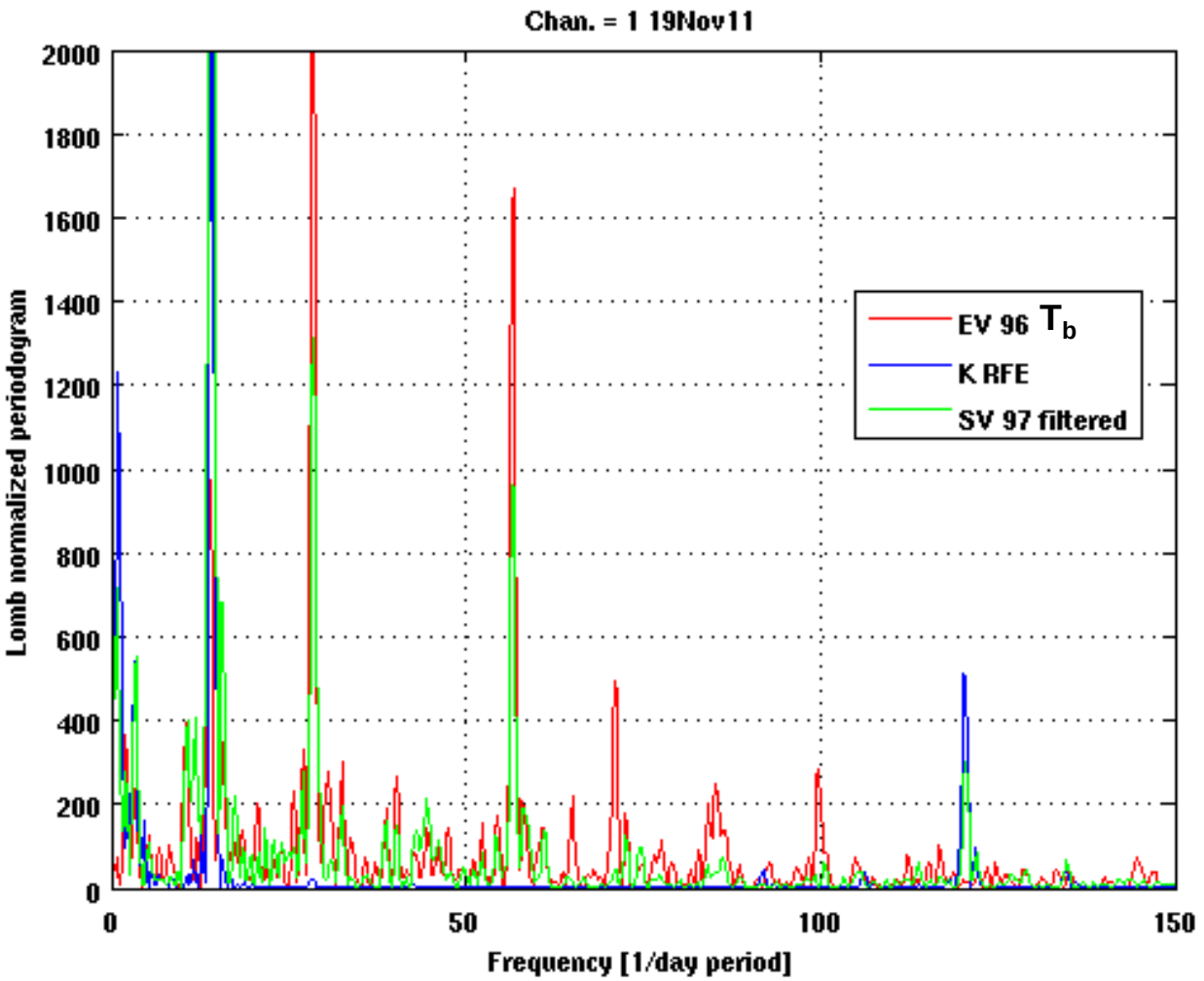
Spectral Analysis: Internal Cal. Target



- Normalized Lomb Periodogram
- Mean removed
- Entire day 19Nov11
- EV Spot 96 Tb (red)
- Filtered HC spot 102 counts (green)
- K RFE HK temp. (blue)
- Channel 1 K band

Internal cal. target shares harmonics with thermal drift only

Spectral Analysis: SVS1



SV shares harmonics with thermal drift *and EV Tb*

- Normalized Lomb Periodogram
- Mean removed
- Entire day 19Nov11
- EV Spot 96 Tb (red)
- Filtered SV 97 counts (green)
- K RFE HK temp. (blue)
- Channel 1 K band
- Similar results with other SV spots

ATMS SDR Algorithm: Cold Space Bias

- NGES supplied estimates of the cold calibration observation uncertainties:
  - Earth Contamination through antenna sidelobes
  - Spacecraft contamination through antenna sidelobes
  - Uncertainty of the actual cosmic background temperature

- ATMS SDR algorithm has an additive cold bias correction factor
  - Has two user options: per channel or per “band”
  - Size is either (# of chan. x # of SVS) or (5 bands x # of SVS)
  - Only SVS1 (6.66°) has values calculated
  - Cold bias correction is in the ATMS-SDR-CC PCT

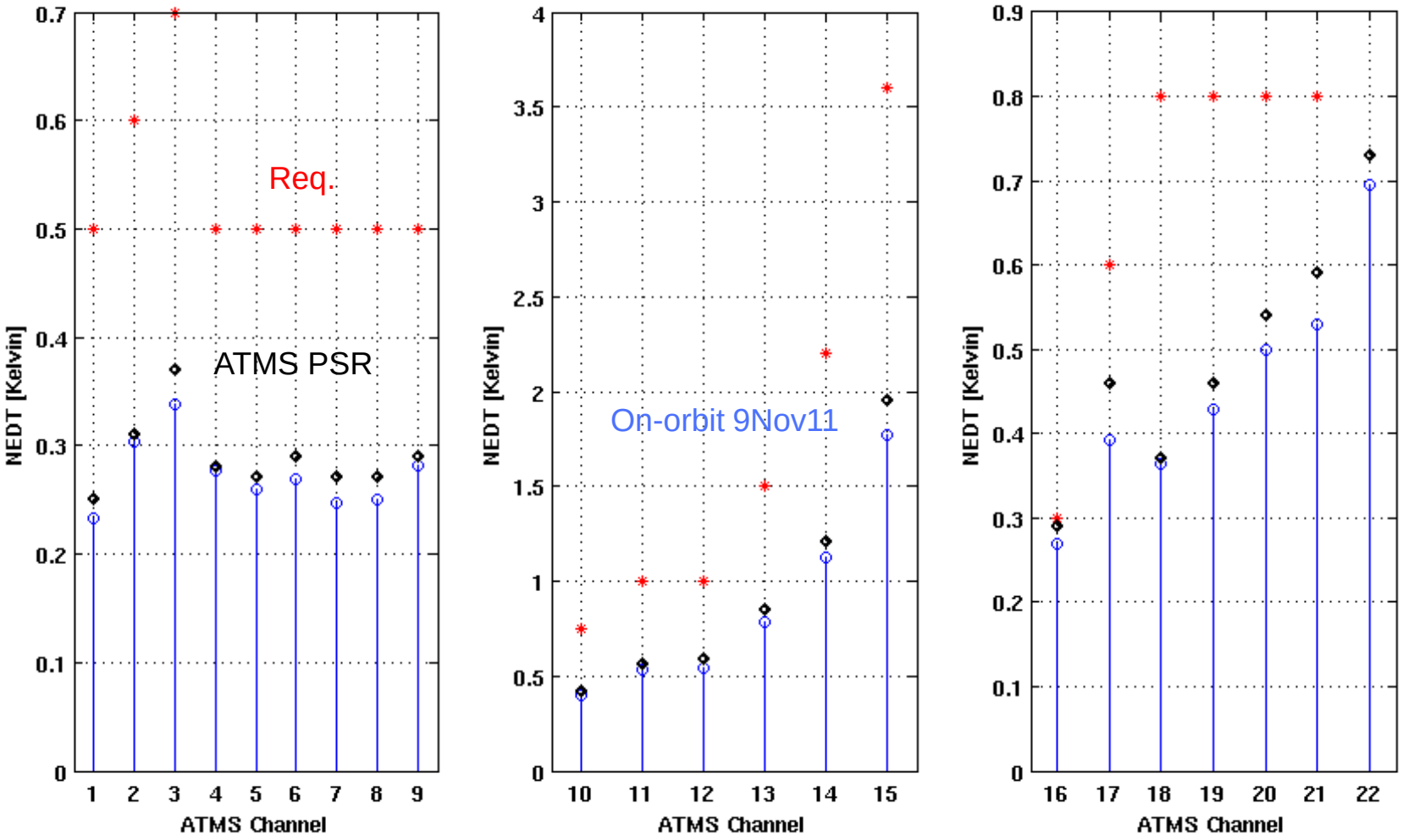
SVS Conclusions

- Ch. 1, 2, & 16 have correlation between SVS counts and EV Tb and share harmonics (but not internal calibration load)
- Quasi H-pol. Ch. 3 shows some correlation as the quasi V-pol. above
- Ch. 18 SV, which seems to have little correlation, also has harmonics shared by EV (same with many chan. that showed little correlation); will try to identify physical artifacts for Tb harmonics (e.g., poles)
- Need to investigate:
  - Quantify TDR/SDR impact
  - Potential impact on scan bias and non-linearity measurements
  - Whether heritage sensors have same correlation
  - Leverage TVac measurements
- Identify possible mitigation technique in either existing calibration framework or with a code change (e.g., a cold bias correction that is a function of EV counts) but only really needed for CDR

Radiometric Sensitivity

- **Objective: Determine if the ATMS radiometric sensitivity has changed post launch**
- **Compare NEDT post-launch with values at ATMS Pre-Ship Review (PSR) and NEDT requirements**
- **Results: No change from ground measurements (i.e., meets requirements)**
- **NEDT calculation followed the NGES ATMS System Calibration Test Procedure (AE-26842C)**
- **Used 4,000 measurements in following graph, but did not extrapolate to 300 K (yet)**
  - **Red asterisks: NEDT requirements (@ 300 K)**
  - **Black diamonds: NEDT reported at ATMS PSR (@ 300K)**
  - **Blue circles: NEDT measurement from 9Nov11 (post launch at ~ 280 K)**

Radiometric Sensitivity



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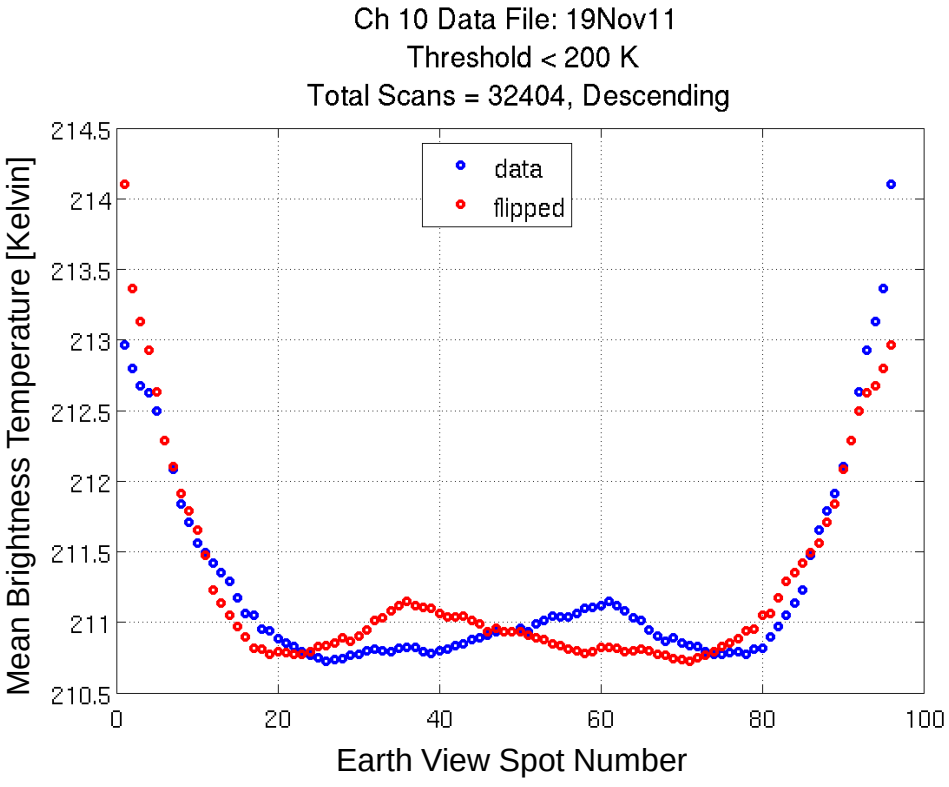
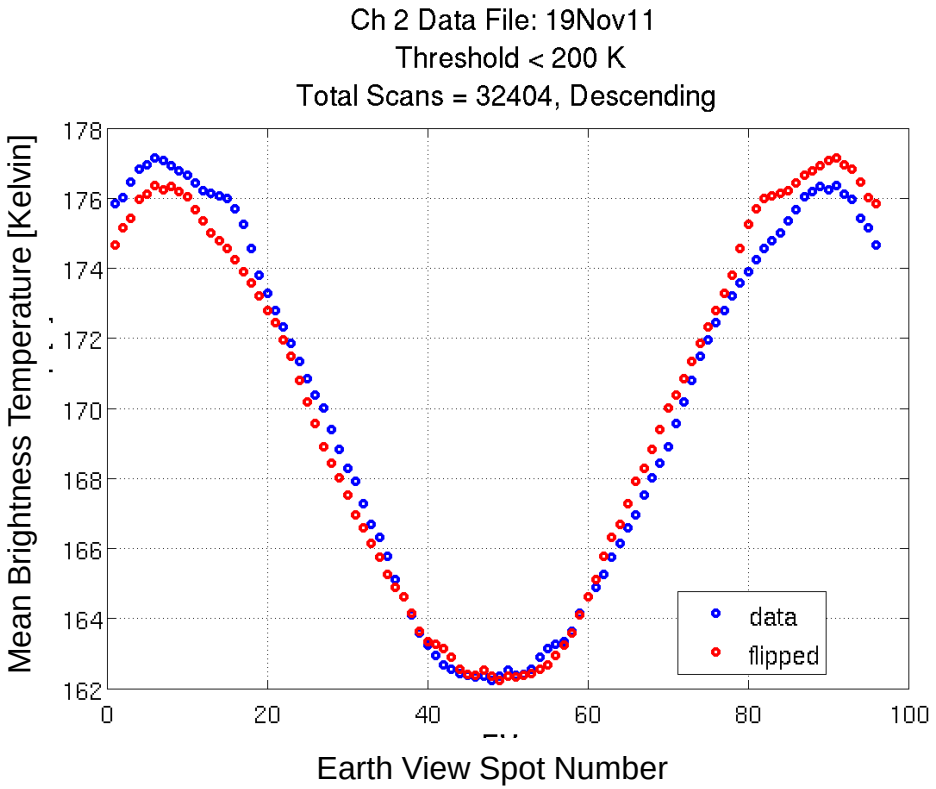
NPP ATMS S/C Maneuvers

- **Objective: Use the Earth's limb to identify antenna pattern asymmetries**
- **Goal: Use maneuver data (along with other empirical measurements) to determine the TDR to SDR correction factors in the ATMS SDR algorithm (NWP & RTM agnostic)**
- **Tasks: TUN-4, TUN-5, & TUN-6 (-65° roll, 25° roll, & pitch)**
- **Resource: ATMS SDR Validation Operations Concept (OPSCON) and Cal/Val Task Description (24May2011)**
- **Results: Still analyzing data…**

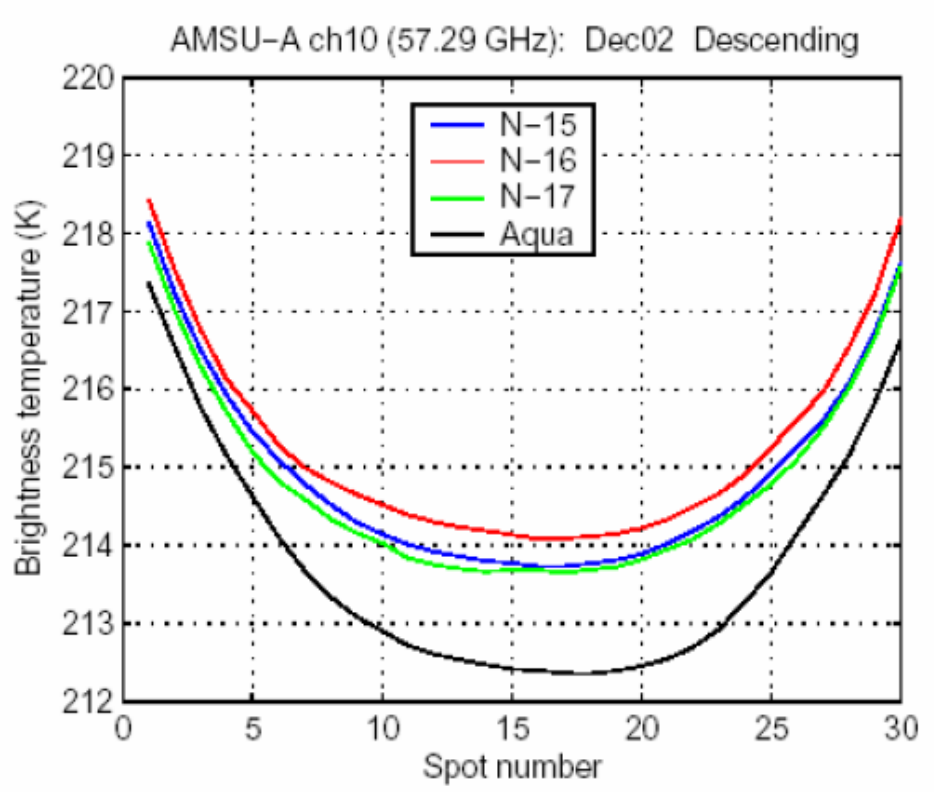
Preliminary NPP ATMS Asymmetry

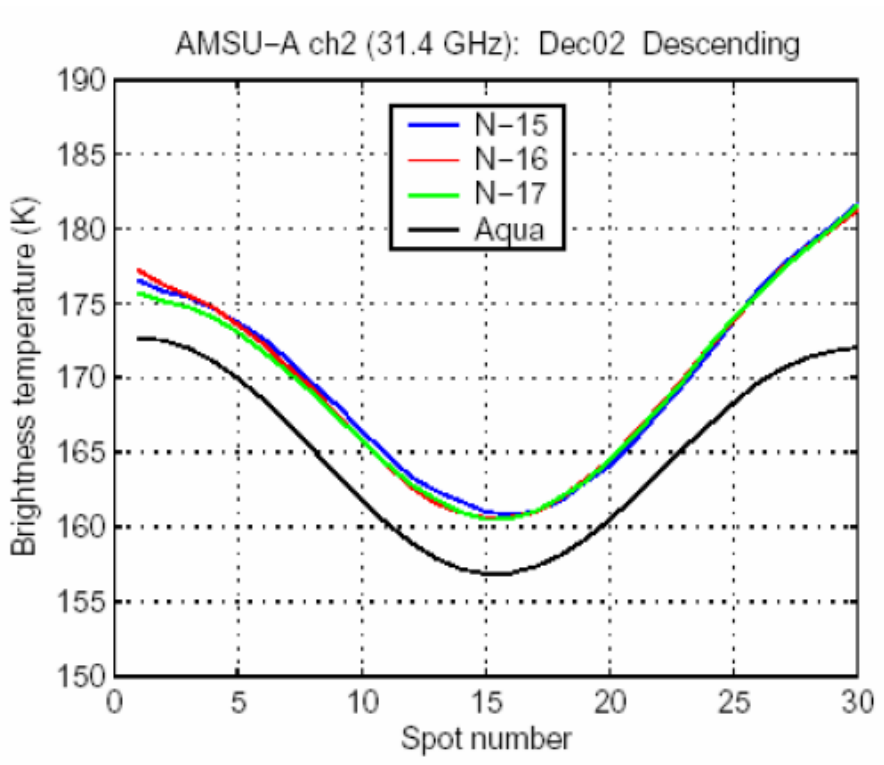




Includes only pixels with a Ch. 2 Tb less than 200 K (rudimentary method to identify clear-air ocean conditions; next will use the VCM)

Heritage AMSU Asymmetry



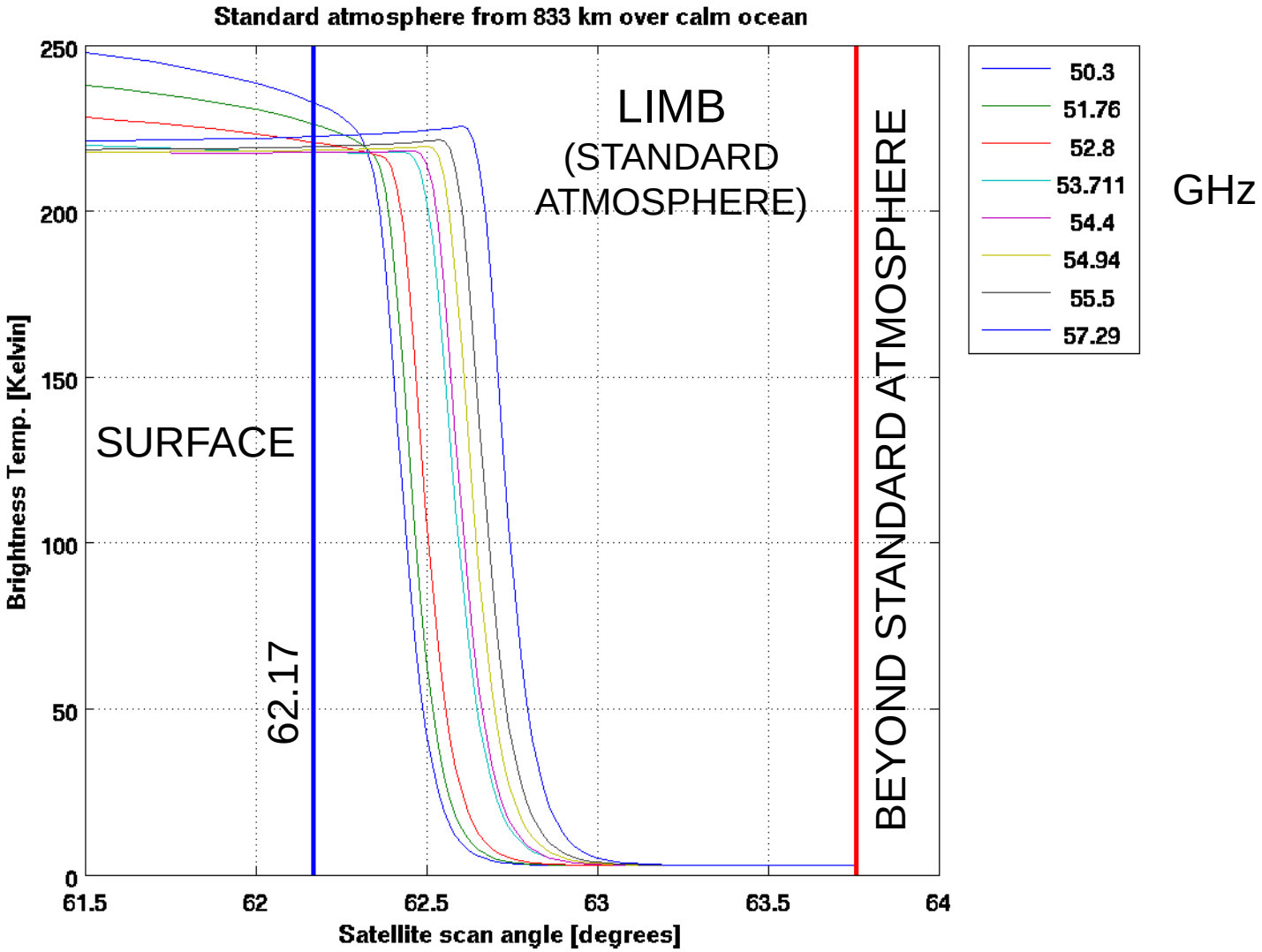


William J. Blackwell "Characterization and Possible Causes of Antenna Temperature Cross-Track Asymmetries for the AMSU-A Instruments on NOAA-KLM and Aqua" Project Report NOAA-32 23 Mar 2005

Analysis Technique Overview

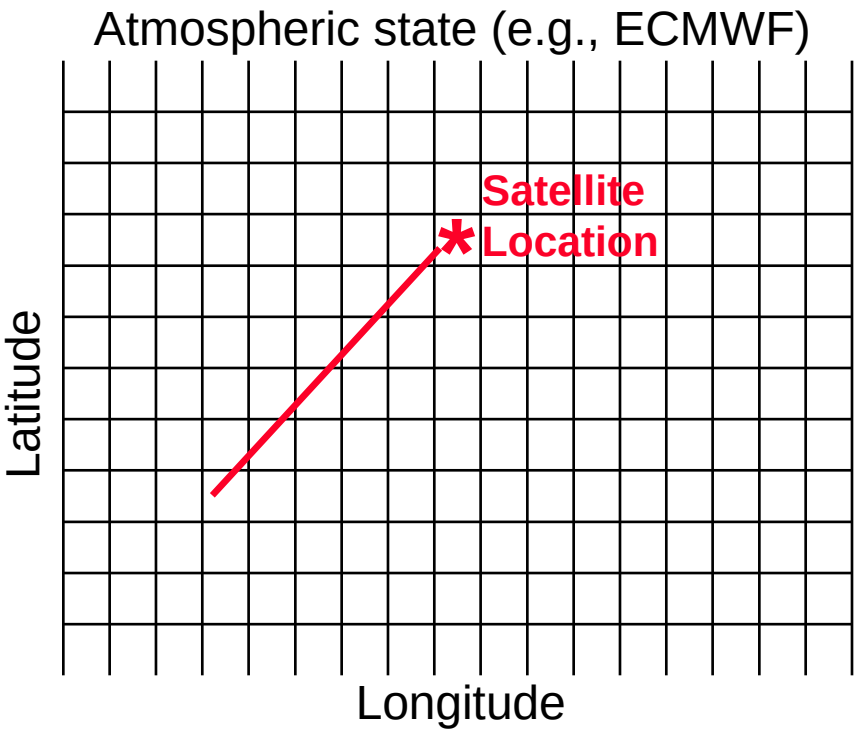
- **Simulate the sensor's antenna temperature across the Earth's limb**
- **Simulation includes**
  - **Frequency characterization (passband)**
  - **Spatial characterization (antenna pattern)**
  - **Globe geometry (not planar stratified)**
  - **Atmospheric state (NWP)**
- **Compare simulations verse actual measurements**
- **Correction would utilize these results and investigate all of the other potential sources of asymmetry (see Blackwell report)**
- **Correction would be applied to TDR to see if the scan bias diminishes (would need an exhaustive data set)**

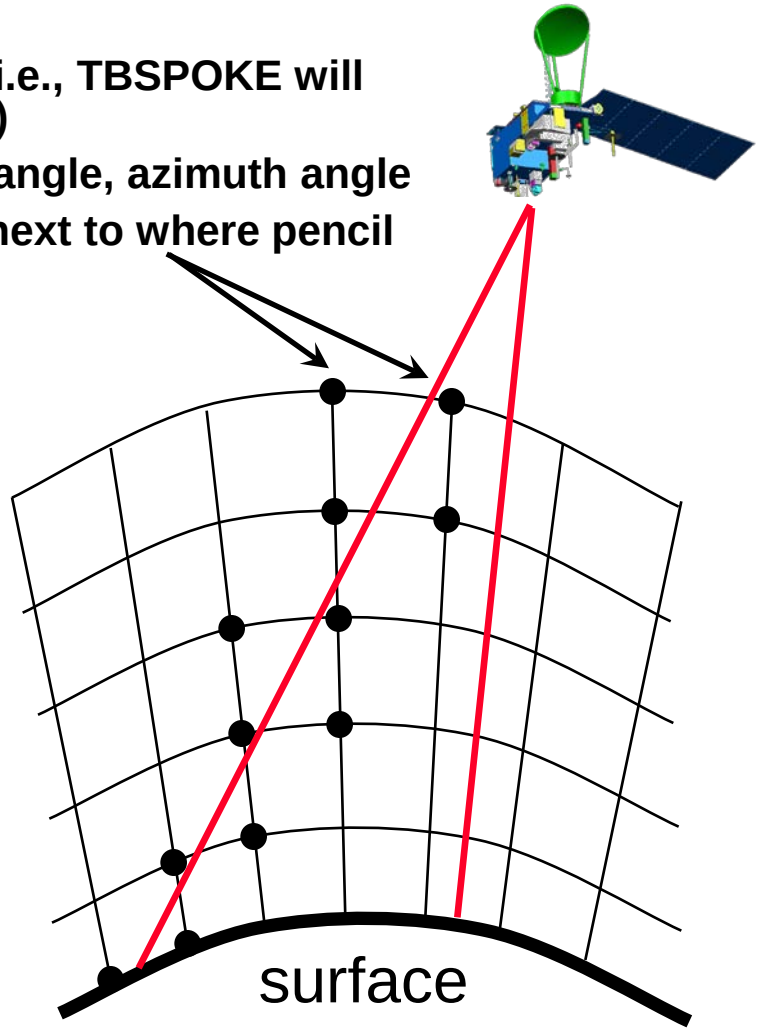
T_B's Across Earth/Space Transition



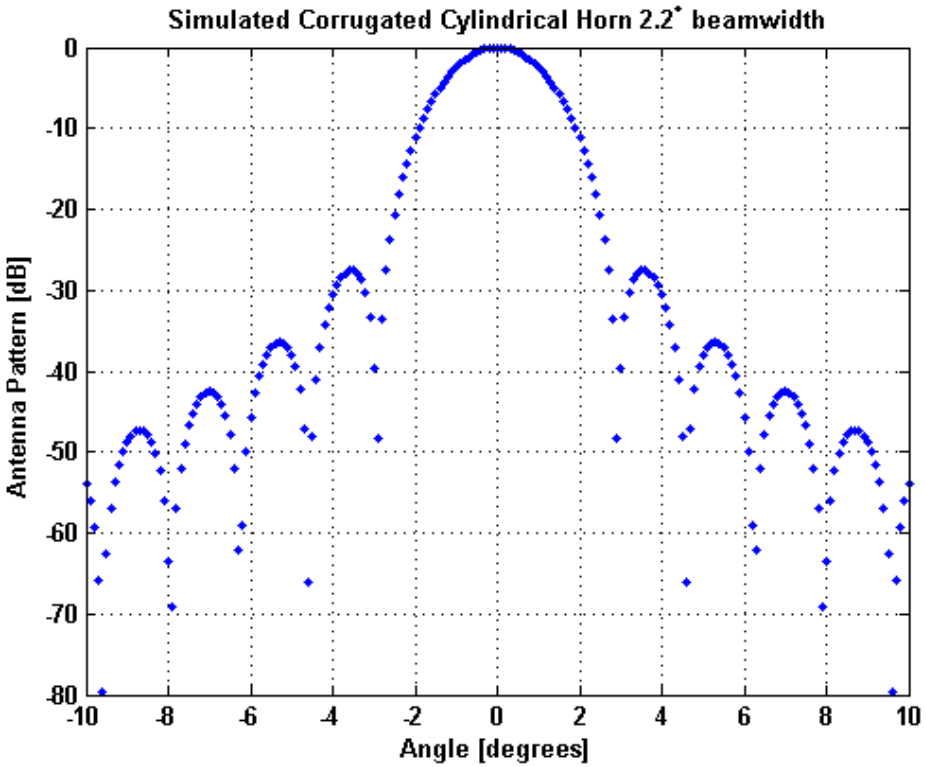
Radiative Transfer Model: TBSPOKE

- **Pencil-beam calculation**
- **Use with 3-D atmospheric state matrices**
- **TBSPOKE will be a code wrapper to TBSPHERE (i.e., TBSPOKE will output a single profile made up from the 3-D field)**
- **Potential TBSPOKE inputs: satellite lat/lon, scan angle, azimuth angle**
- **Use a weighted average of the parameter values next to where pencil beam enters contour**

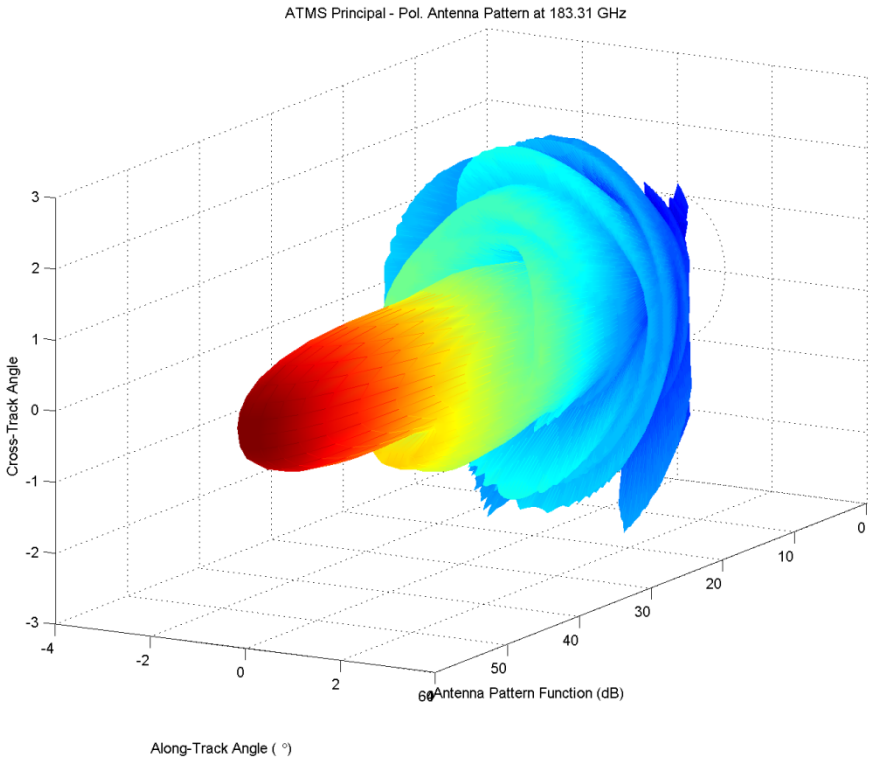




Antenna Patterns

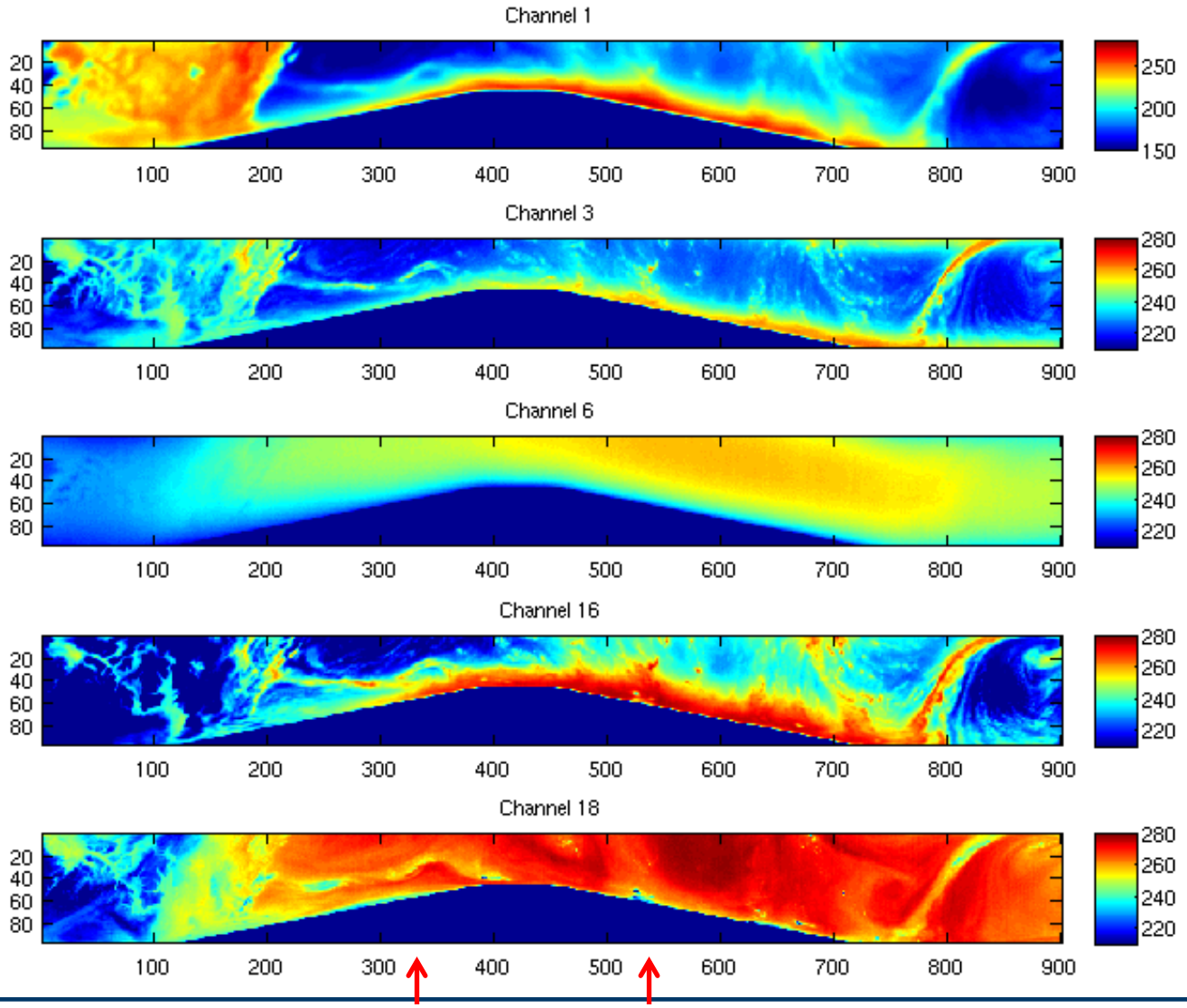


Simulated Corrugated Cylindrical horn (2.2°)



NPP ATMS CATR measurements

NPP ATMS 65° Roll (250)



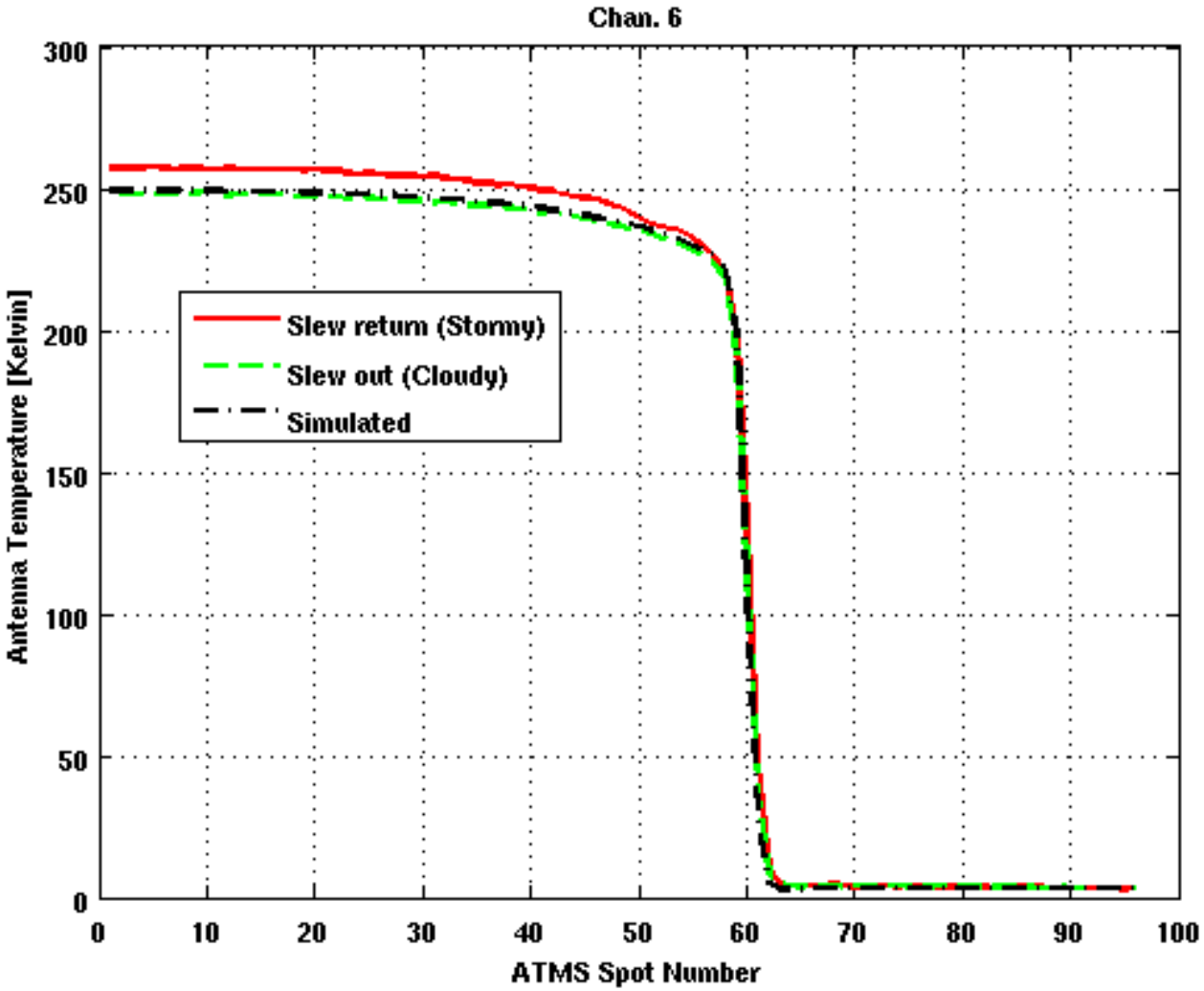
ATMS Cross Track Spot

Brightness Temperature [Kelvin]

9Dec11

ATMS Down Track Scan

Antenna Temperature Across Earth's Limb



- **Red is a scan during the slew back to nadir pointing**
- **Green is a scan during the slew toward deep space**
- **Black is a simulated scan using the Std76 atmos. and a Gaussian antenna pattern (cloud free)**
- **Opaque V-band channel (Ch. 6) that measures high in the atmosphere (above precipitation)**

Red is scan 525 (precip. near limb) & Green is scan 325 in previous slide (red arrows)

S/C Maneuver Conclusion

- Received ATMS data from the roll maneuvers on 9Dec11 & 12Jan12
- RT model is ready with minor upgrades planned
- Started scan bias assessment and plan to upgrade to use VCM
- Need to analyze NWP data (NCEP GFS & ECMWF forecasts are available)
- Need to incorporate S/C ephemeris and attitude data into an “absolute” angle calculation (i.e., convert quaternion to yaw, pitch, & roll)
- Need to start analyzing the difference between idealized antenna patterns and actual measurements

BACKUP SLIDES

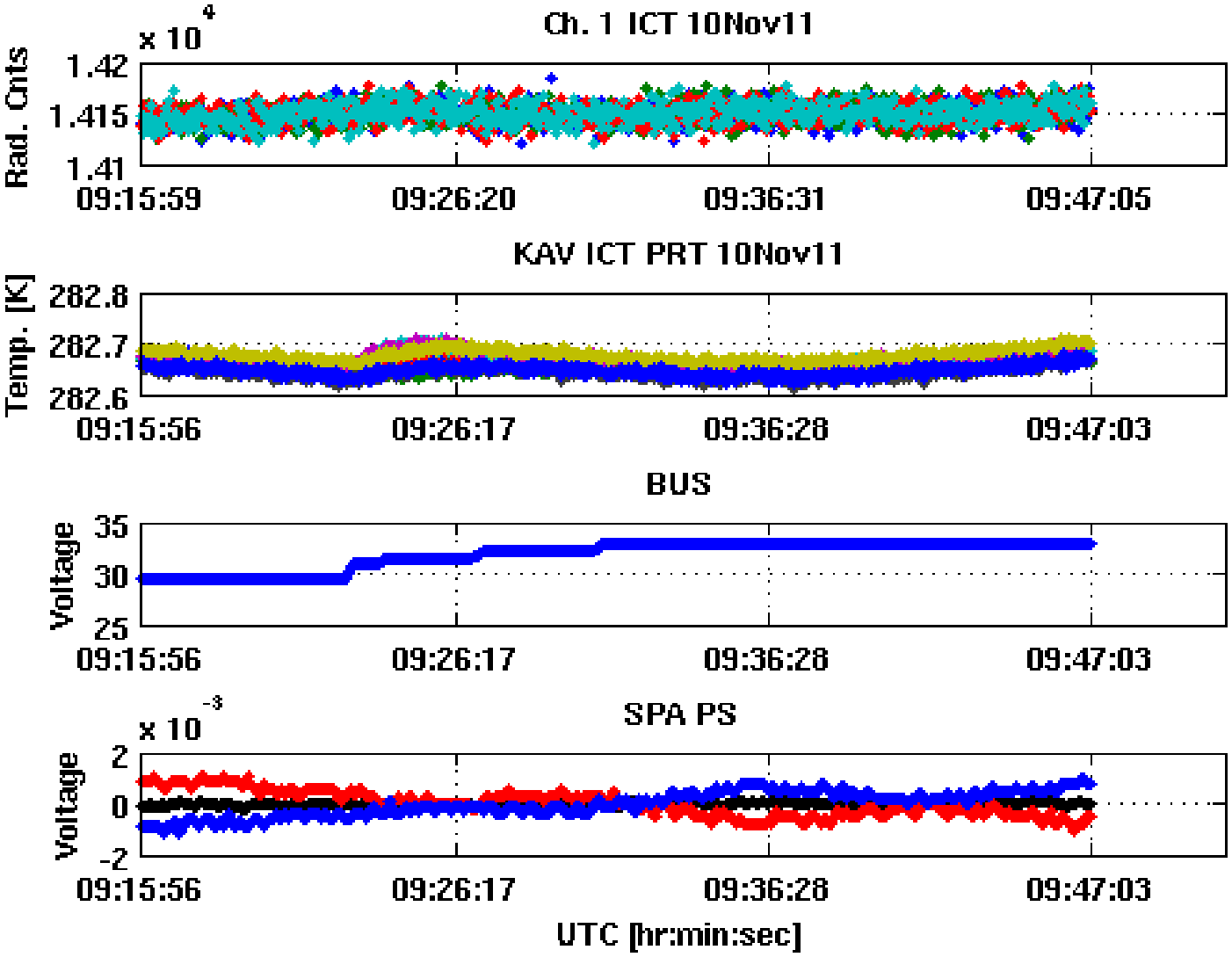
Correlation Coefficient per SVS

Ch.	1	2	3	4	5	6	7	8	9	10	11
SP1 (6.66°)	0.569	0.379	0.167	0.174	0.196	0.128	0.051	0.023	0.034	0.008	0.058
SP2 (8.33°)	0.578	0.408	0.176	0.175	0.196	0.108	0.029	0.017	0.026	-0.002	0.068
SP3 (10.0°)	0.584	0.433	0.198	0.206	0.234	0.104	-0.072	-0.110	-0.060	-0.016	0.057
SP4 (13.33°)	0.571	0.391	0.168	0.179	0.202	0.084	-0.073	-0.099	-0.008	-0.055	0.038

Ch.	12	13	14	15	16	17	18	19	20	21	22
SP1	0.223	0.207	0.161	0.063	0.485	0.095	-0.006	0.012	0.027	0.007	-0.016
SP2	0.233	0.226	0.171	0.064	0.457	0.050	-0.034	-0.017	-0.014	-0.026	-0.040
SP3	0.228	0.217	0.168	0.060	0.466	0.008	-0.005	-0.011	0.024	0.016	0.006
SP4	0.221	0.221	0.168	0.057	0.506	-0.006	-0.014	0.031	0.015	0.004	-0.005

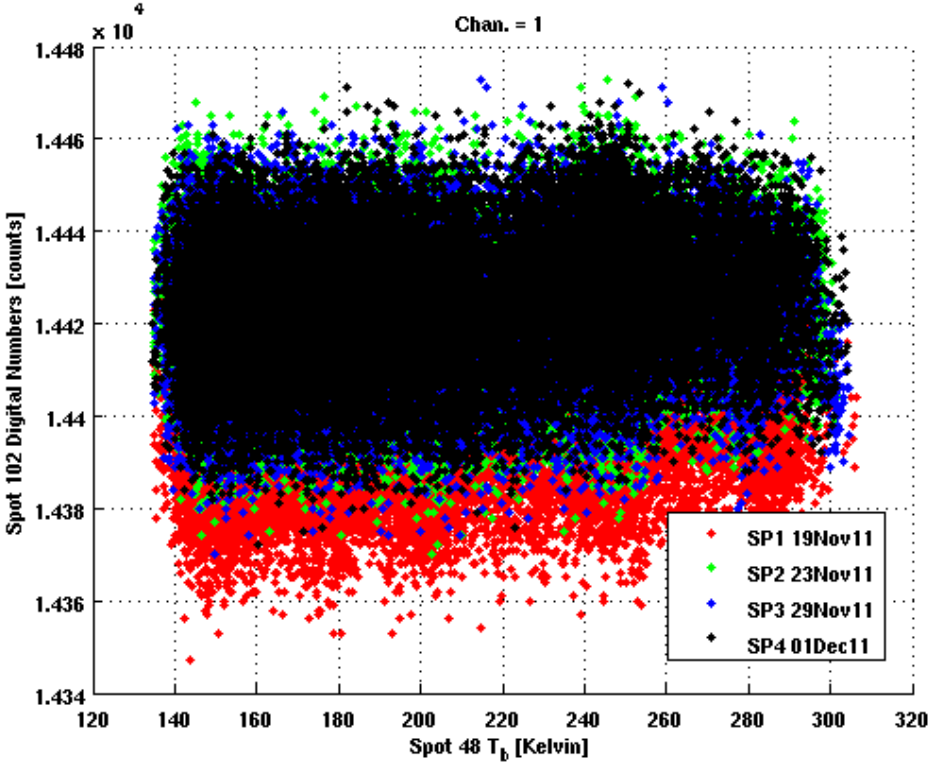
- Correlation coefficient between EV brightness temperature (Spot 96) and the SV spot
- Values above averaged the correlation coefficient of the four SV spots
- SPx data came from 19Nov11, 23Nov11, 29Nov11, and 01Dec11, respectively

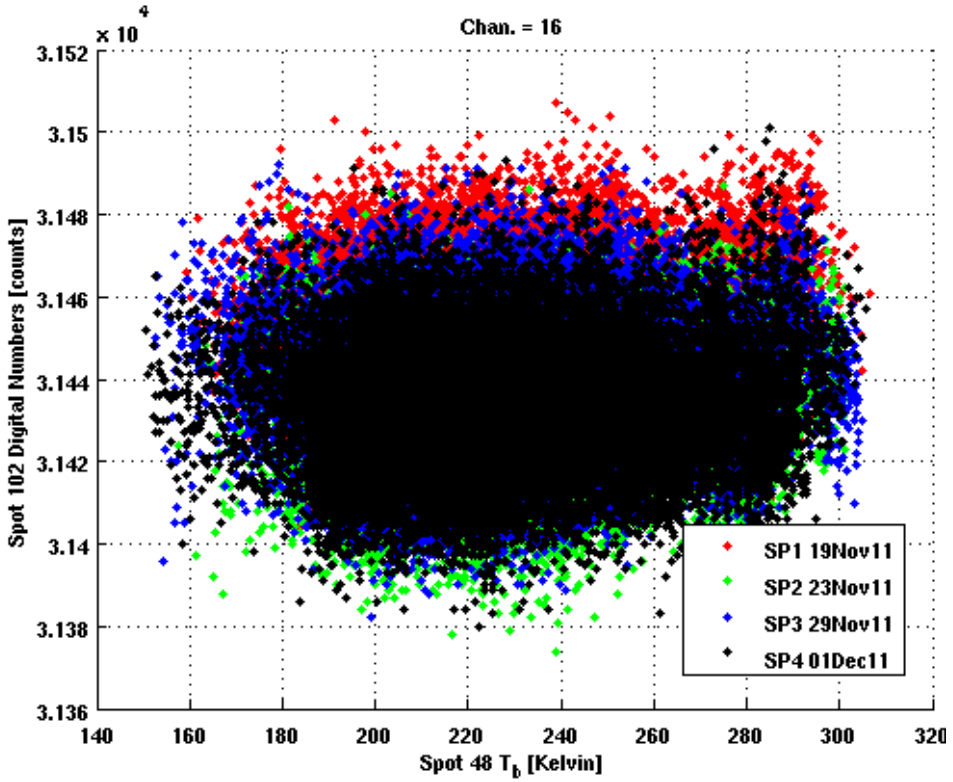
Investigating HK Voltages



Black: SPA +5VDC
Red: SPA +15VDC
Blue: SPA -15VDC
Plotted difference from mean value
Note: $1x10^{-3}$

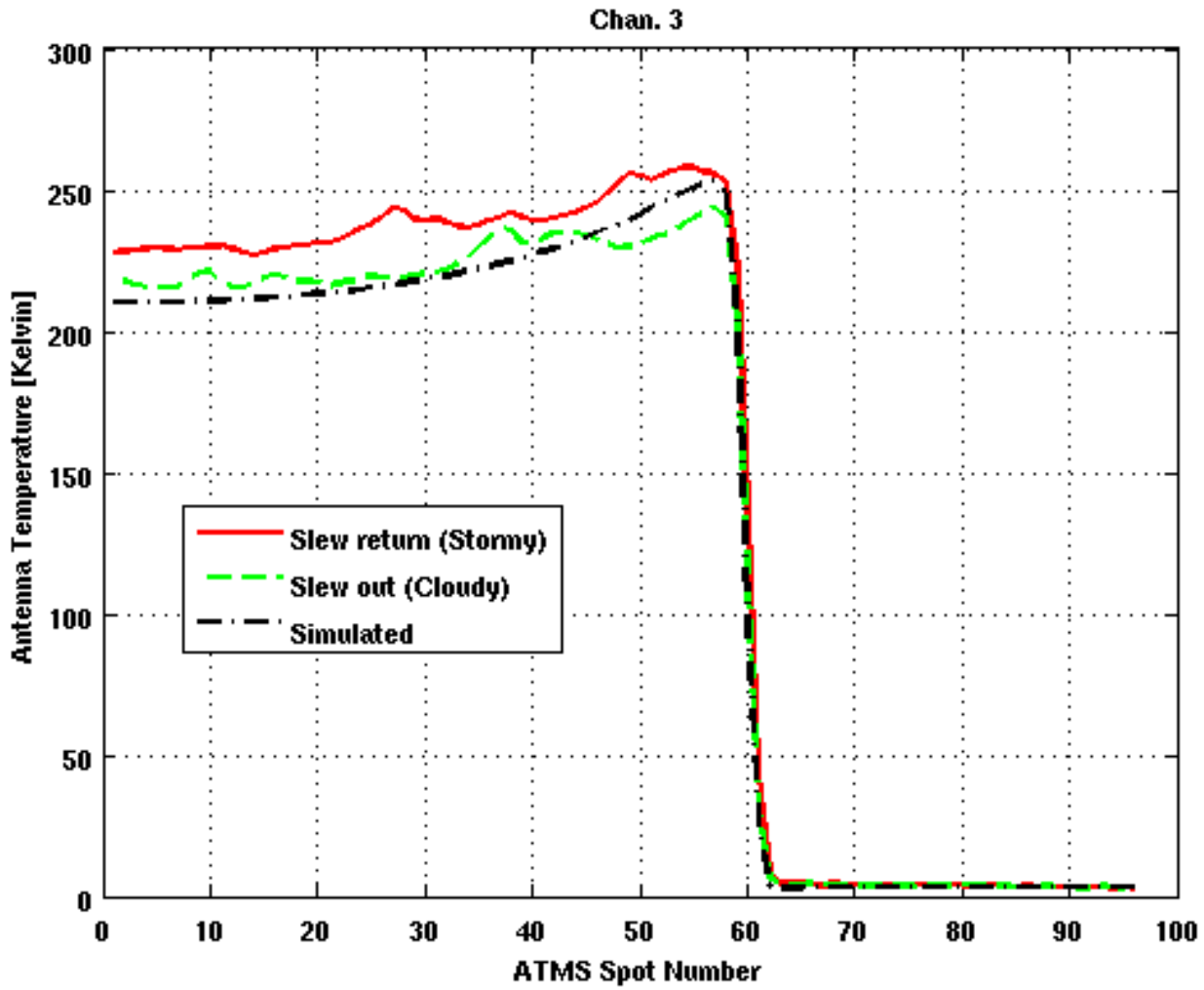
Scatter Plots: Hot Cal. Load Cnts vs EV48 Tb





- Plots above are what we expect (i.e., no correlation)
- Disclosure: Tb calibrated using all 8 calibration measurement (4 SV & 4 HC)

Antenna Temperature Across Earth's Limb

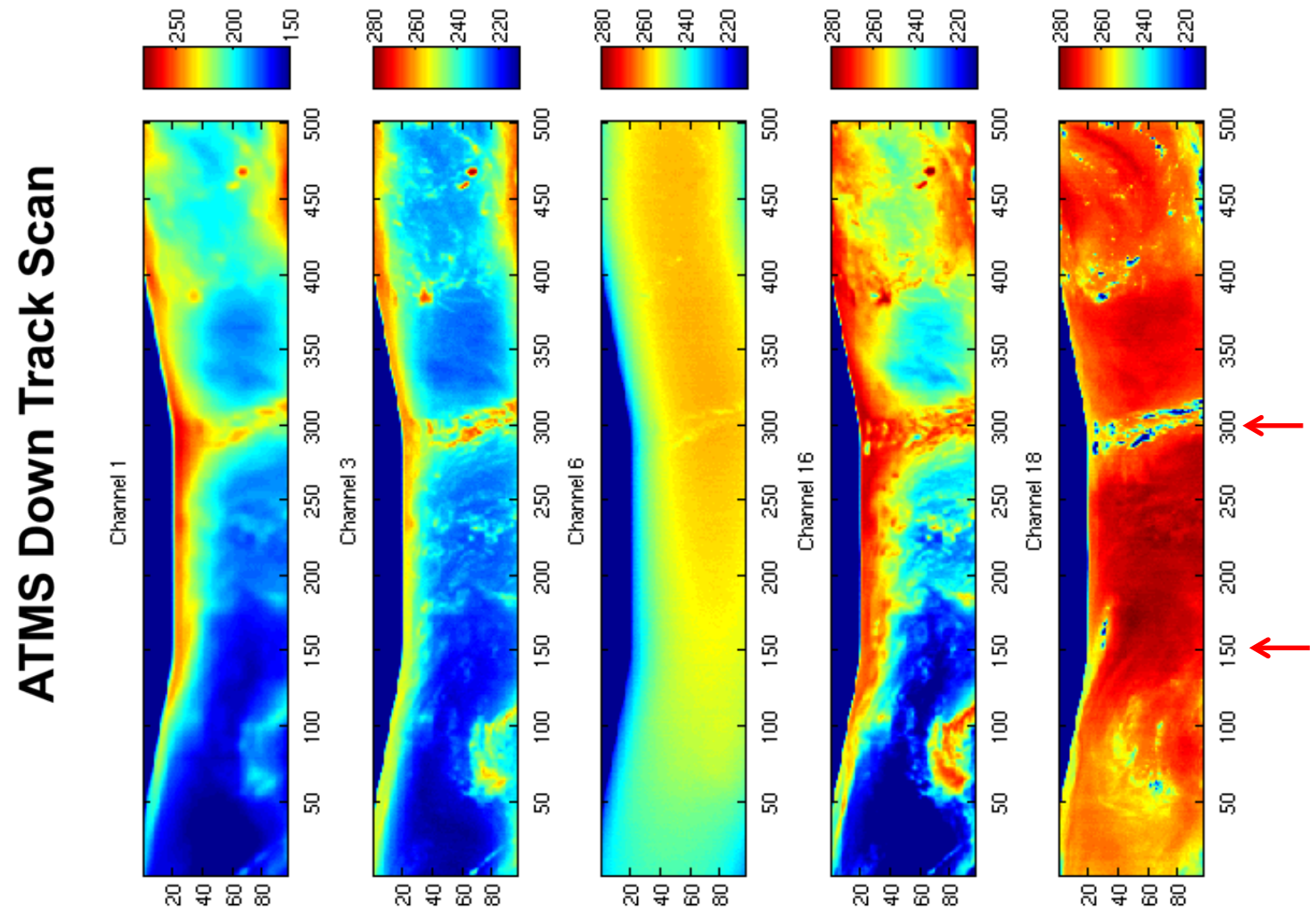


- Red is a scan during the slew back to nadir pointing
- Green is a scan during the slew toward deep space
- Black is a simulated scan using Std76 atmos. and Gaussian antenna pattern (cloud free)
- Transparent V-band channel (Ch. 3) that is sensitivity to surface emissivity

Red is scan 525 & Green is scan 325 in previous slide

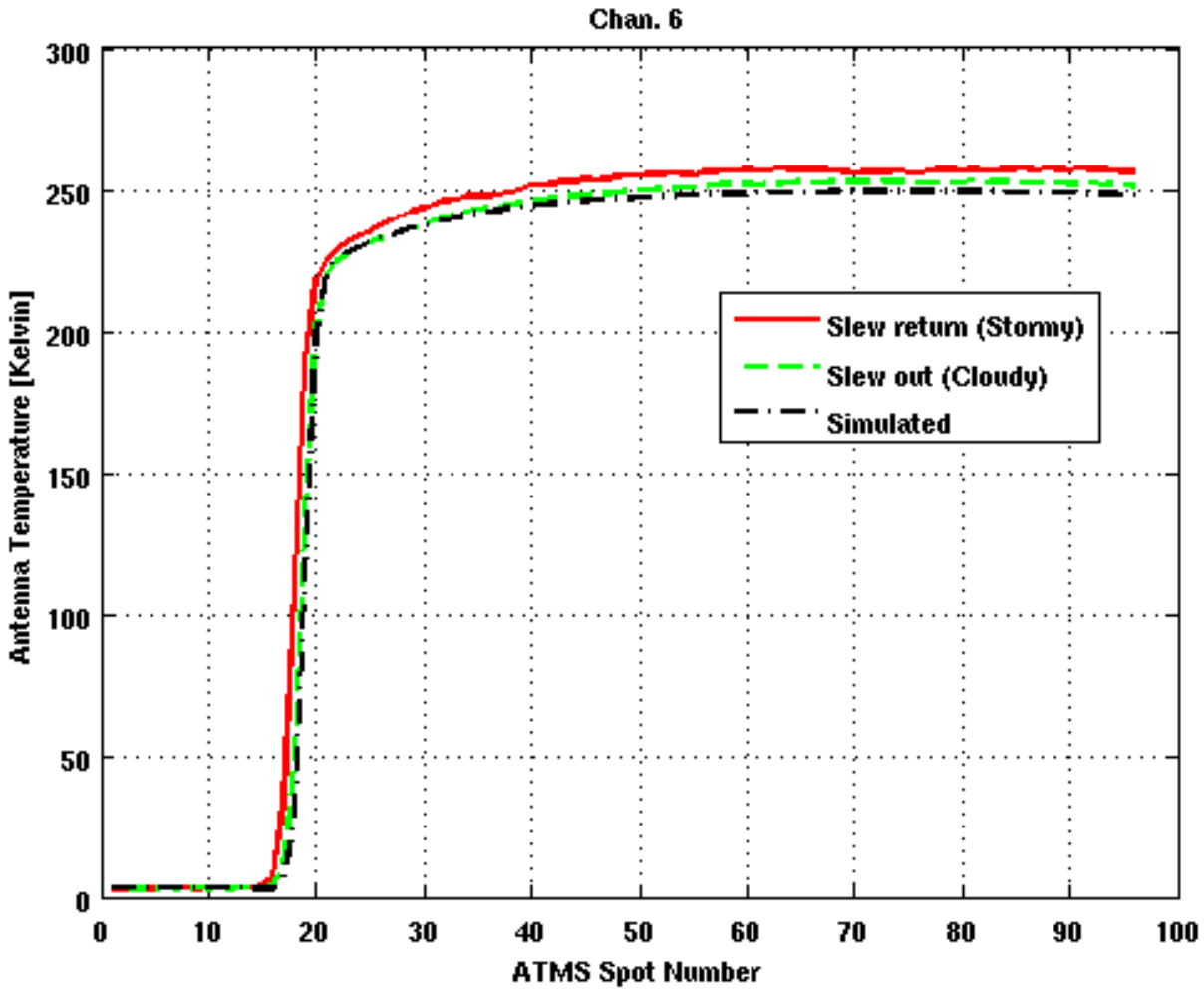
NPP ATMS 25° Roll (251)

Brightness Temperature [Kelvin]



9Dec11

Antenna Temperature Across Earth's Limb



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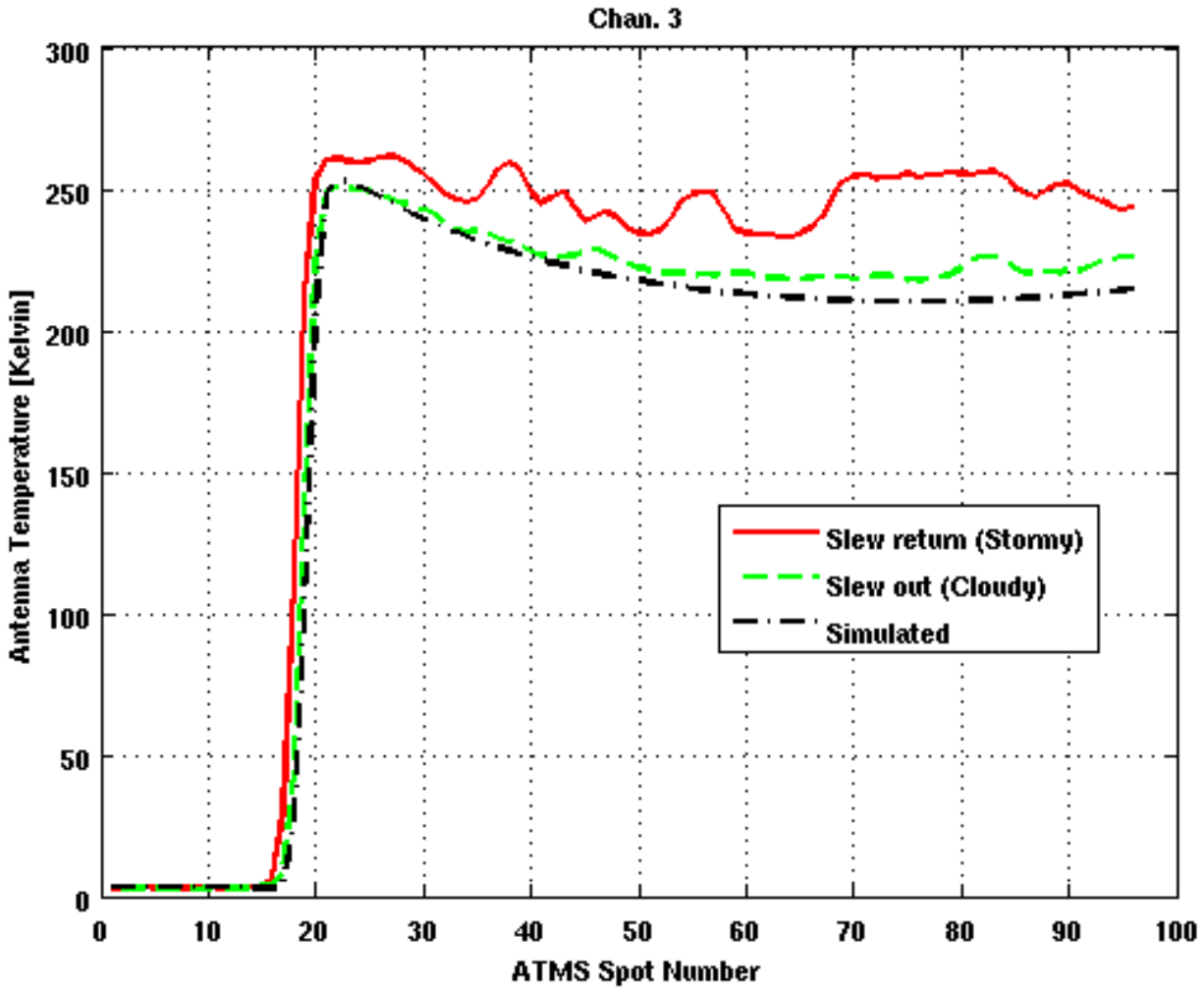
- Black is a simulated scan using Std76 atmos. and Gaussian antenna pattern (cloud free)
- Opaque V-band channel (Ch. 6)

Red is scan 300 (precip. near limb) & Green is scan 150 in previous slide

Antenna Temperature Across Earth's Limb



- Red is a scan during the slew back to nadir pointing
- Green is a scan during the slew toward deep space
- Black is a simulated scan using Std76 atmos. and Gaussian antenna pattern (cloud free)
- Transparent V-band channel (Ch. 3)

Red is scan 300 & Green is scan 150 in previous slide