ATMS SDR Provisional Maturity Readiness

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Suomi NPP SDR Product Review

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LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LL’s Role Within ATMS SDR Team

- **Bridge sensor technology and testing with operational calibration**
- **Assess and optimize calibration parameters**
- **Run and update ATMS SDR ADL code and generate LUT & code deliverables to JPSS DPE**
- **Foster team synergy to evaluate SDR performance and data product anomalies**

Presentation Overview

Goal: To describe the MIT LL work toward progressing the ATMS data products to the provisional maturity level

OPSCON Tasks

- RFI (SEV-4 & 5)
- NPP maneuvers (TUN-4 thru 6)
- Remapped SDR verification (VER-3)

Discrepancy Report Tasks

- Quality Flag anomalies
- Data Quality Management planning
- PCT updates
- Brightness temp. striping
- Error budget (i.e., performance verification)

ATMS SDR Error Budget

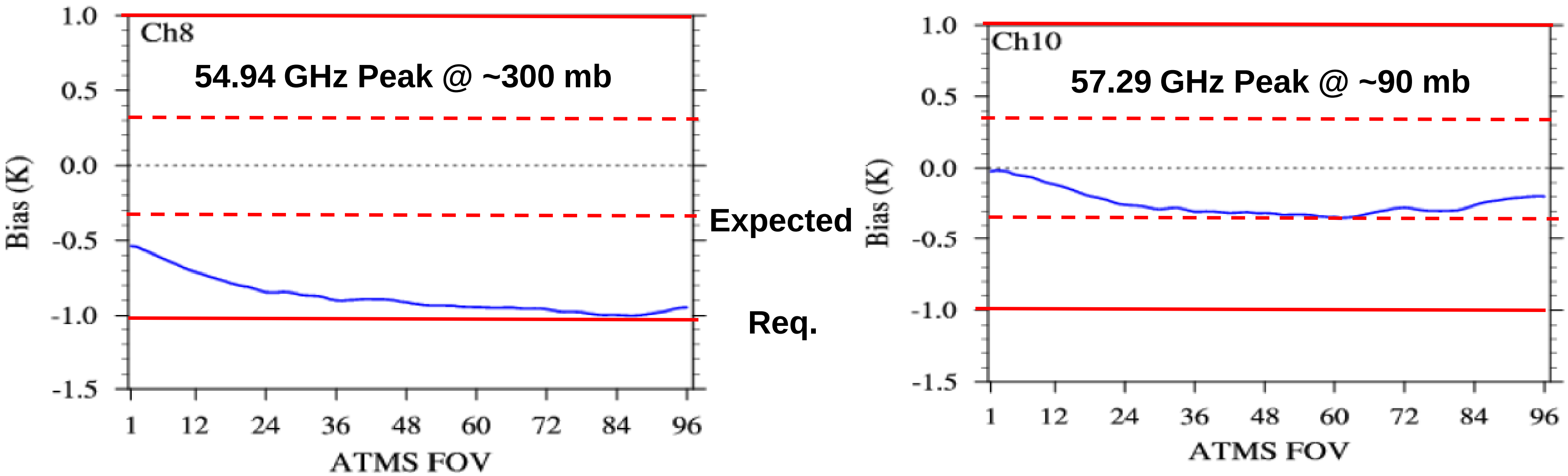
- **ATMS SDR product has three main performance parameters:**
  - **Calibration accuracy**
  - **Calibration precision (i.e., Noise Equivalent Delta Temperature or NEDT)**
  - **Geolocation accuracy**

- **The expected performance is compared with our on-orbit performance to determine how accurate our calibration is**

- **NGES has the nominal and worst-case analysis for the calibration accuracy and precision in the ATMS Radiometric Math Model**

- **STAR monitors the bias between ATMS brightness temperature (SDR) and brightness temperatures using various "truth" sources and CRTM**

ATMS SDR Bias Assessment

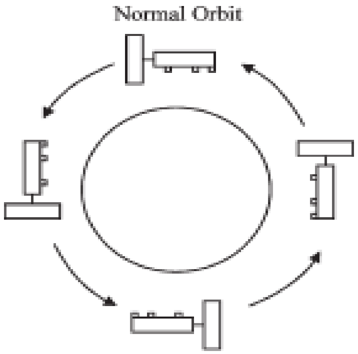


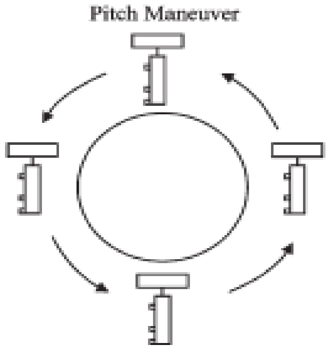
- **STAR analysis and NGES error budget and requirements**
- **COSMIC GPSRO w/ CRTM 2.0.5**
- **Ocean clear air**
- **Includes STAR's preliminary scan bias correction**

- **GPSRO is most accurate between 300 to 10 mb w/ ~0.4 K accuracy**
- **CRTM 2.0.5 uses boxcar spectral response (~0.1 K bias)**
- **Need to map truth sources to each channel (e.g., NWP, RAOB, GPSRO)**

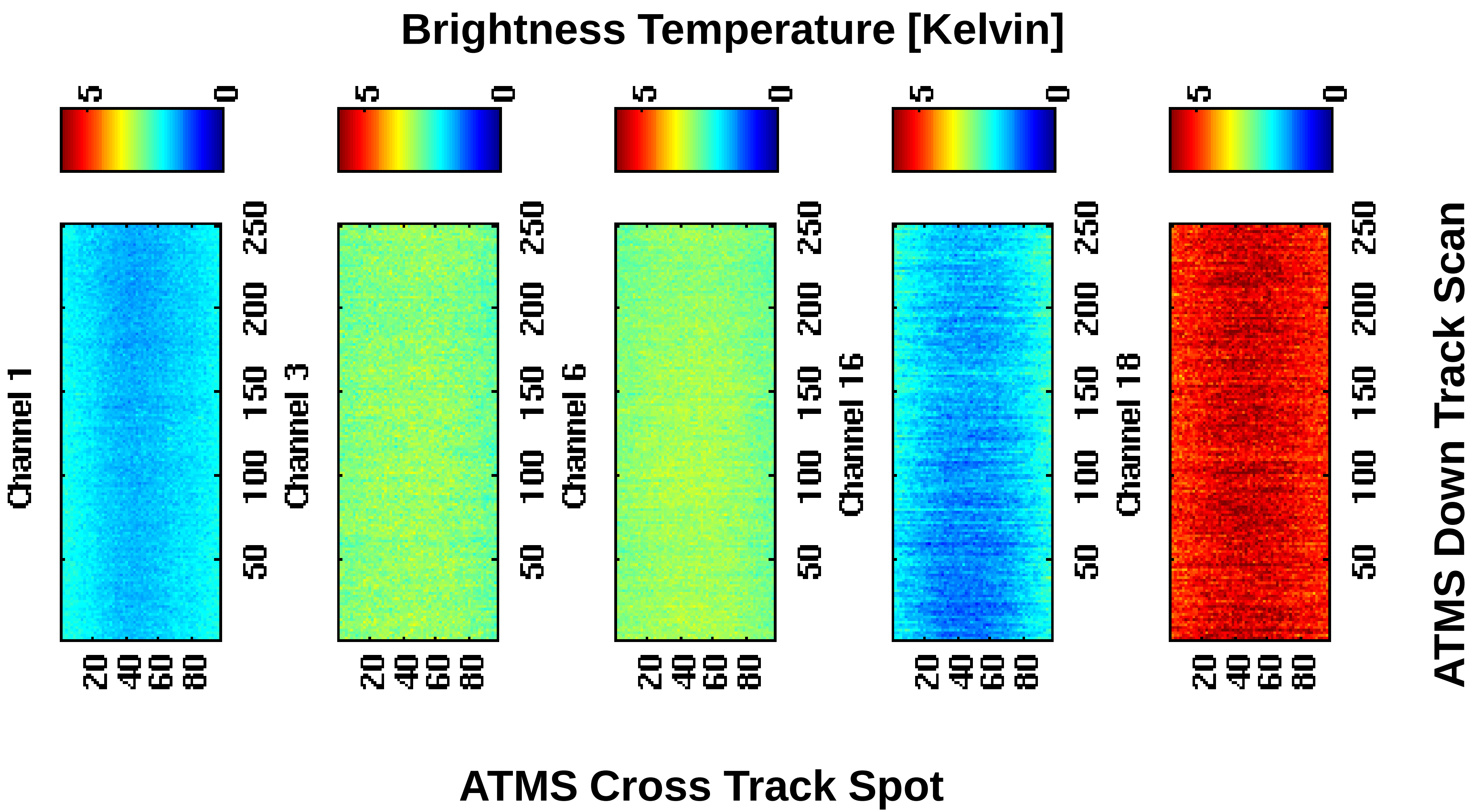
NPP S/C Maneuvers

- **NPP spacecraft maneuvers have been very productive**
- **The NPP pitchover maneuver:**
  - **Allowed the first full field of view of a homogenous source while on the spacecraft (i.e., deep space)**
  - **Illuminated a scan bias artifact which was promptly added to the NGES error budget**
  - **Provided unique and crucial data to**
    - **Investigate Tb striping**
    - **Develop a scan bias correction (antenna temperature to brightness temperature conversion)**
- **Next slides will introduce:**
  - **Scan bias artifact**
  - **Striping investigation**

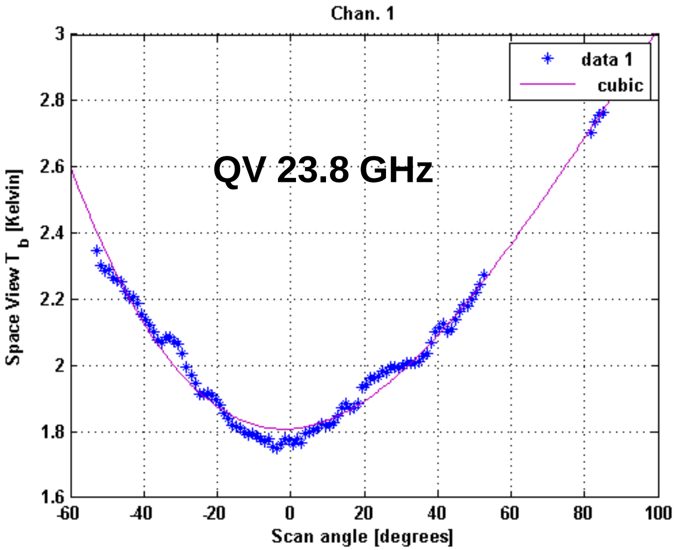




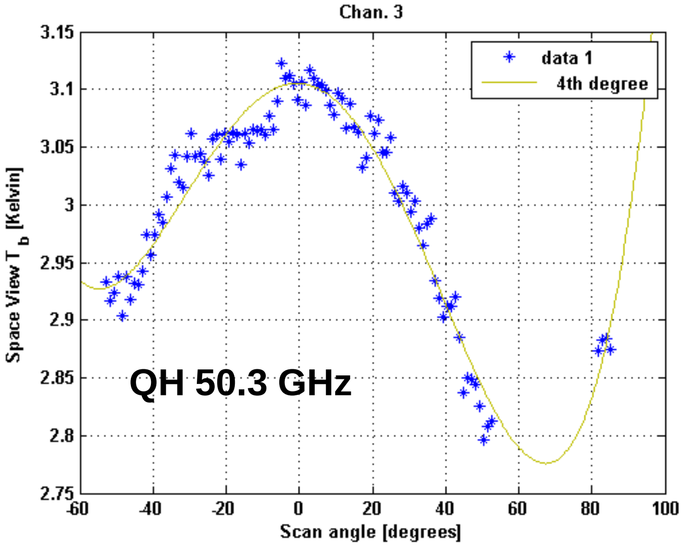
ATMS Deep Space Scans

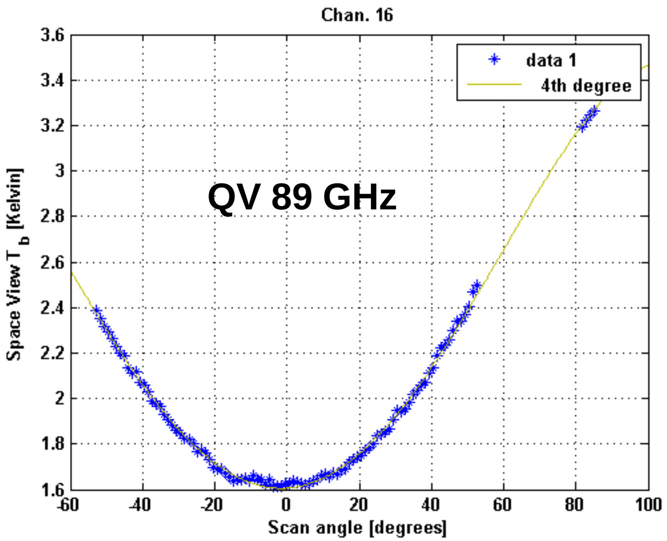


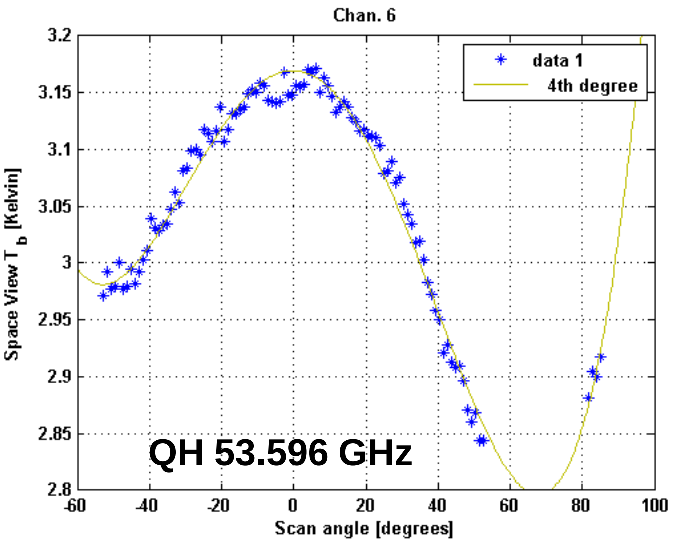
NPP Pitchover ATMS Scan Angle Bias



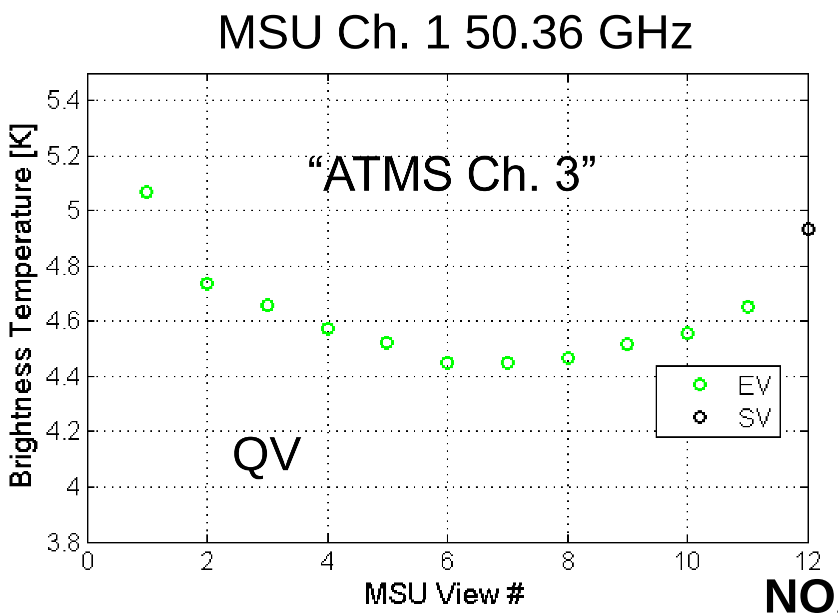
- **Quasi-V polarized channels have a "smile"**
- **Quasi-H channels have a "frown"**
- **If you include the SVS measurements, the data is best fit with a 4th degree (i.e., x^3) polynomial in angle space**



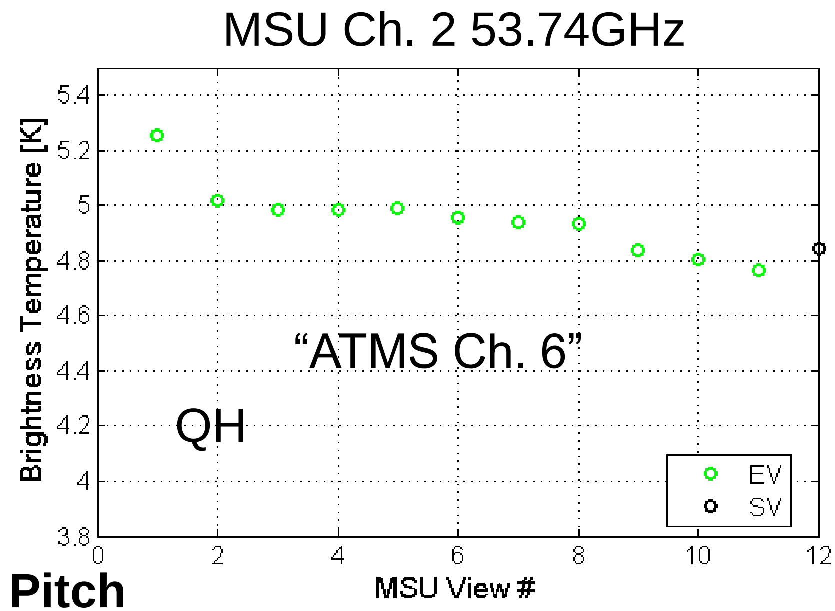




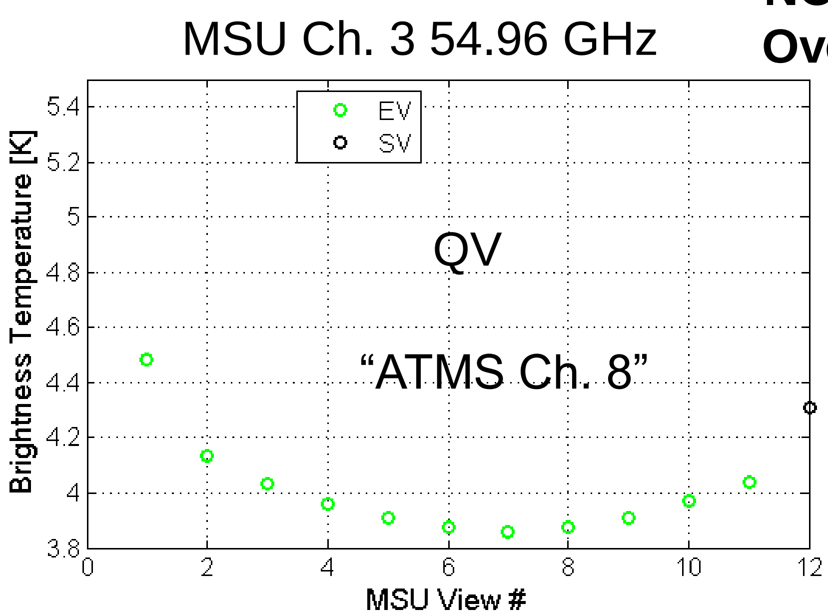
NOAA-14 MSU Deep Space Scan Bias



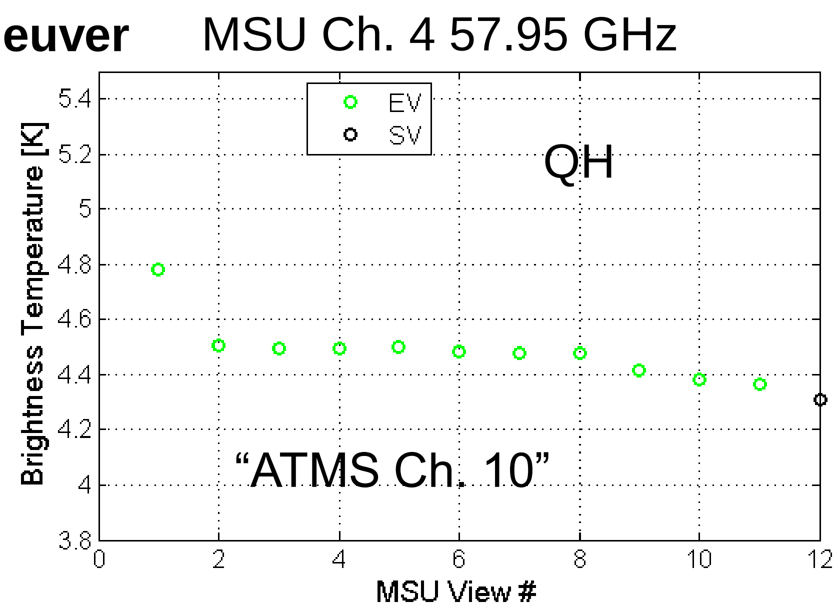
Ant. 1



NOAA-14 Pitch Over Maneuver



Ant. 2



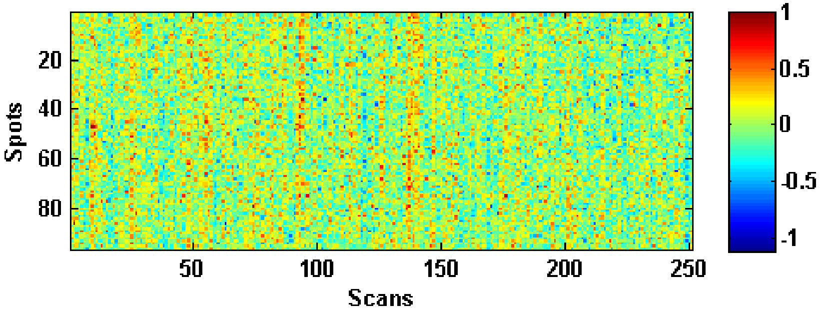
Brightness Temperature Striping

- **NWP community noticed ATMS brightness temperature "stripes" in their comparisons against NWP/RTM fields which were not in their AMSU comparisons**
- **Initial thoughts were to increase the calibration target filtering, but analysis by various teams indicated that the striping was still evident**
- **NGES assessment is that the striping is "at same level as 1/f noise measured during ground calibration" and "<u>not</u> due to temperature fluctuations" (see Kent Anderson's NGES presentation)**
- **Next slides give the status of the LL analysis into the root cause**

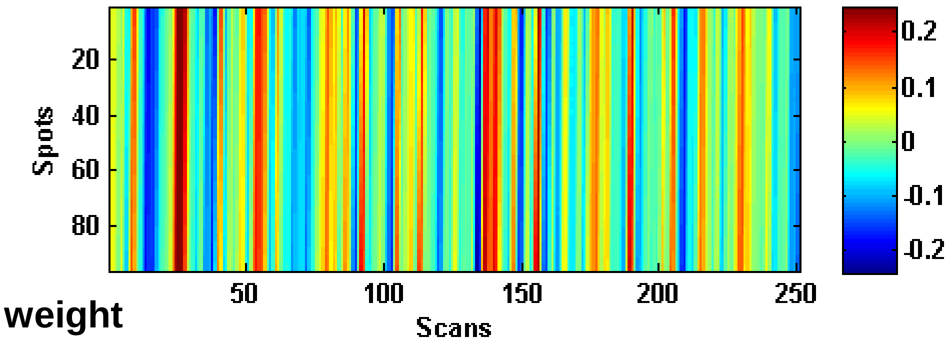
ATMS Pitchover Brightness Temperatures

equal weight

T_b N=2 Chan. 10

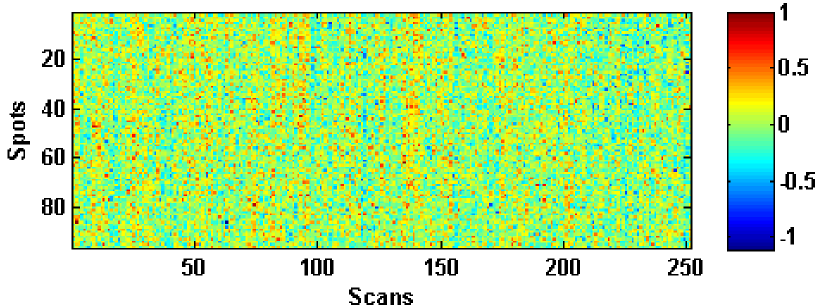


T_b N=2 minus N=25 Ch. 10

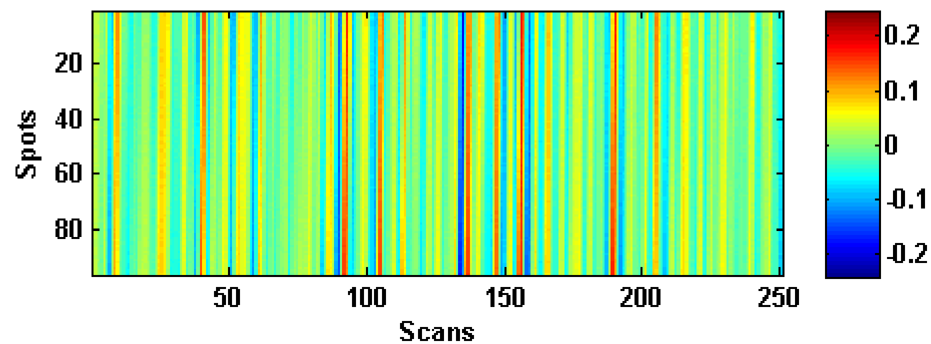


T_b IDPS Chan. 10

9-scan triangular weight

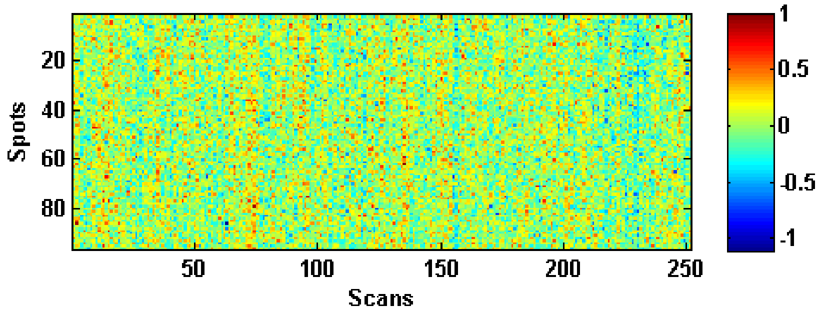


T_b N=2 minus IDPS Ch. 10



equal weight

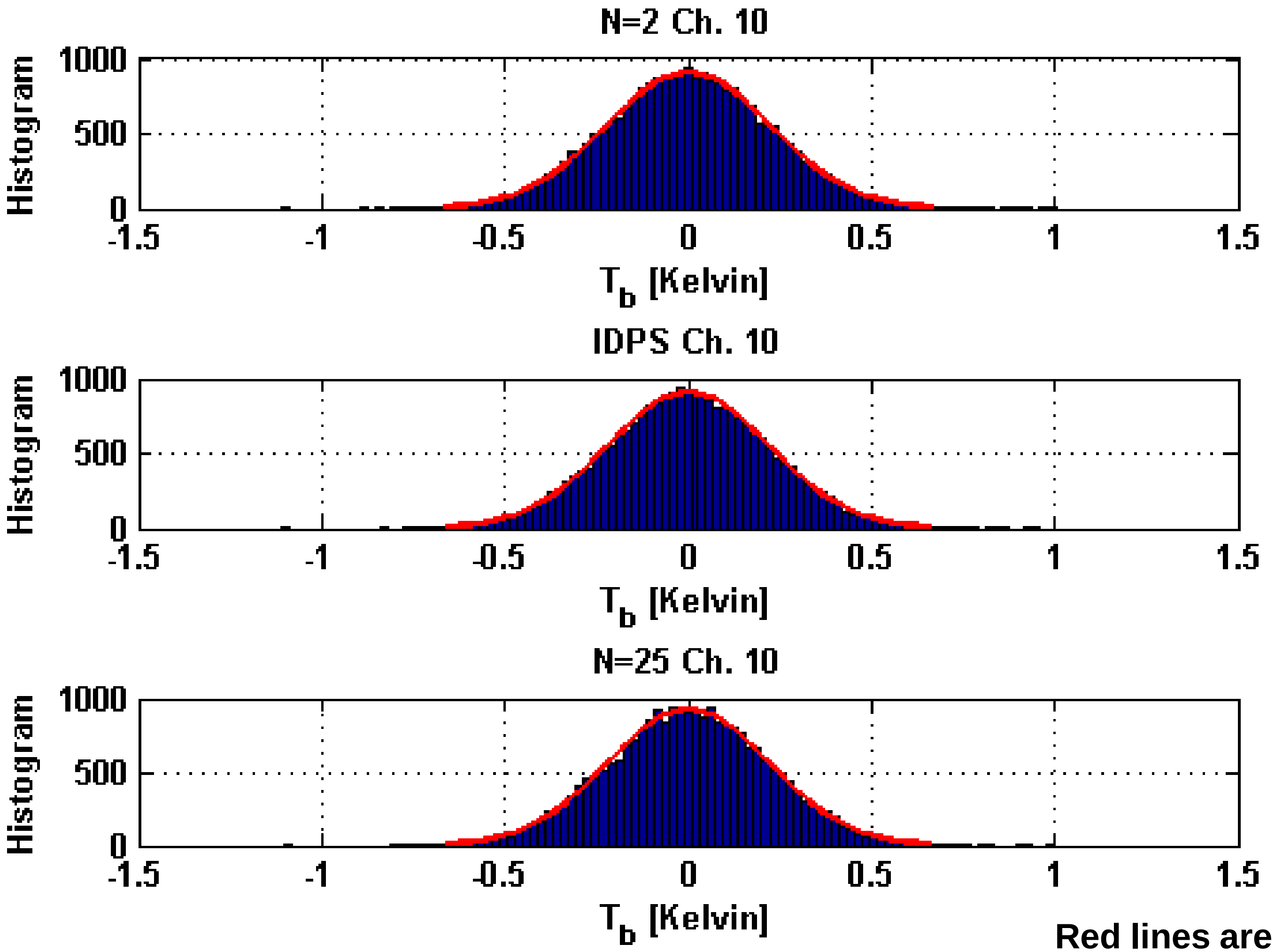
T_b N=25 Chan. 10



Comparing the striping against different cal. count filtering

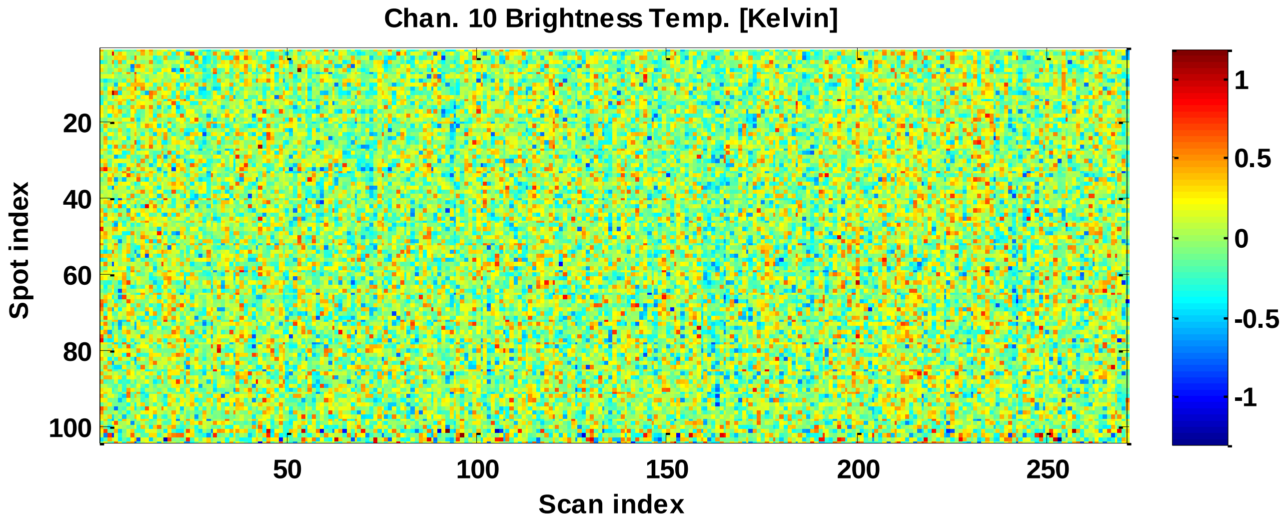
N = 2 averages just the two nearest calibration measurements (worst case)

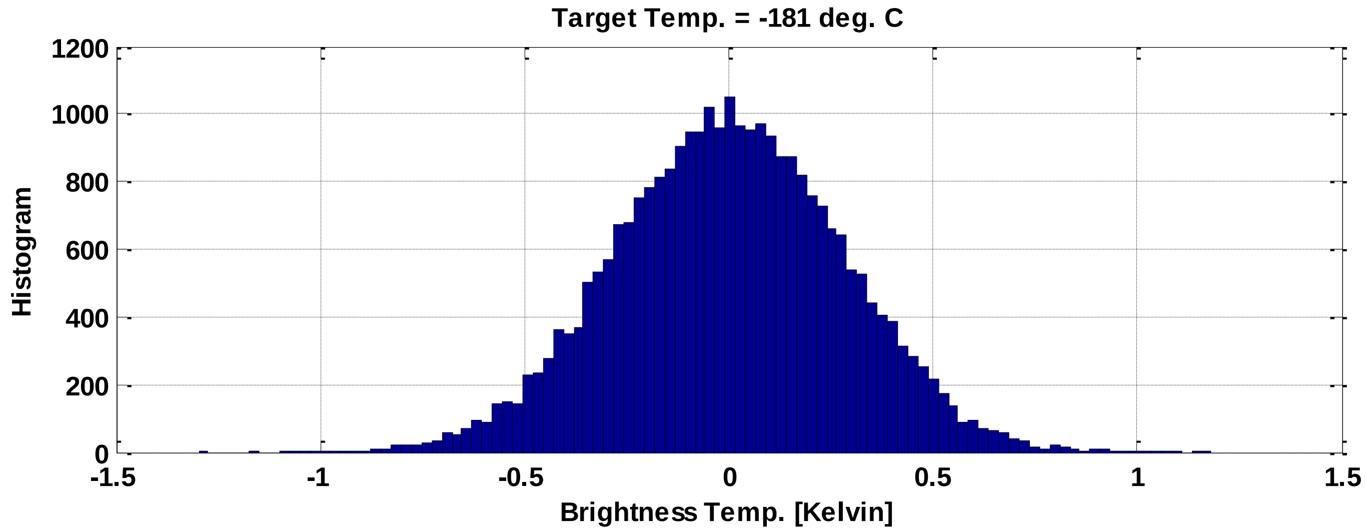
ATMS Pitchover T_b Histograms



Red lines are Gaussian fits

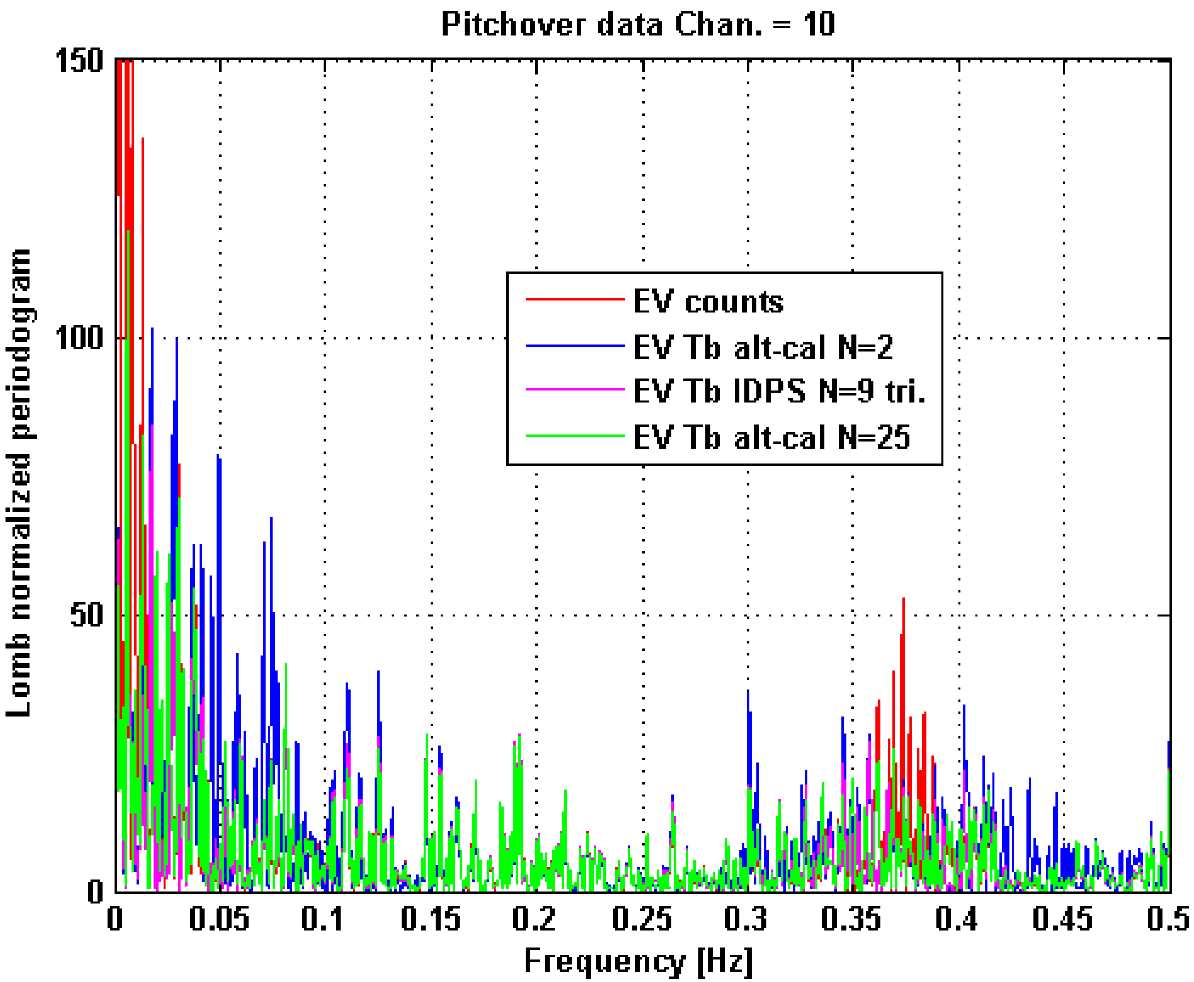
ATMS Sensor-level TVAC Data





ATMS Pitchover Spectral Analysis

- **Compare spectrums between different calibrations**
- **0.375 Hz peak is ATMS scan period (8/3 sec) (with harmonics)**
- **Striping period is at ~30 scans or 80 sec or 0.0125 Hz**
- **Will search ATMS housekeeping parameters for similar harmonics**



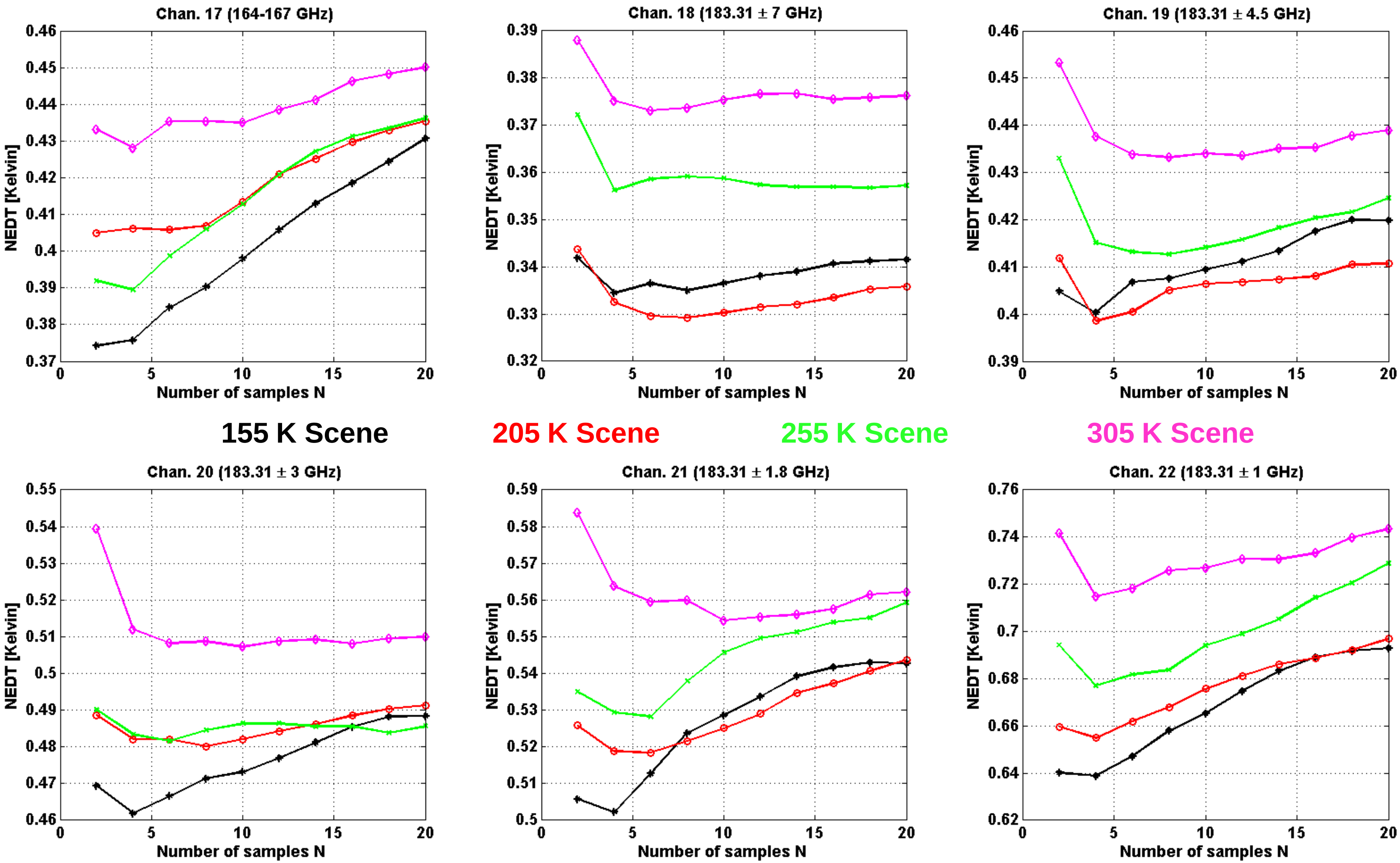
Future Work on Striping

- **Look for harmonics in housekeeping temperatures and voltages that match the period/frequency of the striping**
- **Compare G-band with similar front end technology (MHS & AMSU-B)**
- **Use stare data to create an image (removes reflector/motor movement)**
- **Use statistical metrics on images to measure striping instead of qualitative assessment**

Calibration Count Filtering

- Calibration parameters are derived from noisy measurements of the internal target and deep space
- Filtering the calibration measurements can reduce the thermal noise component, but too much filtering can increase the flicker noise contribution
- At launch, all channels had 9-scan triangular filtering (AMSU-B has 7-scan triangular with a similar scan period)
- DR4472 indicated that the 9-scans were too long for the G-band channels
- ATMS calibration striping was noticed by the NWP community and, early on, they requested more filtering in an attempt to reduce the noise (and therefore the striping)
- Analysis indicated that the 10-scan boxcar weighting (max. the SDR algorithm presently allows) didn’t eliminate the striping, but did reduce the noise on the calibration load measurements (slightly)
- Some of the G-band channels had their filters reduced to 5-scan boxcars to address DR4472

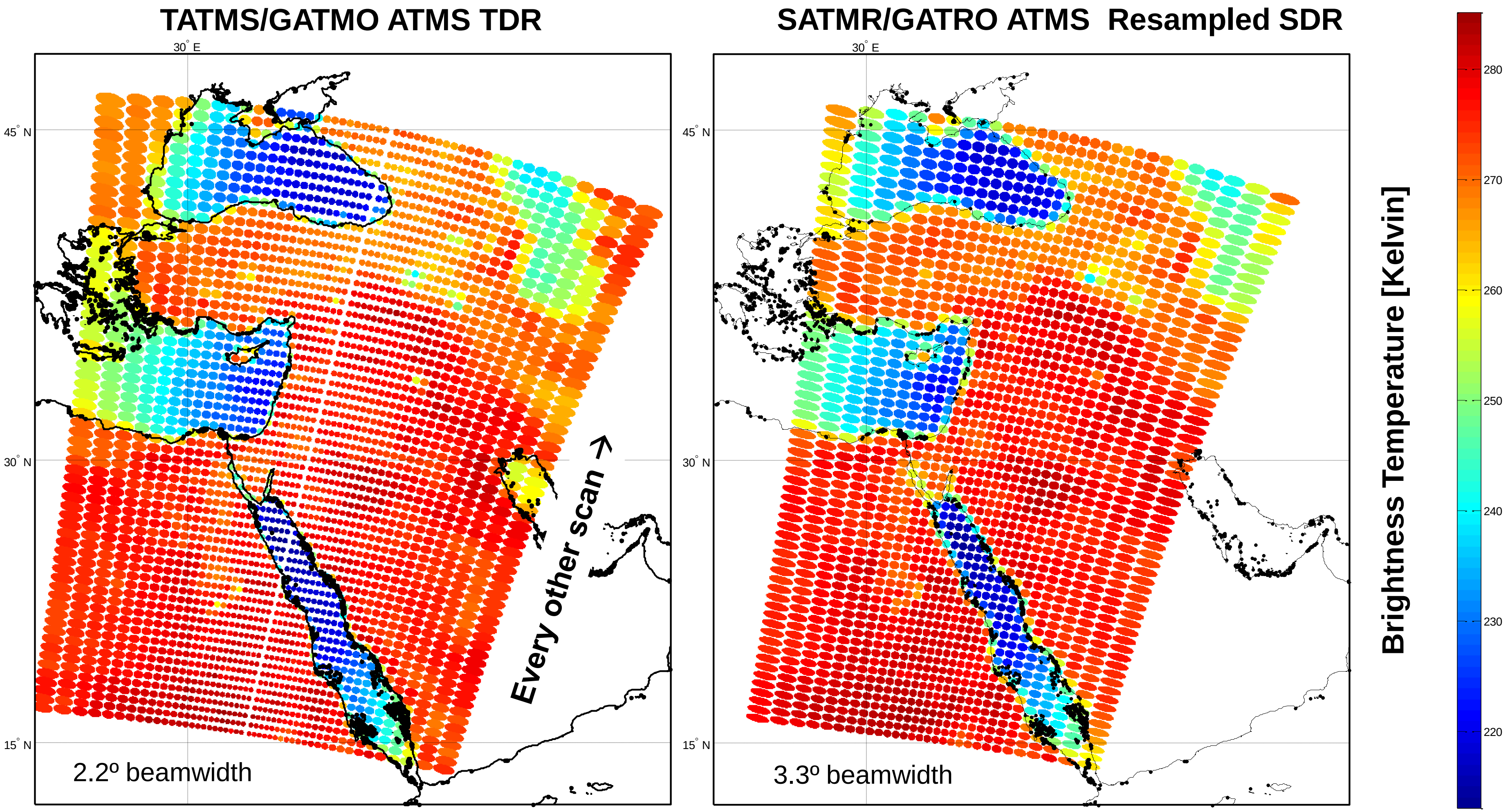
NEDT vs # of scans – G band



ATMS Remapped SDR

- **Plotted IDPS data products (SATMR/GATRO) against high-resolution coast line map for qualitative assessment**
- **Compared the ATMS SDR bias against the ATMS Remapped SDR bias to determine if remapping had an impact on the bias**
- **Set up ADL/RAOB framework to assess the impact of the remapping coefficients against EDR performance**

Chan. 3: 50.3 GHz at 2.2º Beamwidth



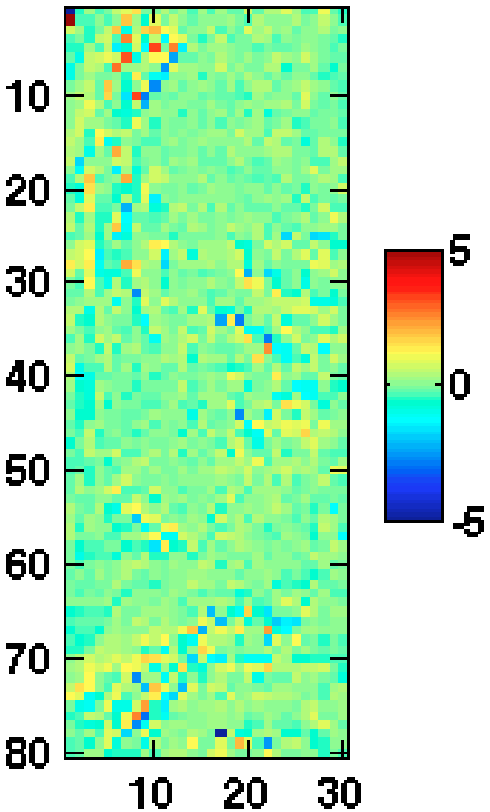
ATMS and CrIS are operational

Spot numbers 1 – 47 odd and 50 – 96 even (left image)

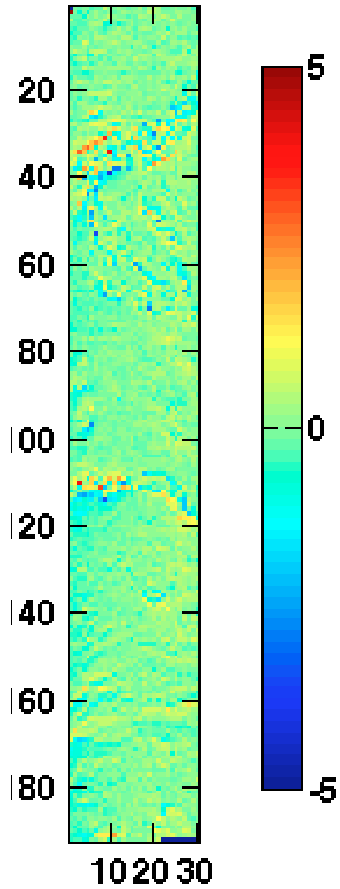
Note: Foot print is an approximation

Chan. 4 & Geodetic Interpolation Summary

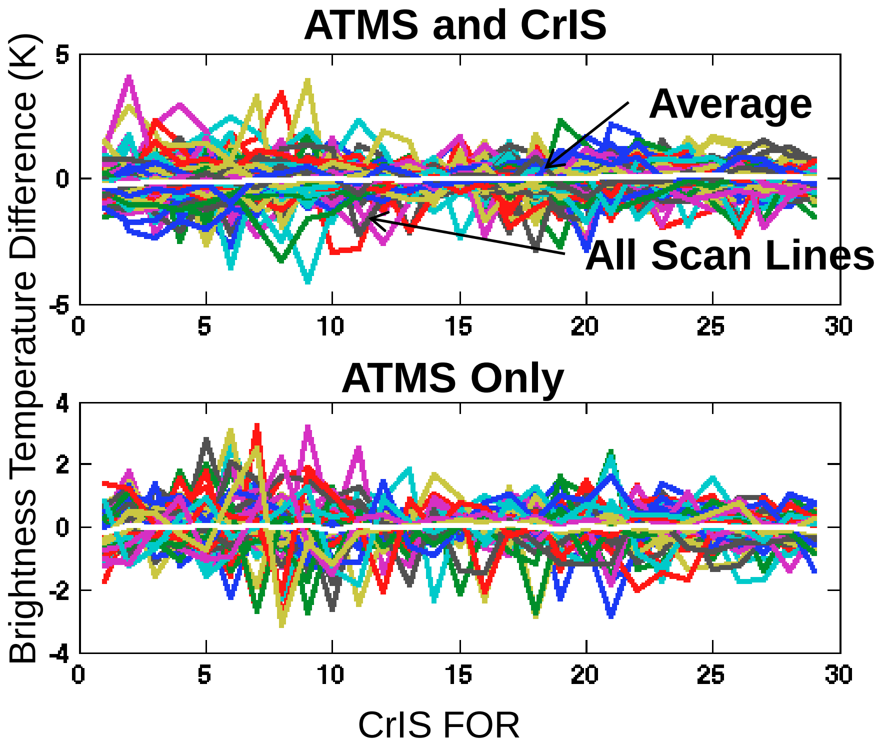
Diff: RSDR - TDR



ATMS Only



ATMS and CrIS



Average temperature Difference
ATMS + CrIS: -0.021 K
ATMS Only: 0.012 K
RMS temperature Difference
ATMS + CrIS: 0.52 K
ATMS Only: 0.59 K

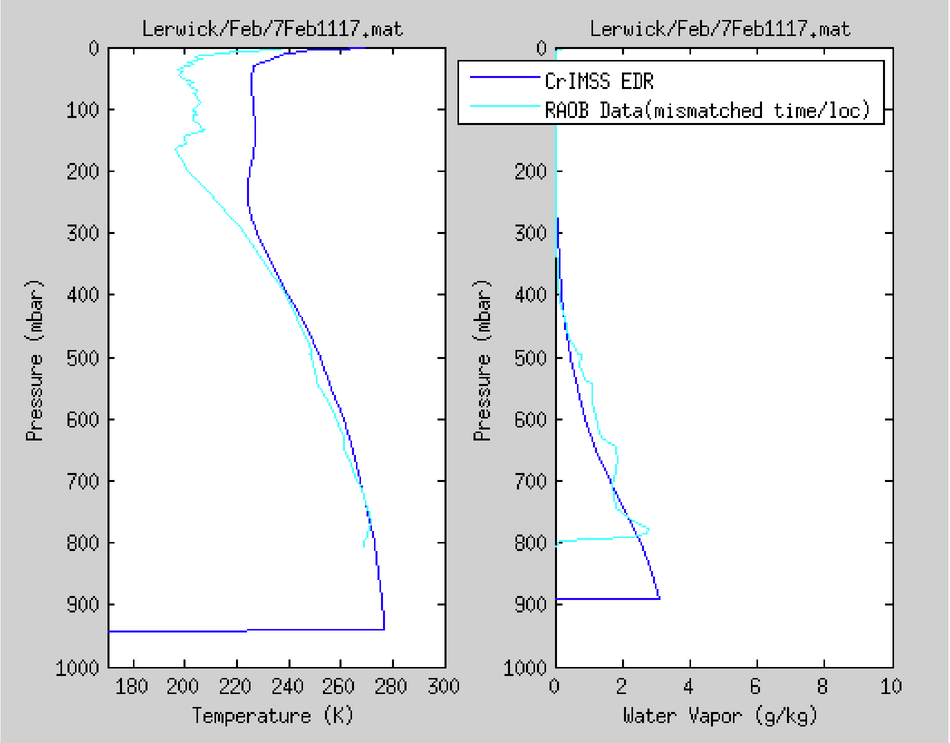
EDR Impact Study

- **Objective: Assess accuracy of resampled SDR**
  - **Radiometrically**
  - **Geo-spatially**
- **Challenge: How to obtain radiometric truth for comparison?**
- **Approach:**
    - **Compute CrIMSS EDR product using ADL 4.0**
    - **Compare temperature and water vapor vs. pressure to radiosonde derived data**
- **Current status**
  - **ADL algorithms:**
    - **RDR to SDR (ATMS and CrIS)**
    - **ATMS SDR to rSDR**
    - **ATMS rSDR and CrIS RDR to CrIMSS EDR: Need improved access to ancillary files**
  - **Access to RAOB**
    - **Identification of closest geospatial match of satellite granules to radiosonde**
    - **Utilizing SDL radiosonde dataset**

Comparison of EDR with RAOB data

- **Metrics**
  - **Noise: RMS difference between EDR and RAOB data**
  - **Fit error: Sharpness of transition of EDR coastline crossings**
- **Follow-on analyses**
  - **Compare resampling alternatives w.r.t. EDR**
    - **BG coefficient sets**
    - **Least squares**
    - **AAPP**
  - **Evaluate EDR retrieval**

Example profile matchup



ATMS RFI Introduction

- Radio Frequency Interference (RFI) tasks for ATMS
  - SEV-4 NPP Instruments and Transmitters (RFI)
    - Task Name: ATMS NPP intra-satellite interference evaluation
    - Objective: Determine ATMS RFI susceptibility to instruments and transmitters on Suomi-NPP
    - Rationale: Indicate after launch if ATMS is susceptible to RF interference from either the other Suomi-NPP sensors (CrIS, CERES, VIIRS, or OMPS) or any other Suomi-NPP transmitter (High Rate Data, Stored Mission Data, and Telemetry transmitters).
    - Pre-launch analysis implemented to identify potential RFI sources aboard S/C
  - SEV-5 NPP Terrestrial sources (RFI)
    - Task Name: ATMS NPP Terrestrial Interference evaluation
    - Objective: Identification of RFI from ground sources
    - Rationale: ATMS must be evaluated early and continuously for RFI mainly in the lower frequency channels

ATMS Instruments and Transmitters RFI

- RFI algorithm implemented to analyze changes to radiometric counts above a rolling average as instruments and transmitters aboard Suomi-NPP are powered on and off.
- Instruments and transmitters to consider for RFI
  - High Rate Data(HRD) Transmitters on/off Transients
    - Pre-launch analysis indicated possible interference
  - Stored Mission Data (SMD) Transmitters on/off Transients
  - NPP Sensors (CERES,OMPS, VIIRS, CRIS) Power up/down
    - Will utilize S/C Anomaly shutdown in June 2012
  - Telemetry (TLM) Transmitters on/off Transients
  - Battery discharge/charge
  - Heaters Cycle On/Off
  - Reaction Wheel Ramp up
- Analysis will resume with transmitters and instruments identified by pre-launch analysis as potential sources of interference

ATMS Terrestrial Sources RFI

- Terrestrial RFI Algorithm will focus on identifying potential RFI from land and sea sources
- Algorithm analyzes ATMS RDR data, establishing average peak radiometric count values over several passes for all locations, and identifies possible RFI Terrestrial sources by comparing average radiometric counts for consecutive ATMS spot positions.
  - Focus on Europe and Asia (Potential RFI sources identified)
- Attention is being given to automobile collision avoidance radars at K-band (23.6 – 24.0GHz)
- Analysis will spotlight known locations of high powered L-Band radars (and harmonics) and X-band systems
- This task requires periodic evaluation to ensure new RFI sources on the ground are identified.

Critical DRs for Provisional Maturity

- Maintain SDR team's DR "matrix" for tracking purposes

- Followed DRs through the "algorithm change process" and eventual change implementation

- Main DRs for provisional:
  – Quality flag anomaly resolution and PCT parameter adjustment
  – Lead the DQM planning
  – Implement PCT updates from the SDR team

Quality Flag DRs

- The ATMS data products have a couple hundred binary Quality Flags (QF)
- Since activation, QFs were:
  - Turned off to allow on-orbit evaluation before activation
  - Triggered, but were false positives
  - Triggered due to incorrect LUT threshold values
- MIT LL evaluated turning on flags, correcting code to remove false alarms, and updated the LUT using the STAR ICVS
- Closed these DRs: 4730, 4561, 4732, 4741, 4479, 4463, 4460
- Remaining issue: PRT Consistency Flag (DR4811)
  - Tested by LL and will present updated LUT values for ATMS SDR team approval
  - Then a DPE G-ADA run will be requested followed by AERB approval

Remaining Quality Flag

Goal: To turn on internal cal. target's PRT quality flag, verify, and update related PCT parameters. (Please see p.28-29 of D39309_A_ATMS_OAD for more information about these parameters)

Examined all quality flags after four trial runs of ADL v.4.0 (with quality flag code changes from version Mx6.3), with the following additional code changes in this order:

0. Changed chkConsistPRT from false to true in ATMS-SDR-PCT
1. Changed low_limit_prt from 245 deg K to 300 deg K (internal loads at ~280 deg K)
2. Changed upp_limit_prt from 340 deg K to 250 deg K (internal loads at ~280 deg K)
3. Changed max_var_prt from 5 deg K to 0.01 deg K

Each trial used three orbits (525 files) worth of ATMS data, and the proper flags were tripped:

QF15_SCAN_KAVPRTTEMPLIMIT had out of range for KAV PRTs 1-8
QF16_SCAN_WGPRTTEMPLIMIT had out of range for WG PRT 1-7
QF17_SCAN_KAVPRTTEMPCONSISTENCY had temp. inconsistency for KAV PRT 1-8
QF18_SCAN_WGPRTTEMPCONSISTENCY had temp. inconsistency for WG PRT 1-7
QF19_SCAN_ATMSSDR had Time Sequence = False, Data Gap = False, Insufficient KAV = True, Insufficient WG = True, Space View Position = False, Blackbody Position = False

Data Quality Management

- Provisional Requirement: Turn on DQN (DR4593)
- MIT LL reviewed existing Data Quality Notifications and Data Quality Threshold Tables
- Submitted DR4687 to request an additional DQN to monitor the "timing sequence error" quality flag, which checks that the start times of the scan are within the expect scan period plus an allowable variance (This new DQN will be implemented before validated maturity and is not required for provisional)
- MIT LL submitted DQTT values following the approach that DQNs are sent for unexpected hardware anomalies (vs expected events like a VIIRS calibration maneuver)
- Updated DQTT received ATMS SDR team approval:
  - Raytheon will test DQTT and report back on DQN generation
  - MIT LL will run DQTT on ADL v4.1 to submit a DPE G-ADA functional test, then present results at AERB for approval

Challenges and Issues

- Work with ATMS SDR team to assess SDR performance
- Continue working with NWP community and ATMS SDR team to determine root cause and impact of striping
- Finish NPP ATMS RFI assessment
- Finish ATMS Remapped SDR assessment
- Assess STAR scan bias correction (& share beam eff. calculations)
- Turn on PRT consistency flag in operational PCT
- Verify the Raytheon evaluation of DQTTs and submit operational DQTTs to DPE

Path Forward

S-NPP

- Aircraft Cal/Val Campaign (~May 2013)
- Validated OPSCON tasks (e.g., LO assessment)
- Mature SDR performance assessment for validated maturity
- Continue to assess PCT parameters for optimization
- Continue updating SDR operational code and PCTs where required

JPSS-1

- Continue close involvement of ATMS SDR team in J1/FM2 calibration and testing
- Continue working with NWP community
- Leverage NPP error budgets with JPSS L1RD Verification and Validation requirements