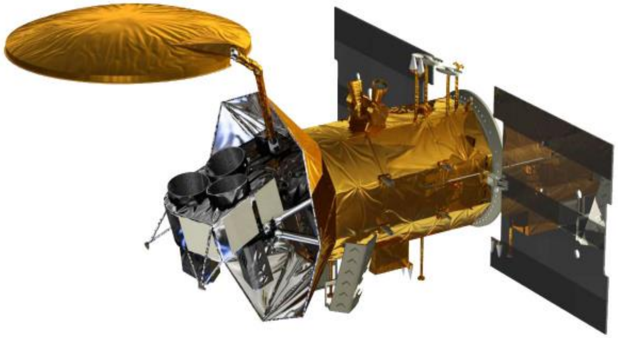
CONAE Microwave Radiometer (MWR) Counts to Tb Algorithm (Version 6.0) and On-orbit Validation



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MWR Calibration Workshop
Buenos Aires, AR
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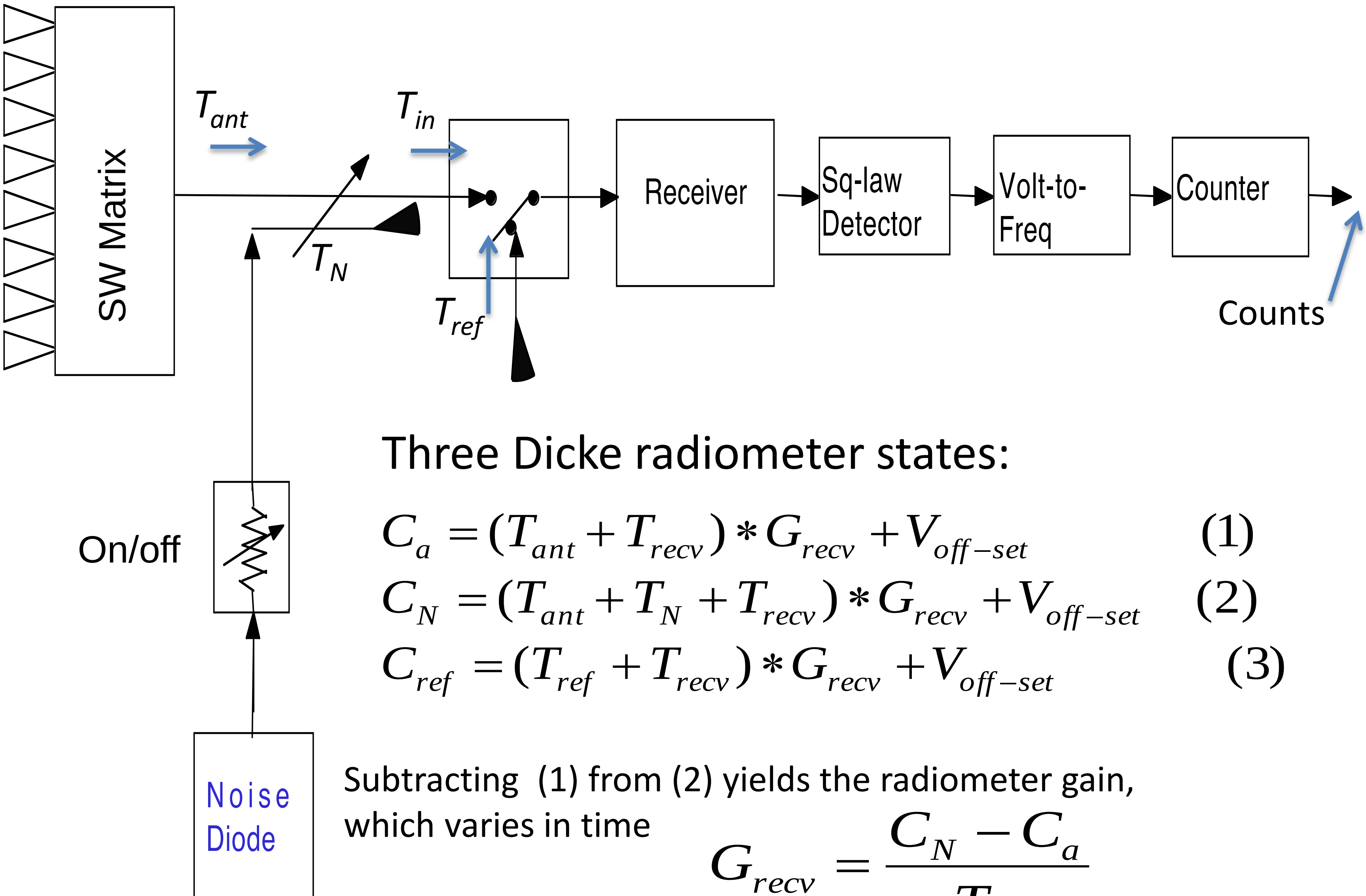
MWR Channel Block Diagram



Three Dicke radiometer states:

$$C_a = (T_{ant} + T_{recv}) * G_{recv} + V_{off-set} \qquad (1)$$

$$C_N = (T_{ant} + T_N + T_{recv}) * G_{recv} + V_{off-set} \qquad (2)$$

$$C_{ref} = (T_{ref} + T_{recv}) * G_{recv} + V_{off-set} \qquad (3)$$

Subtracting (1) from (2) yields the radiometer gain, which varies in time

$$G_{recv} = \frac{C_N - C_a}{T_N}$$

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MWR Counts to Tb V5.0S Algo Validation

- During MWR on-orbit Cal/Val testing, all three radiometer channels exhibited similar brightness temperature (*Tb*) anomalies:
  - The system gain was found to depend upon input scene *Tb*
    - Gain, calc using the excess noise ratio = $(C_N - C_a)/T_N$, changed abruptly at Ocean/Land boundaries where high *Tb* contrast exist
- This anomaly is believed to be the result of a slightly non-linear radiometer transfer function (T_{in} to counts)

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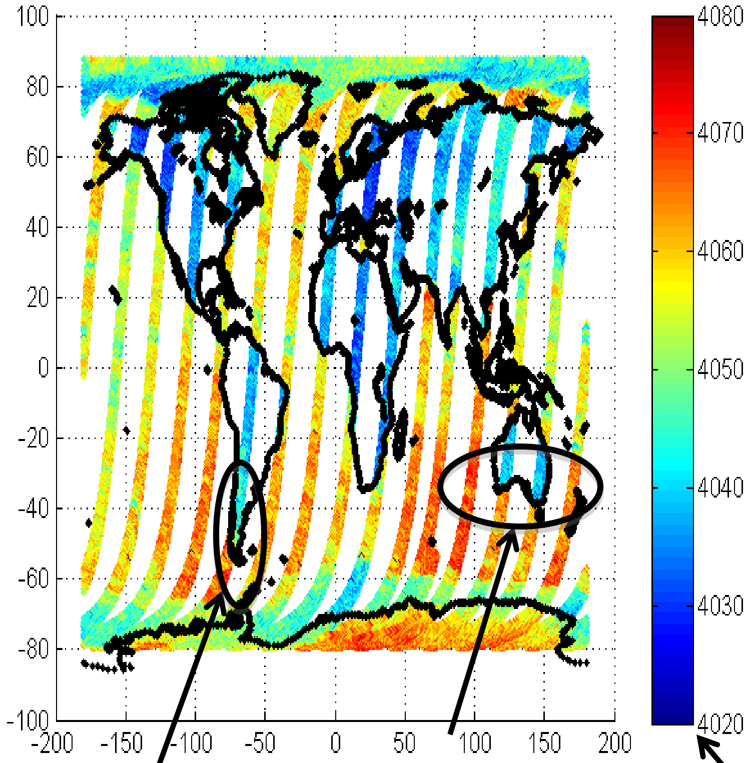
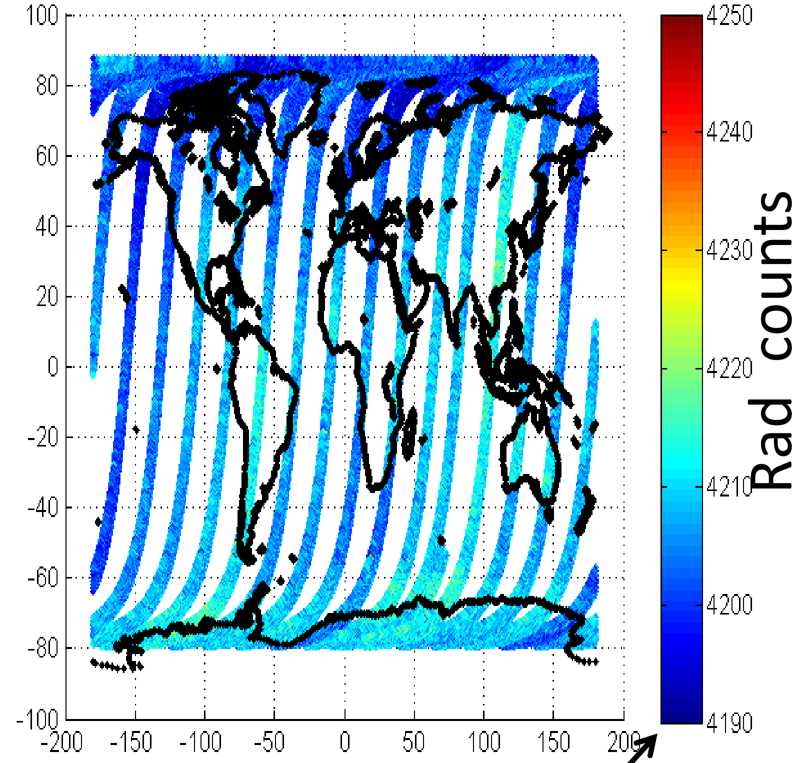
37GHz V-pol, On-orbit Noise Diode Deflection ($C_N - C_A$), Descending Passes for One Day (All Beams)

V5.0S



V6.0



Note: “gain jumps” @ land/water boundaries

Dynamic range = 60 counts

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MWR Counts-to-Tb Algorithm V6.0

- New version V6.0 developed by CFRSL and CONAE incorporates :
  - Smear correction counts (same as V5.0S)
  - Counts linearization
    - Removes radiometer transfer function non-linearity
  - Reanalysis of pre-launch TV calibration data
    - To improve front-end loss coefficients
  - Antenna Pattern Correction (APC)
    - To convert T_{ant} to Tb
- The results are presented in the following charts

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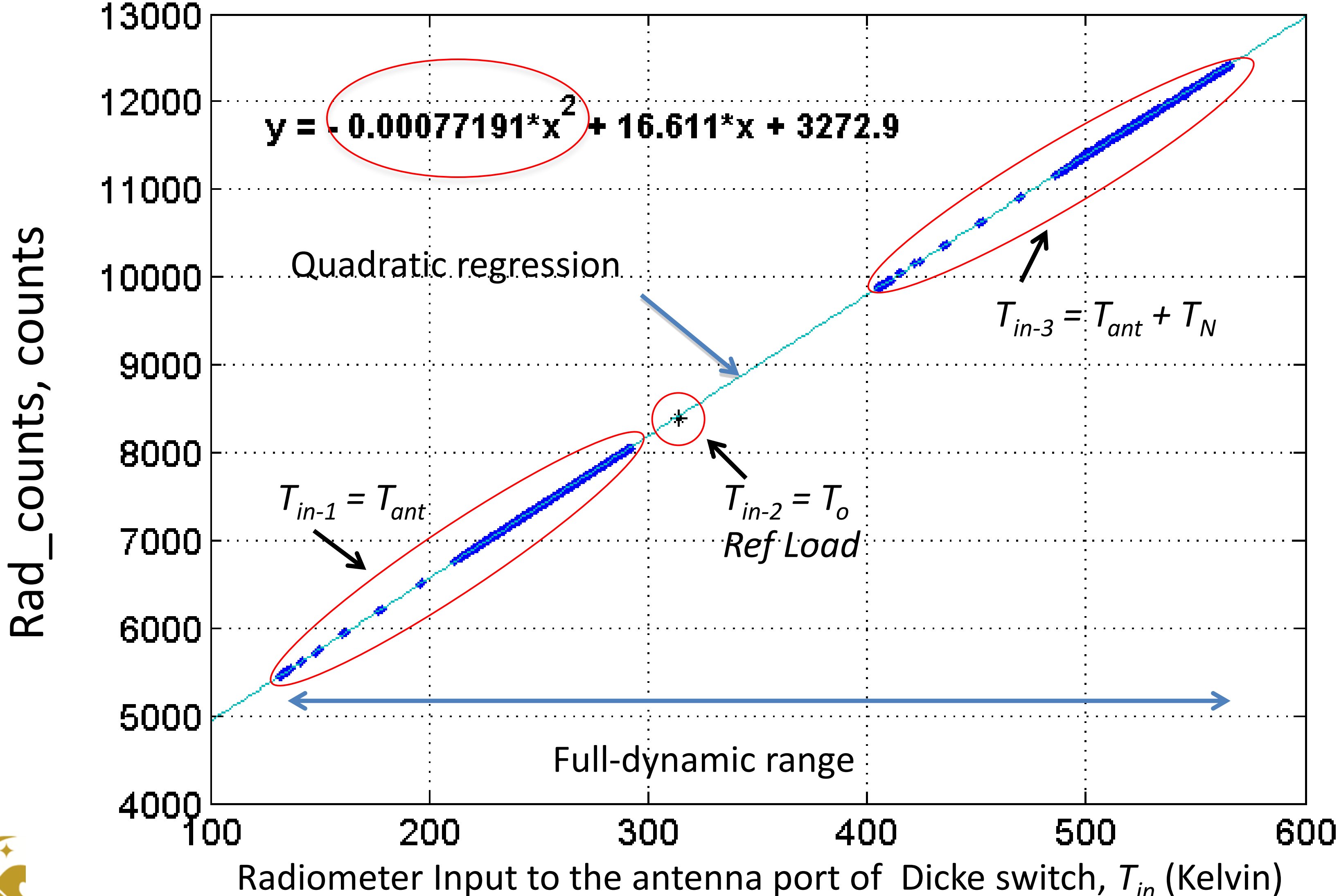
MWR Radiometer Transfer Function for 37V V5.0S (constant gain) for One Orbit



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V6.0 Radiometer Transfer Function Linearization

- Averaging 2nd order regression coeff's from 7 DSC orbits, the instantaneous counts linearization equation is:
  - For 37 V

$$C_{x\_linear} = C_x - (\text{-7.4677e-004}) * \mathrm{T_{in}}^2$$

  - For 37 H

$$C_{x\_linear} = C_x - (\text{-6.9064e-004}) * \mathrm{T_{in}}^2$$

  - For 23 H

$$C_{x\_linear} = C_x - (\text{-2.1708e-004}) * \mathrm{T_{in}}^2$$

Where *x = ant, N, and ref*

Tin is the input *Tb* to the Dicke switch, which is estimated using smear-corrected (non-linear) counts

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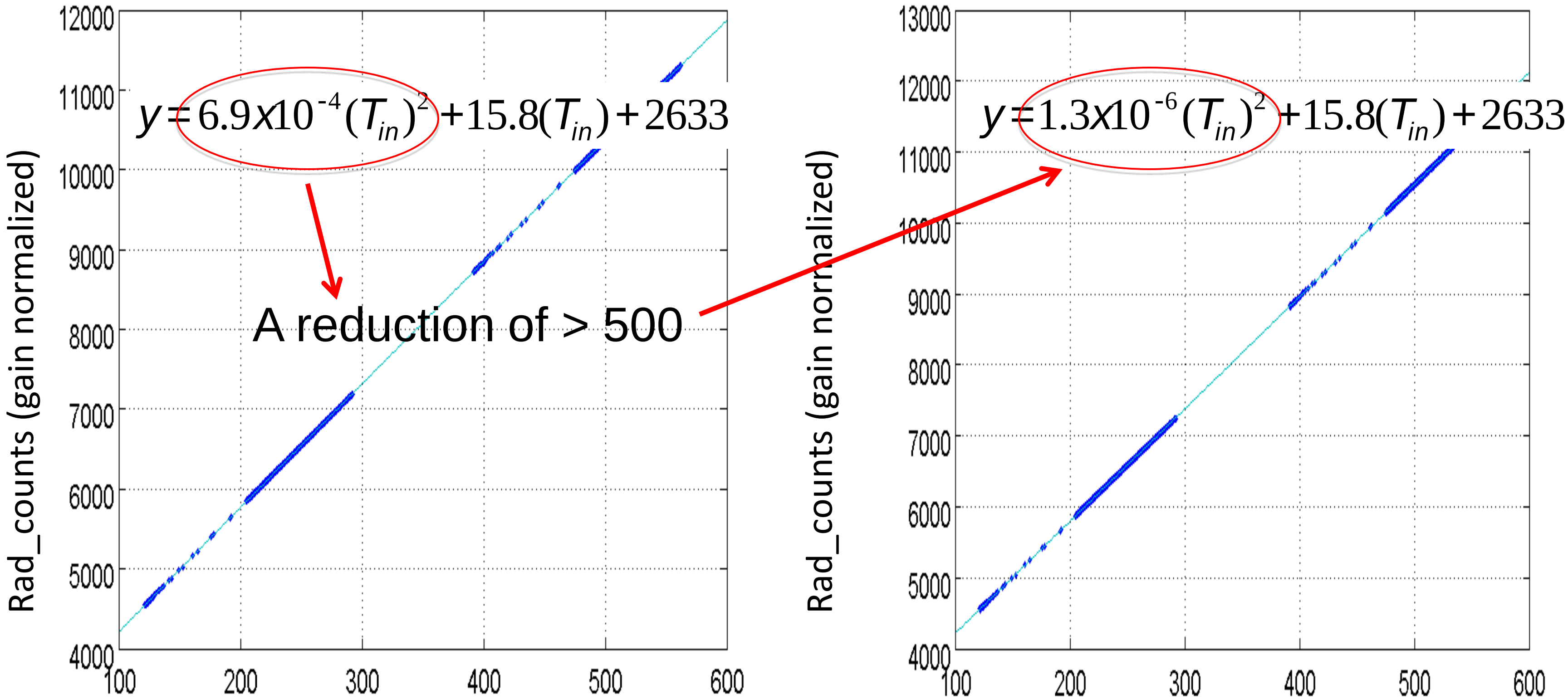
Radiometer Transfer Function 37V (constant gain) V5.0S and V6.0

V5.0S (non-linear counts) | V6.0 (linear counts)



Radiometer Input to the antenna port of Dicke switch, T_{in} (Kelvin)

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Post Launch Analysis

- APC and residual bias correction were applied by inter-satellite XCAL
  - MWR = target & WindSat = reference
- MWR and WindSat have different incident angles, therefore, Tb's were adjusted using theoretical radiative transfer model values for both satellites (MWR_{sim} and WS_{sim})

$$\boldsymbol{WS_{adj} = WS_{obs} + (MWR_{sim} - WS_{sim})}$$

- Double Difference Technique

$$\boldsymbol{DD = MWR_{obs} - WS_{adj}}$$

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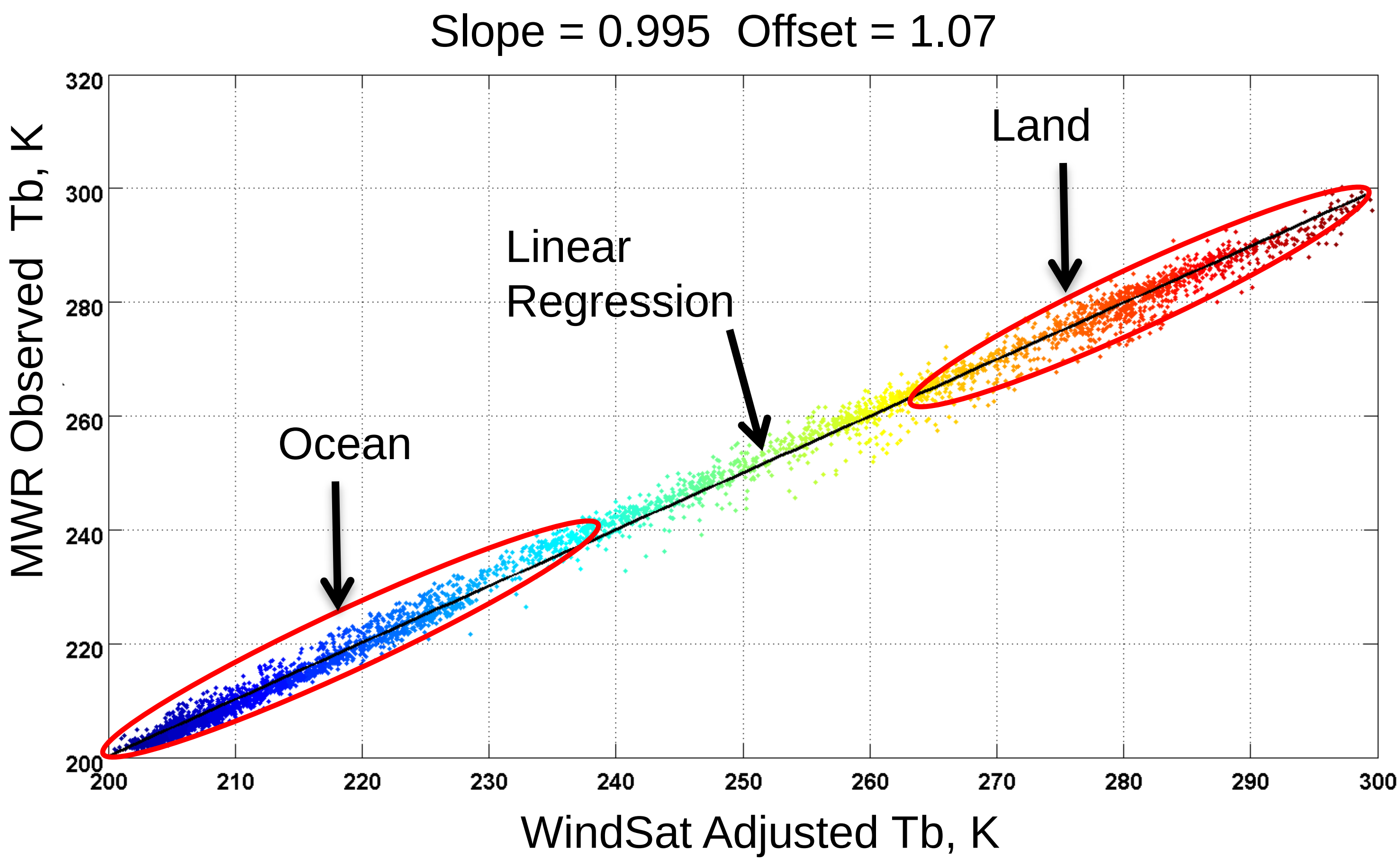
37GHz V-pol, Comparison of MWR V6.0 (Beam 1) and WindSat



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Double Difference Radiometric Biases

MWR/WindSat

(Five Days Average)

Sept 01, 2012 – Feb 28, 2013

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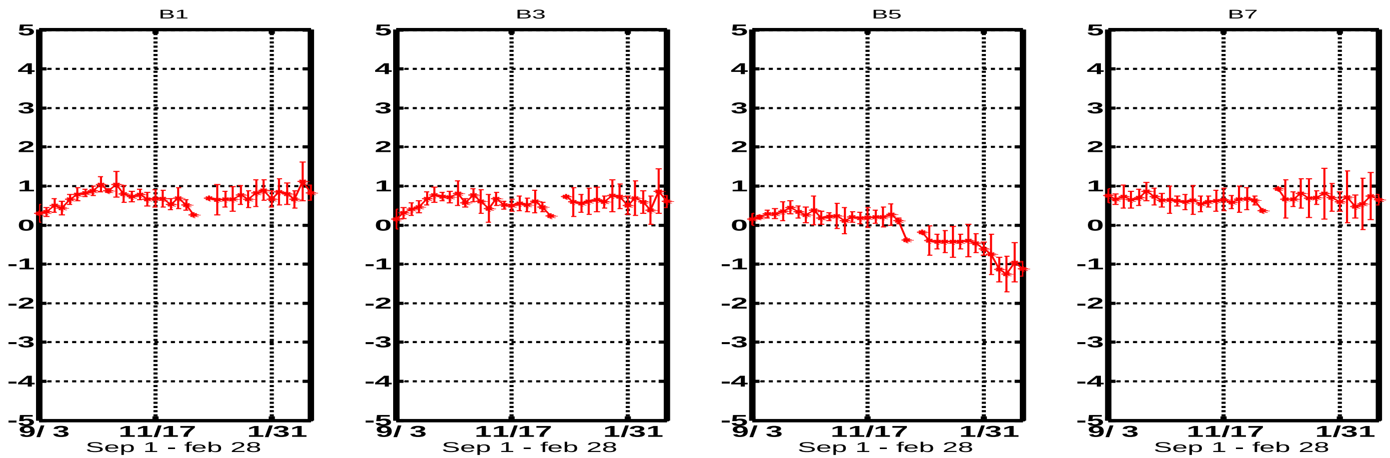
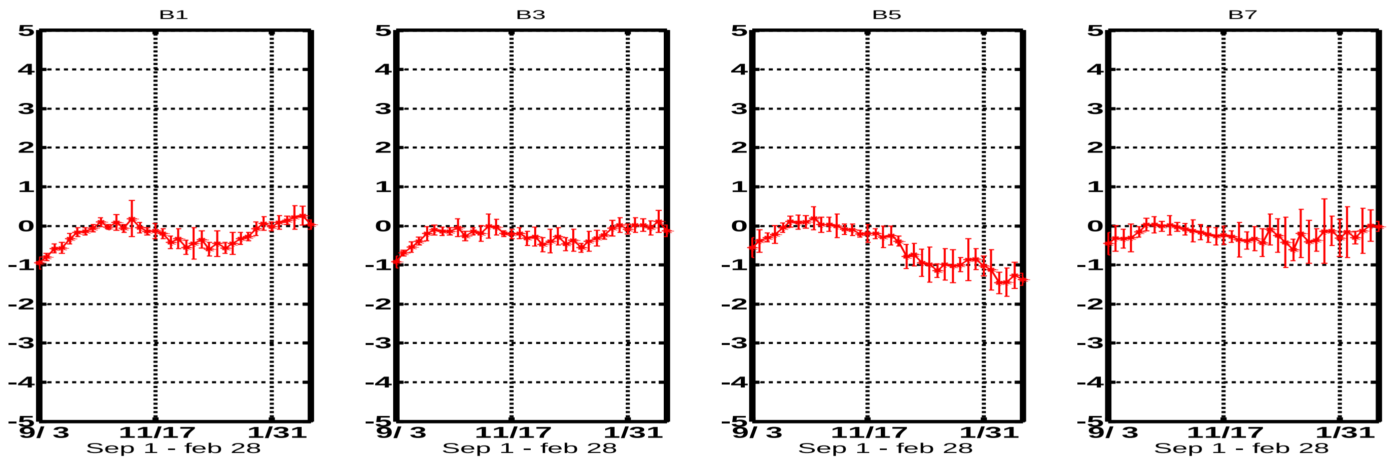
Double Difference Biases 37V, Odd Beams

Version 5.0S



Version 6.0



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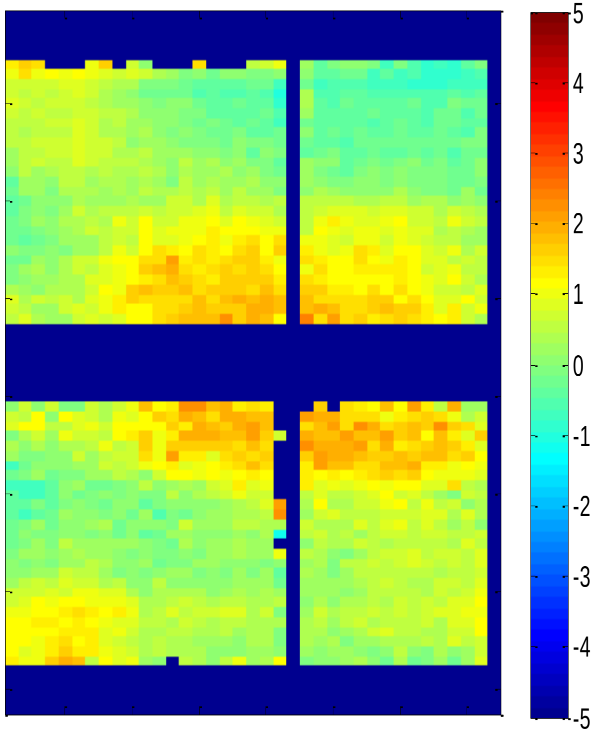
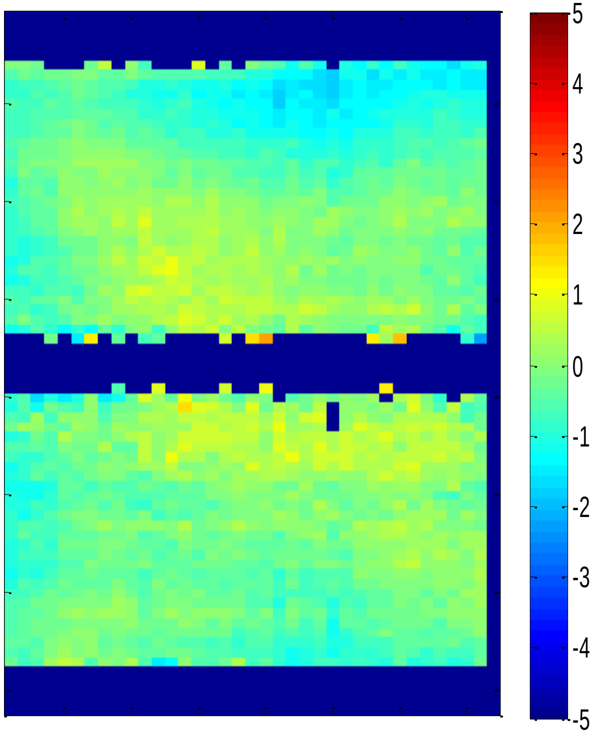
Five days Average in 5° Lat Zones
37V, Odd Beams

Version 5.0S



Sep 01 - Feb 28

Version 6.0



Sep 01 - Feb 28

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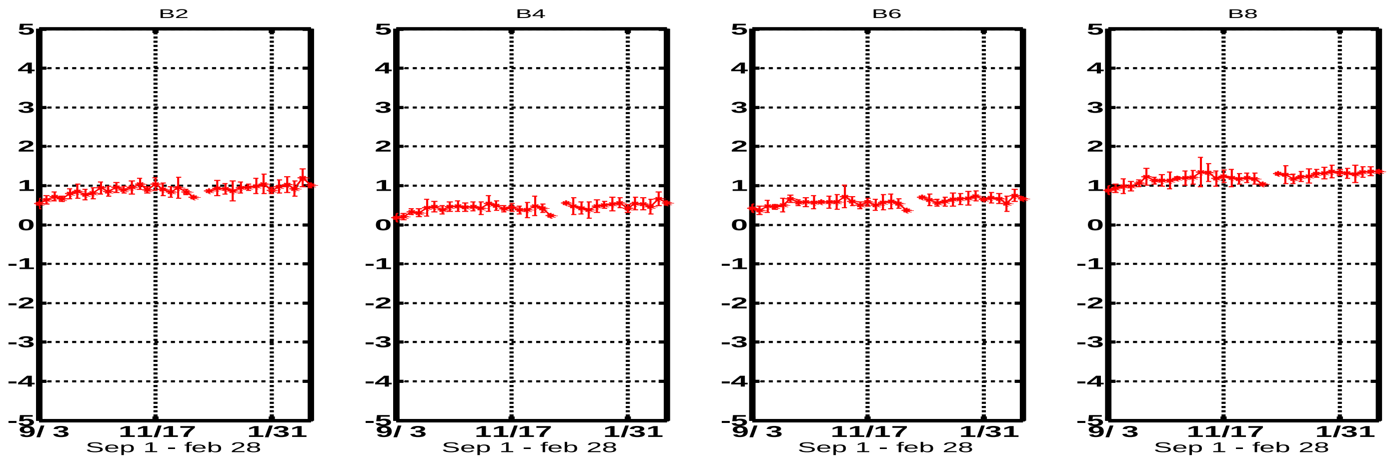
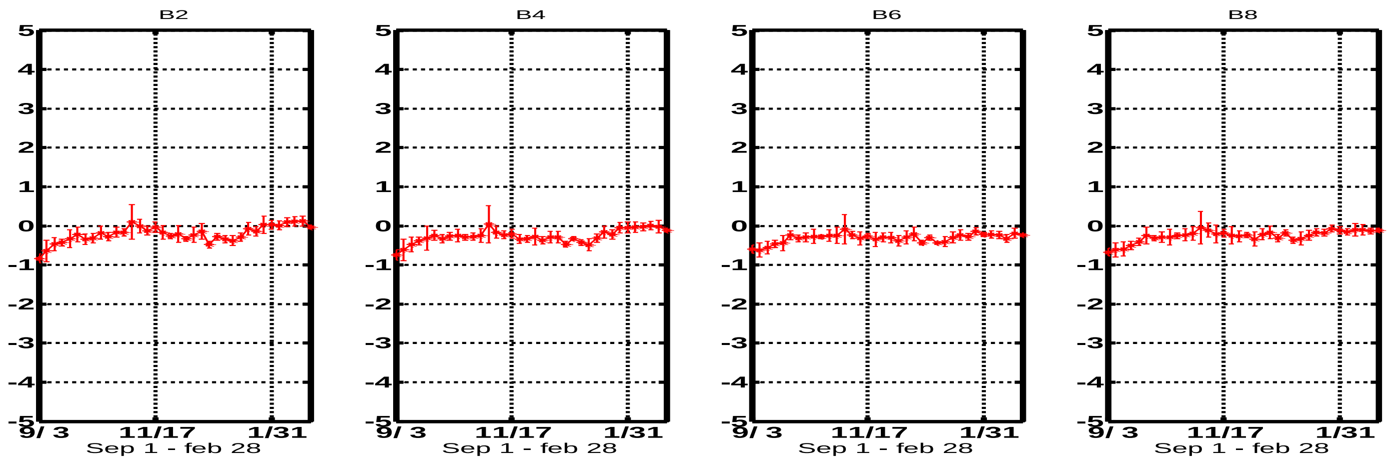
Double Difference Biases 37V, Even Beams

Version 5.0S

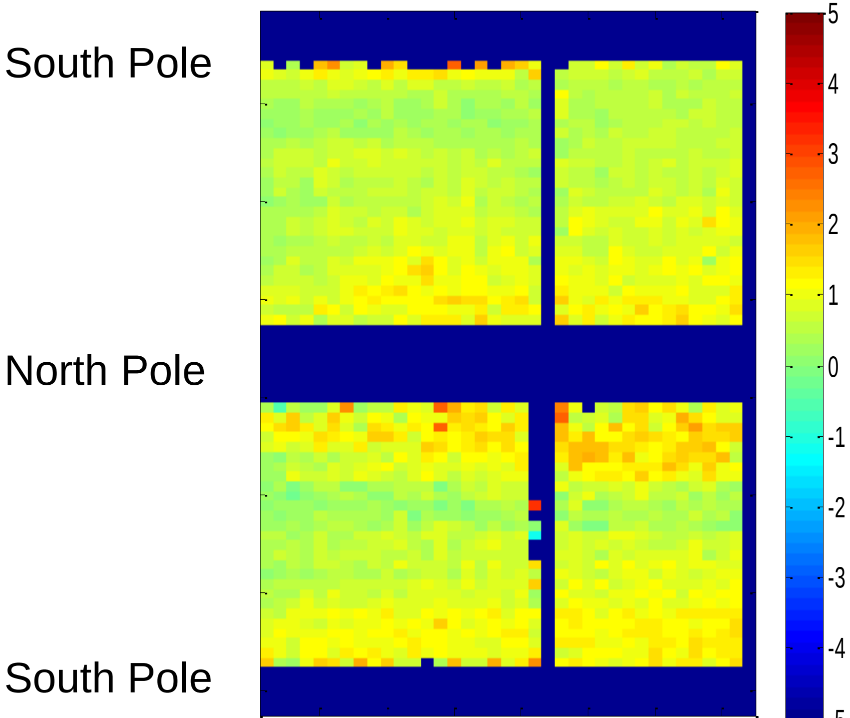


Version 6.0



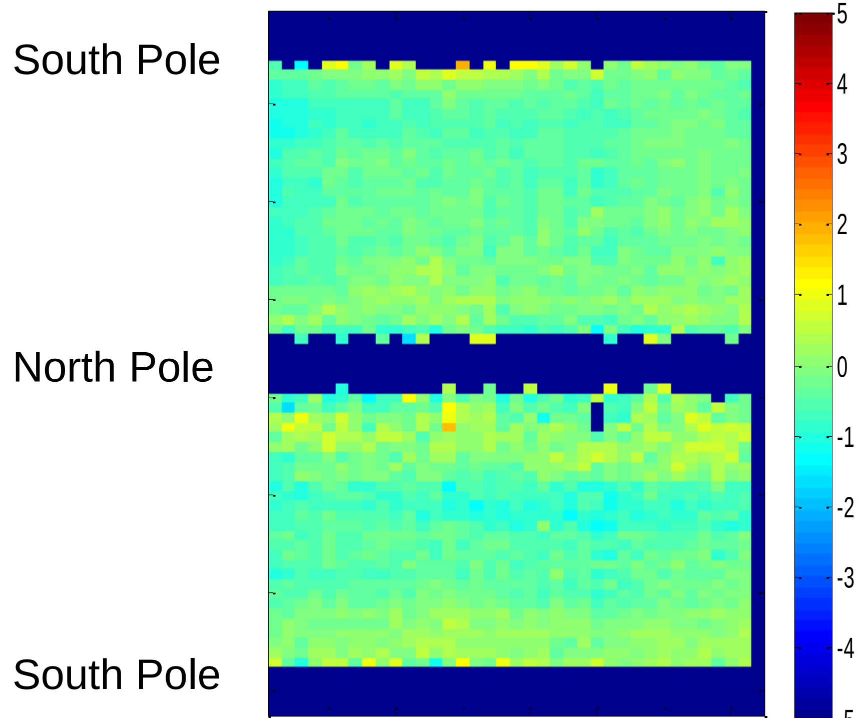
Five days Average in 5° Lat Zones 37V, Even Beams

Version 5.0S



Sep 01 - Feb 28

Version 6.0



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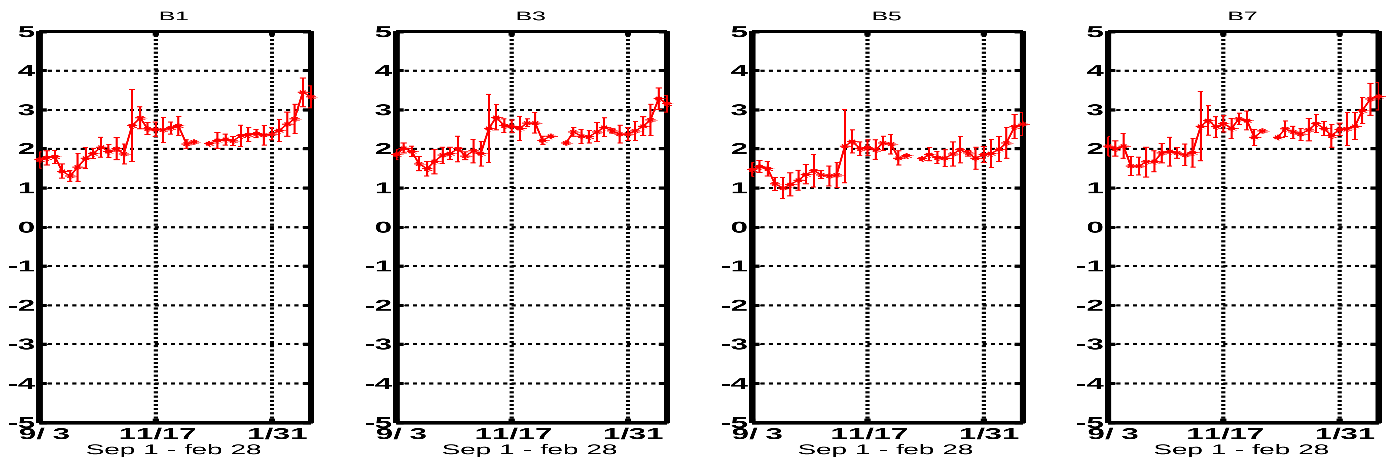
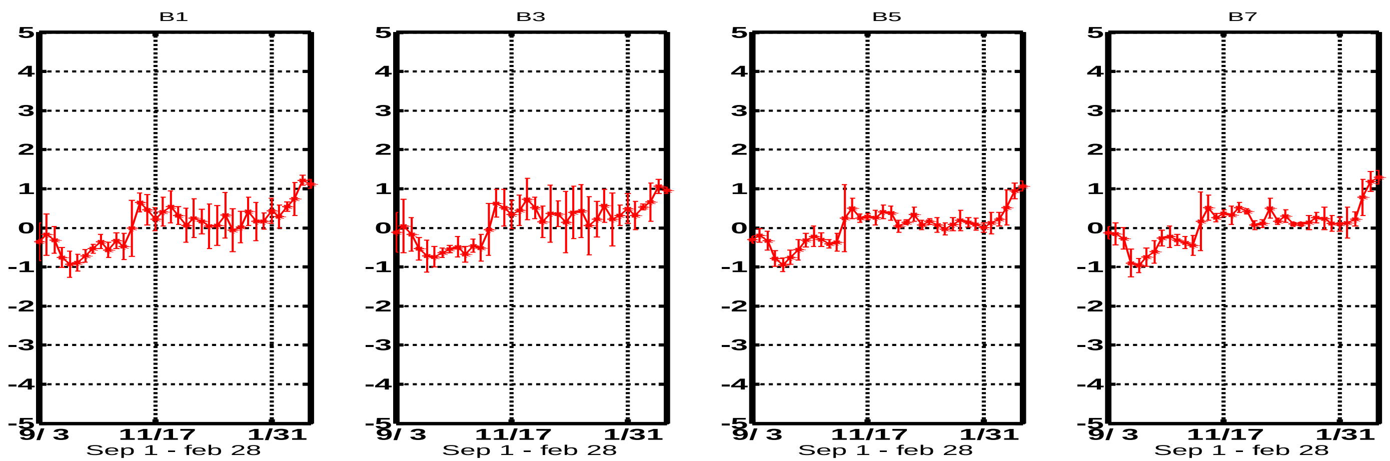
Double Difference Biases 37H, Odd Beams

Version 5.0S



Version 6.0



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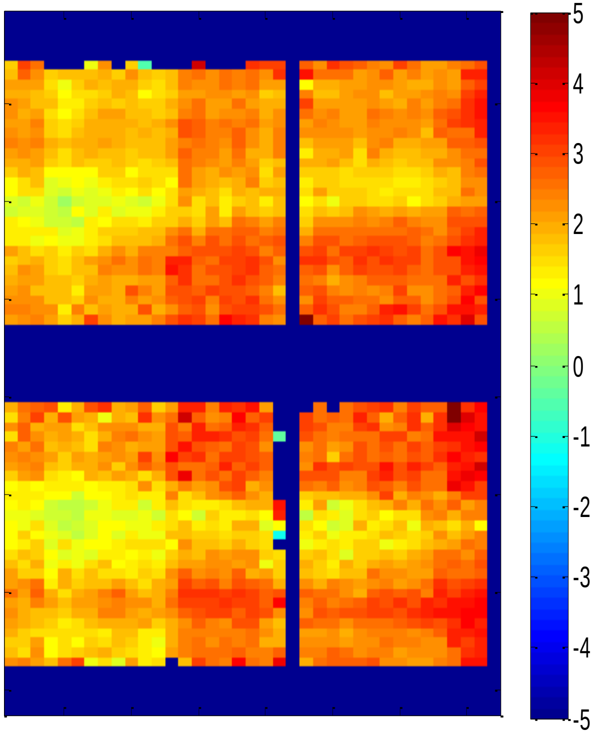
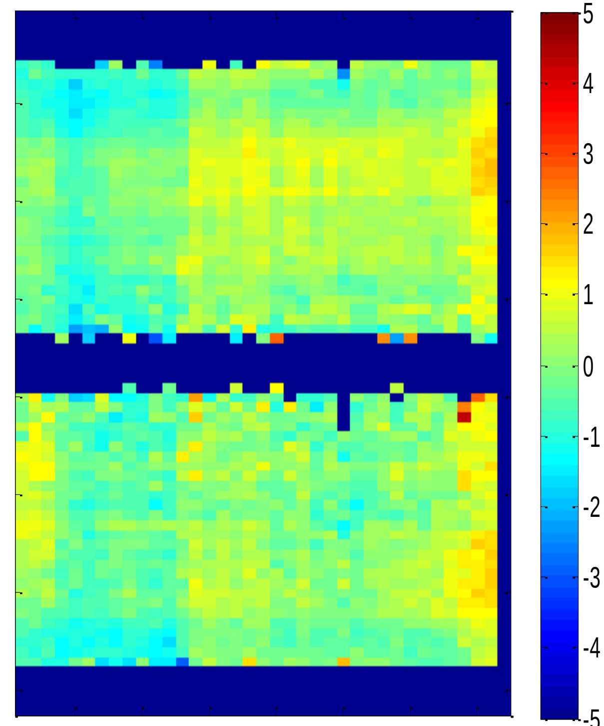
Five days Average in 5° Lat Zones
37H, Odd Beams

Version 5.0S



Sep 01 - Feb 28

Version 6.0



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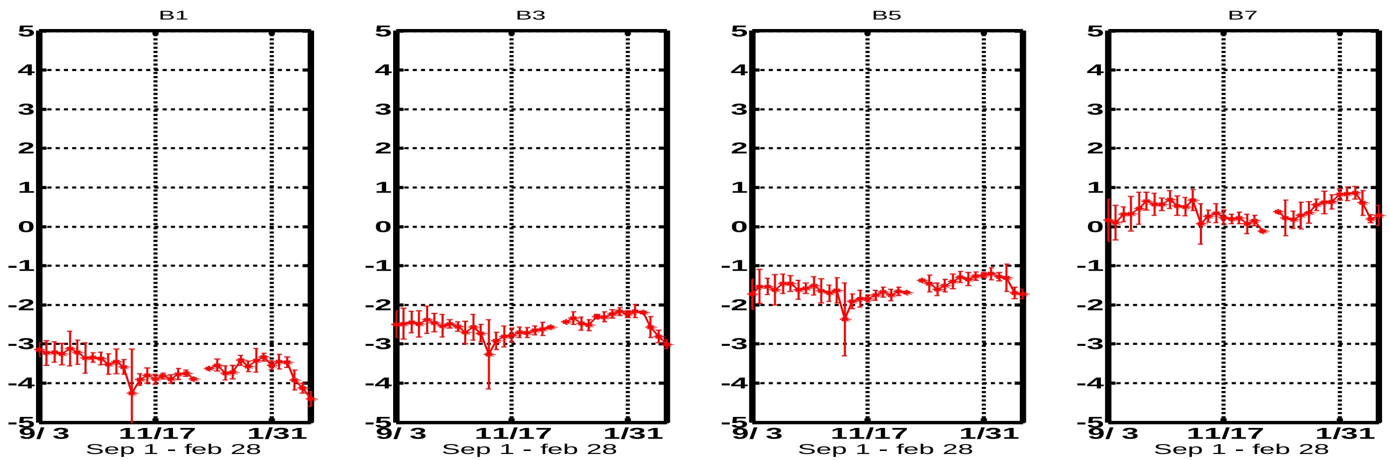
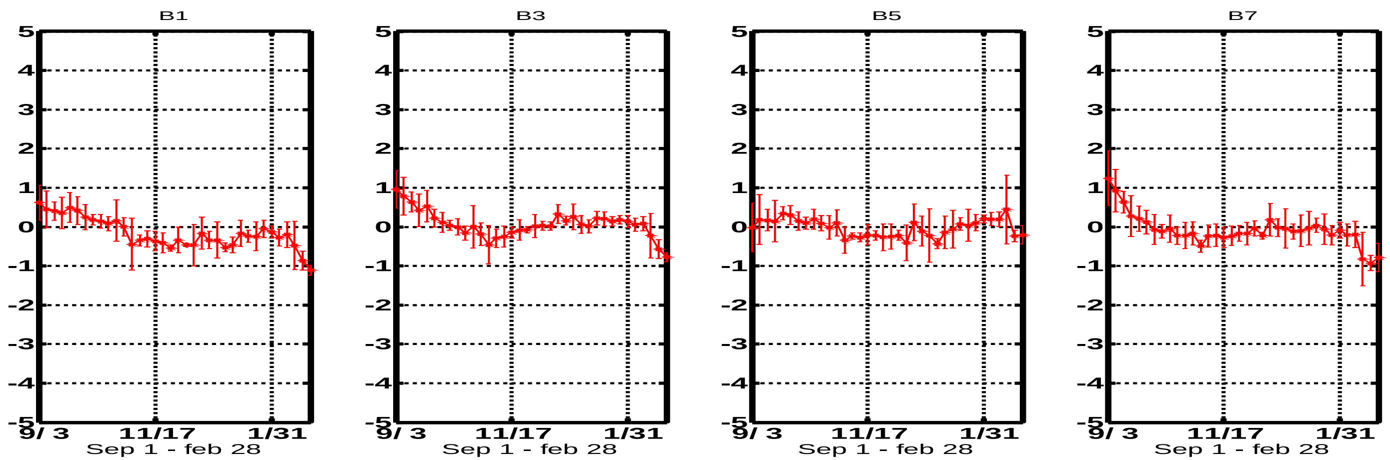
Double Difference Biases 23H, Odd Beams

Version 5.0S



Version 6.0



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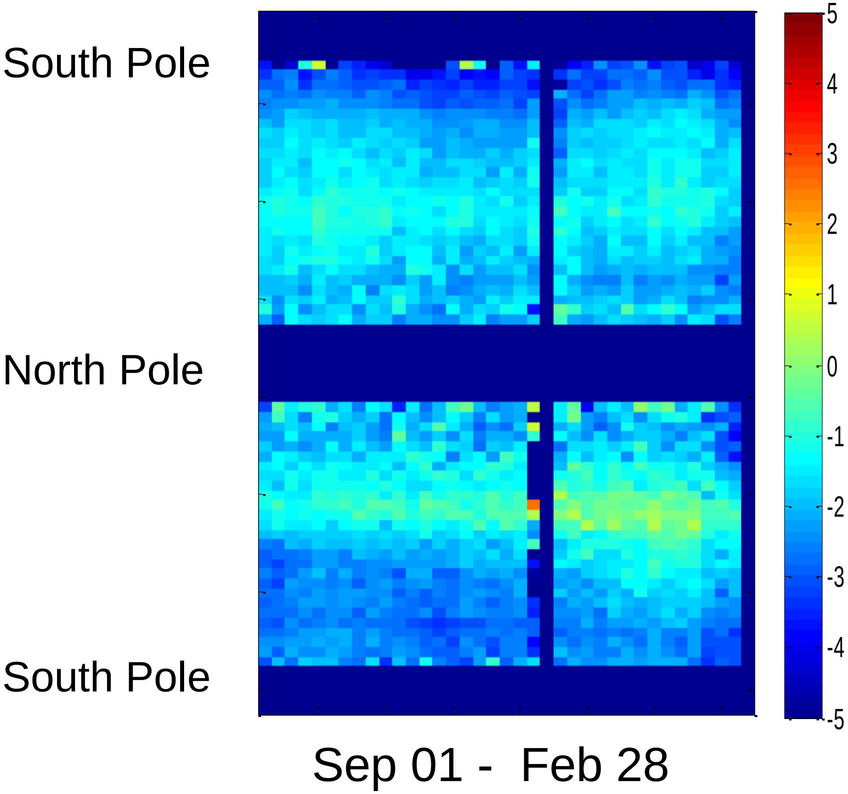
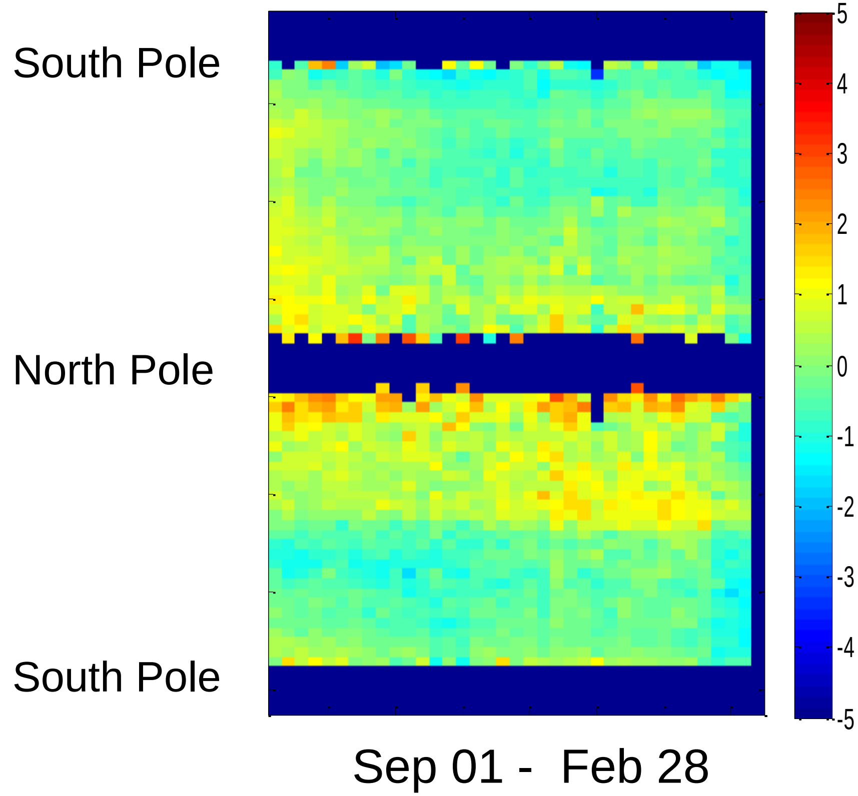
Five days Average in 5° Lat Zones
23H, Odd Beams

Version 5.0S



Version 6.0



Conclusions

- MWR Counts to Tb algorithm V6.0 has been developed and a beta test version has been distributed to the AQ Cal/Val team via PODAAC
- MWR transfer function non-linearity in V5.0S has been characterized and corrected in V6.0
  - A count-linearization procedure has been shown to make the radiometer transfer function linear and removed the effect of gain dependence on the input scene brightness
- On-orbit inter-satellite radiometric calibration (XCAL) between MWR and WindSat have produced the antenna pattern correction (APC) and removed small Tb biases

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Back-up Slides

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Recommendations, that:

- MWR V6.0 Counts to Tb algorithm be adopted by CONAE for L-1B processing
- All MWR data should be reprocessed using V6.0
- L-2 Geophysical retrieval algorithms should be retuned using V6.0 Tb's
- MWR Calib and Application team reviews be held in Spring 2014 to formally release MWR data products

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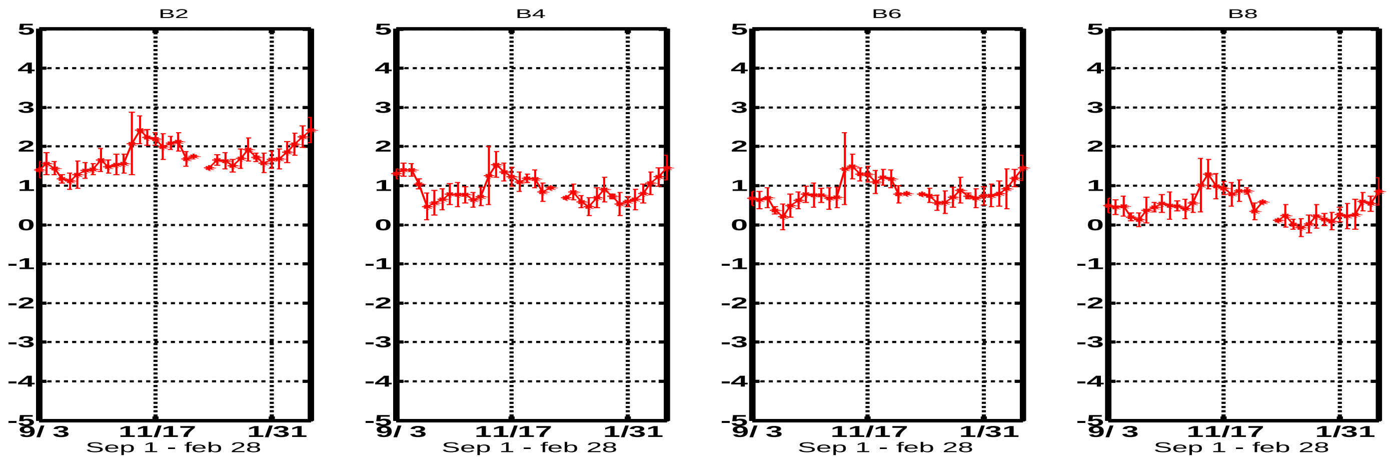
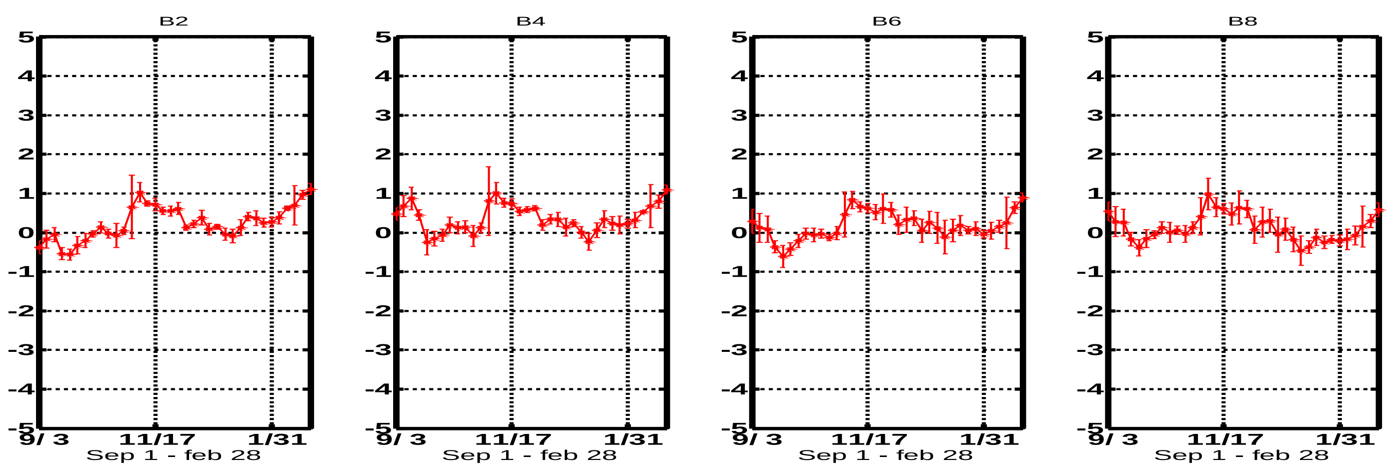
Double Difference Biases 37H, Even Beams

Version 5.0S



Version 6.0



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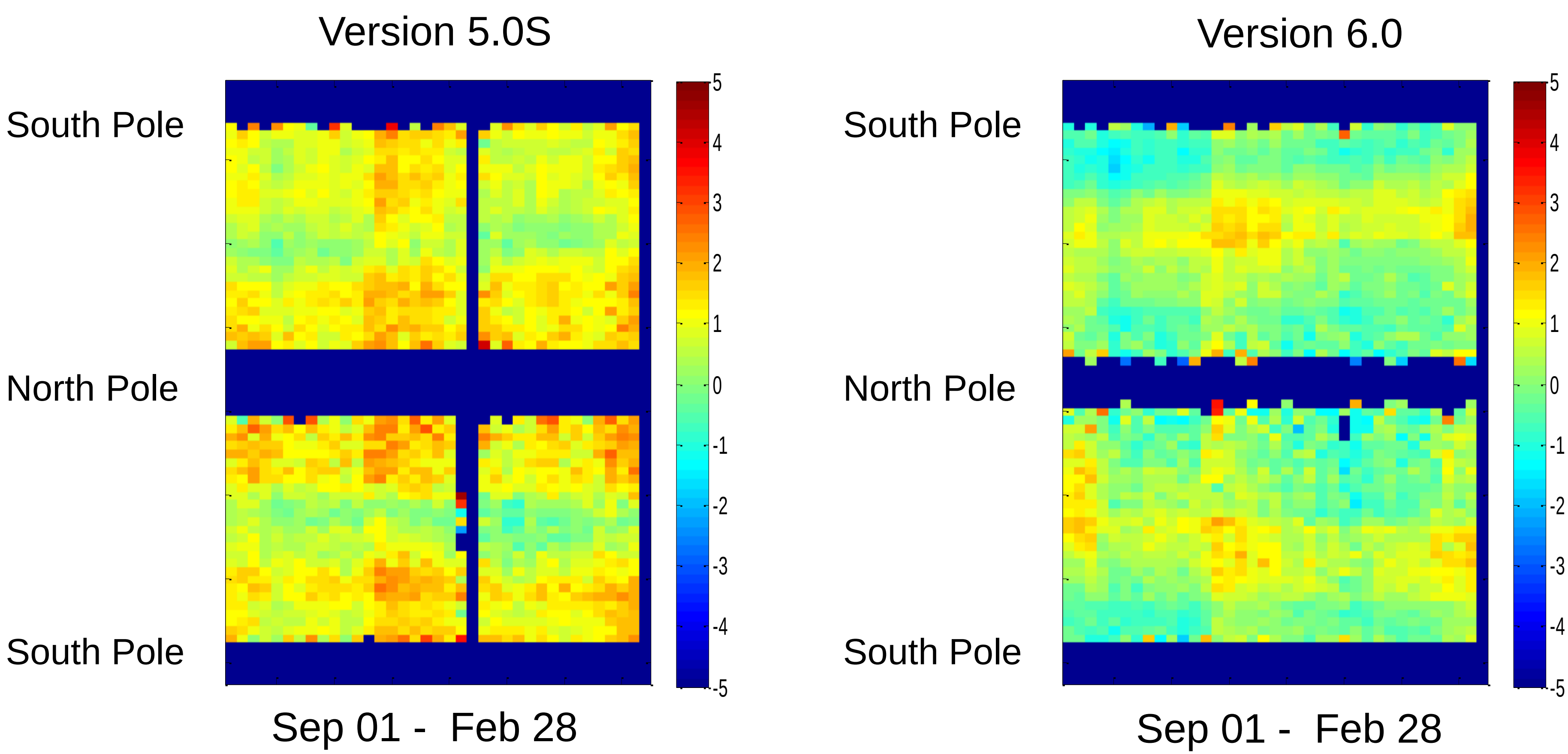
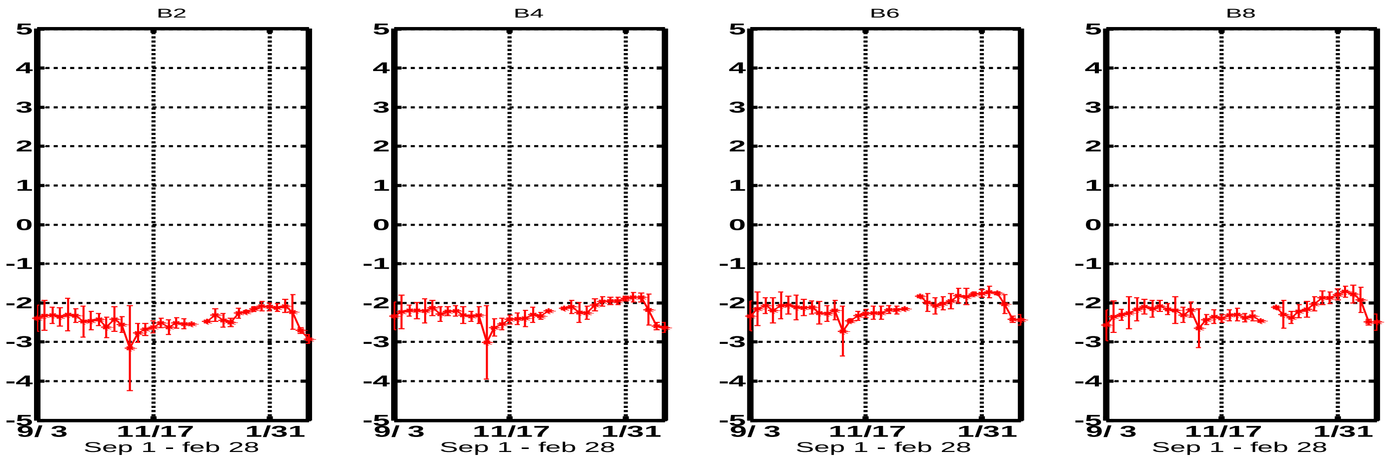
Five days Average in 5° Lat Zones
37H, Even Beams

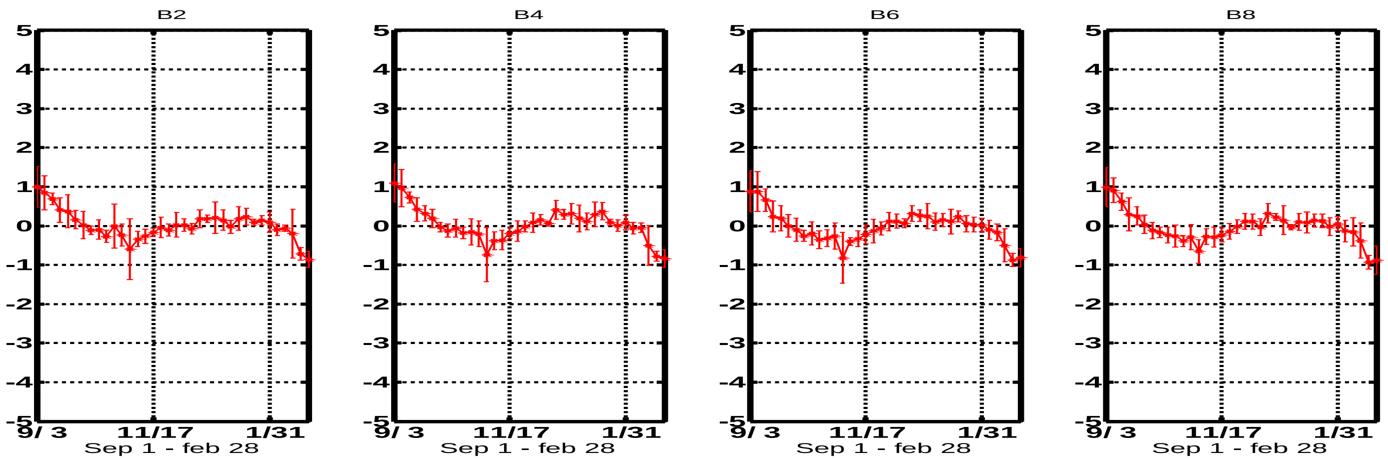


Double Difference Biases 23H, Even Beams

Version 5.0S



Version 6.0



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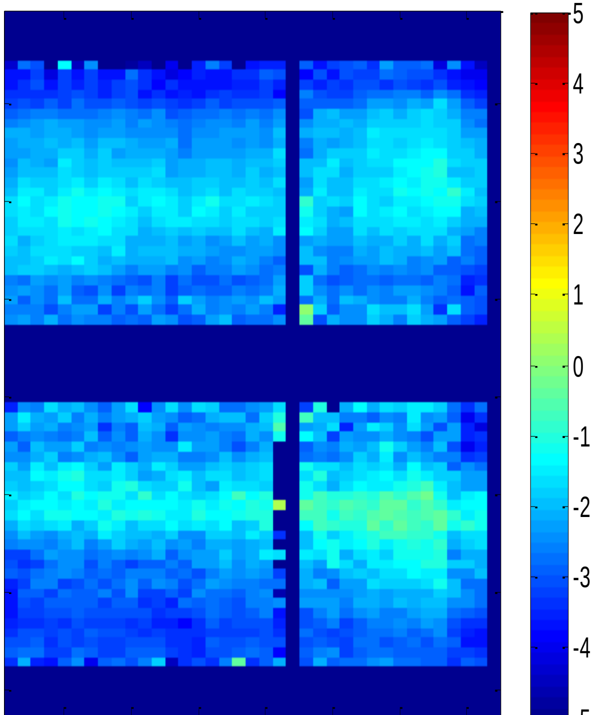
Five days Average in 5° Lat Zones
23H, Even Beams

Version 5.0S

South Pole

North Pole

South Pole



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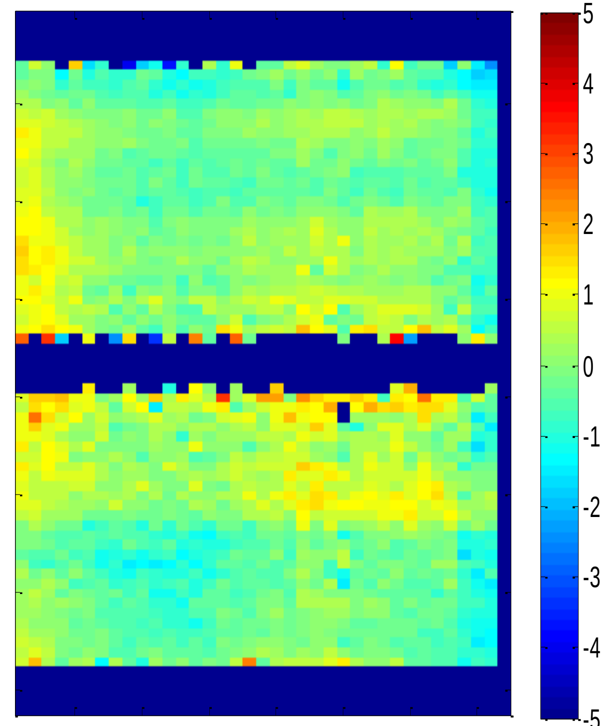
Version 6.0

South Pole

North Pole

South Pole



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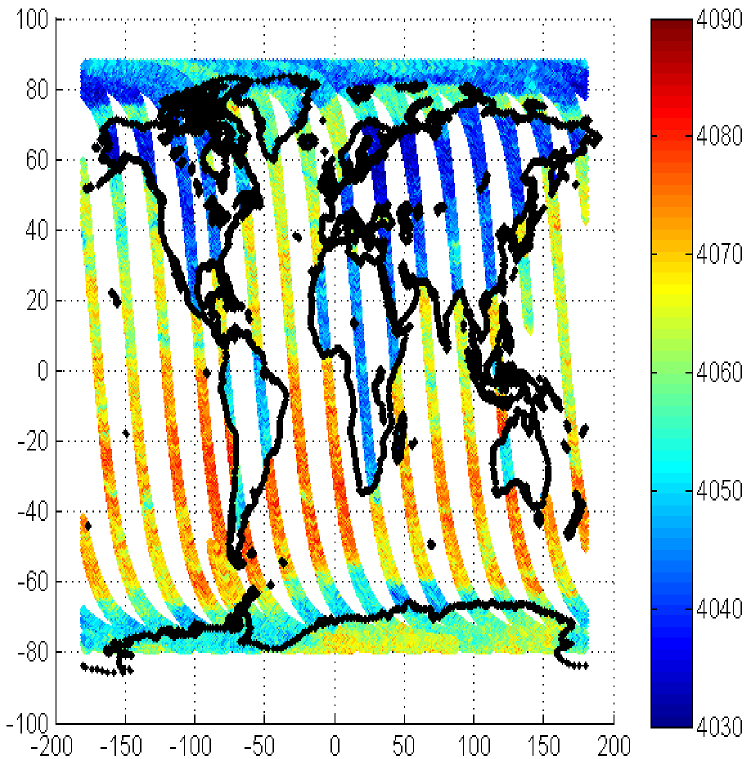
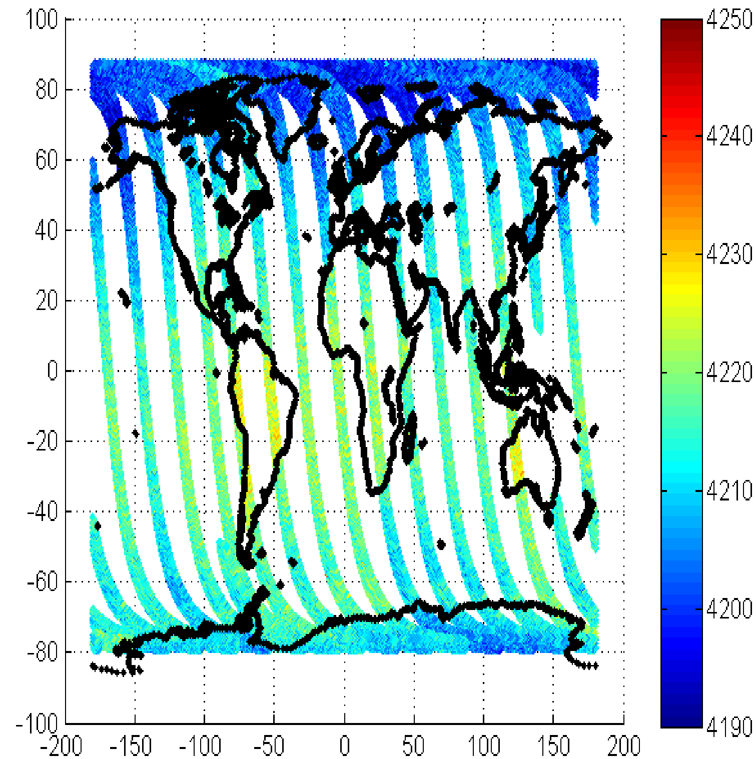
37GHz V-pol, On-orbit Noise Diode Deflection (NOT gain normalized), Ascending Passes for One Day (All Beams)

Version 5.0S



Version 6.0



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Counts Normalization for Constant Receiver Gain

- Under typical on-orbit condition, the radiometer system gain will vary cyclically (once/orbit) due to the receiver physical temperature changes
- However, to determine the radiometer transfer function, the gain must be constant
- Therefore, the time variable gain was removed using the Dicke state-3 (viewing the reference load)

$$G_i = \frac{C_{0_i}}{(To + Trec)_i}$$

- where
  - G_i is the instantaneous channel gain
  - C_o is the reference load counts
  - T_o is the receive physical temperature
  - T_{rec} is the receiver noise temp

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Counts Normalization for Constant Receiver Gain cont.

- Time variable gain was removed and all counts were normalized using the following equation:

$$C_{x\_norm} = C_{x_i} * \frac{mean\{Co/(To+Trec)\}}{[Co_i/(To+Trec)_i]}$$

$$x = a, N, o \ \& \ i = \text{ instantaneous value}$$

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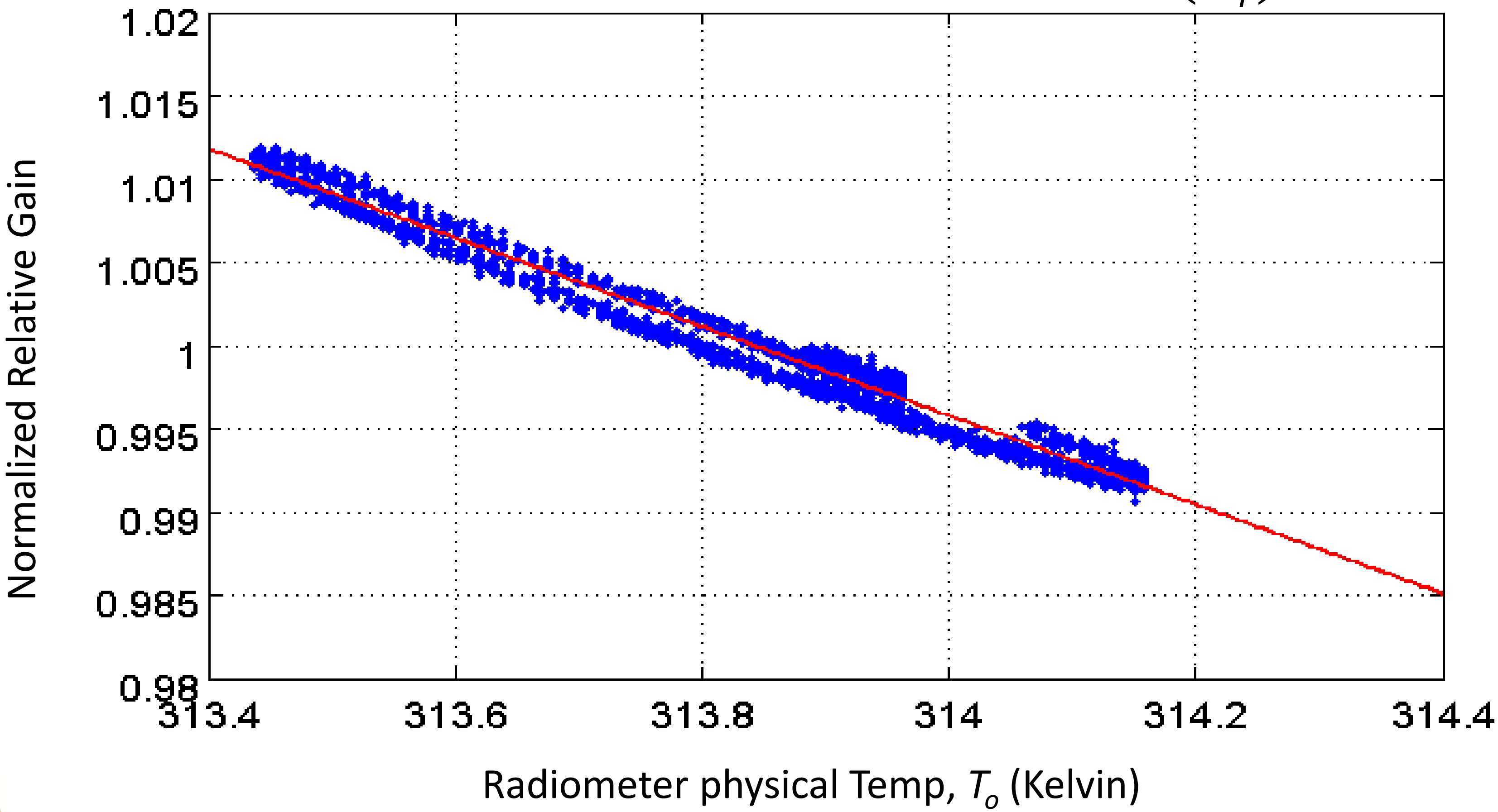
37GHz V-pol, Typical MWR Radiometer Gain for One-orbit

$$Normalized\_relative\_gain = \frac{G_i}{mean(G_i)}$$



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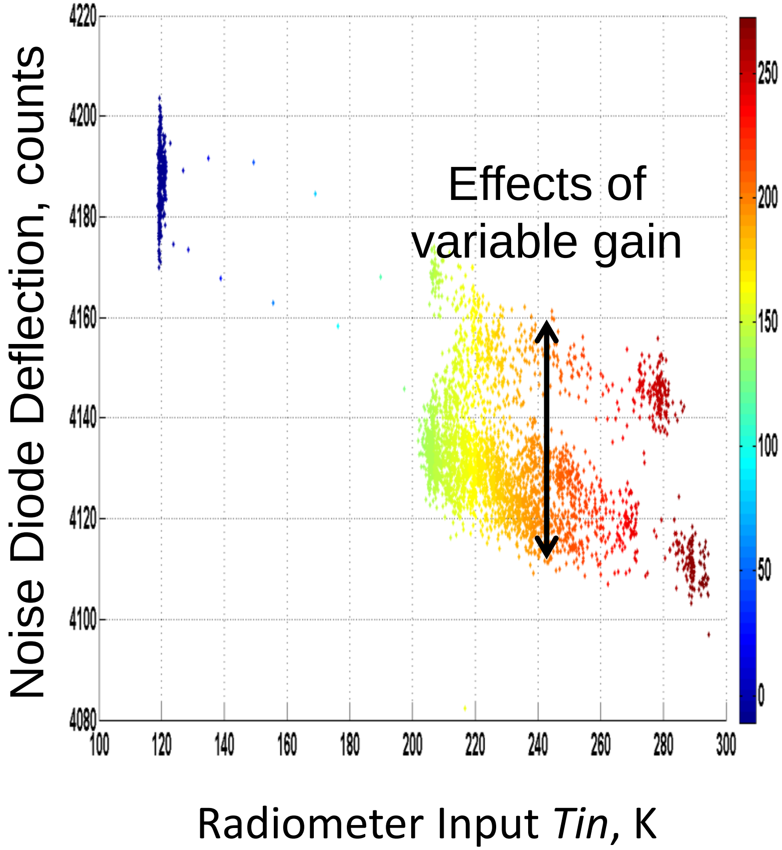
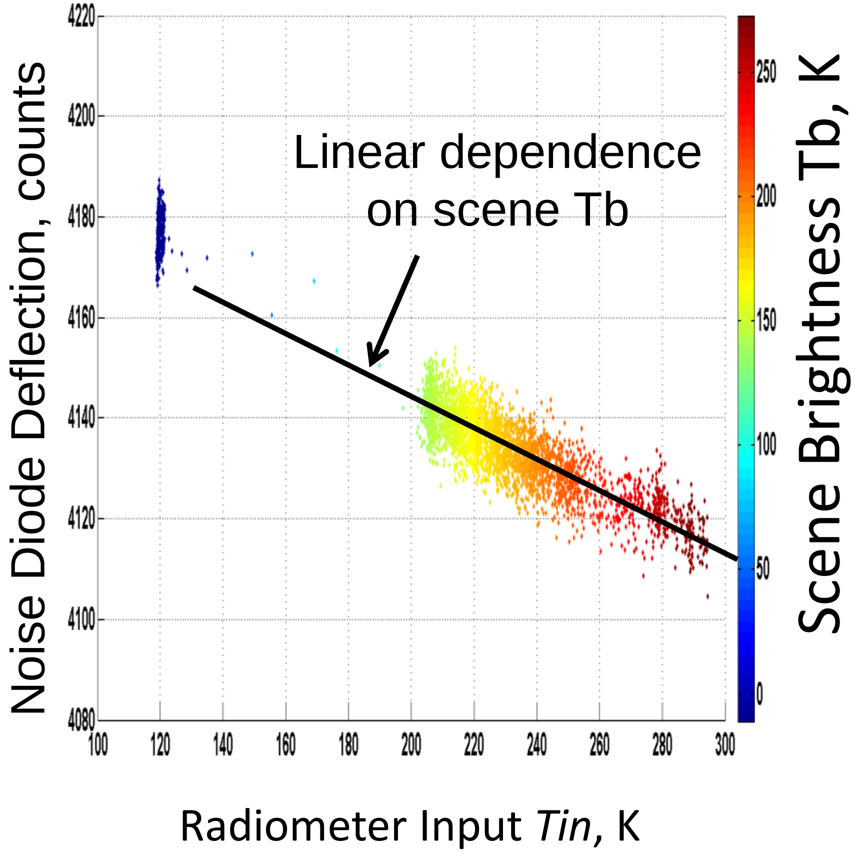
37GHz V-pol, Comparison of V5.0S Noise Diode Deflection = $(C_a - C_N)$

Before Count (gain) Normalization



After Count (gain) Normalization



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Radiometer Transfer Function Linearization V5.0

- Seven Deep Space Calibration (DSC) orbits that included, space, ocean, and land observations were used to cover wide range of scene Tb's
- After counts (gain) normalization, the radiometer transfer function was established
  - $Rad\_counts = f(T_{in})$
- Quadratic regression for 37V channel yielded the following

$$Rad\_counts = 7.719 x 10^{-4} (T_{in})^2 + 16.61\,(T_{in}) + 3272.9$$

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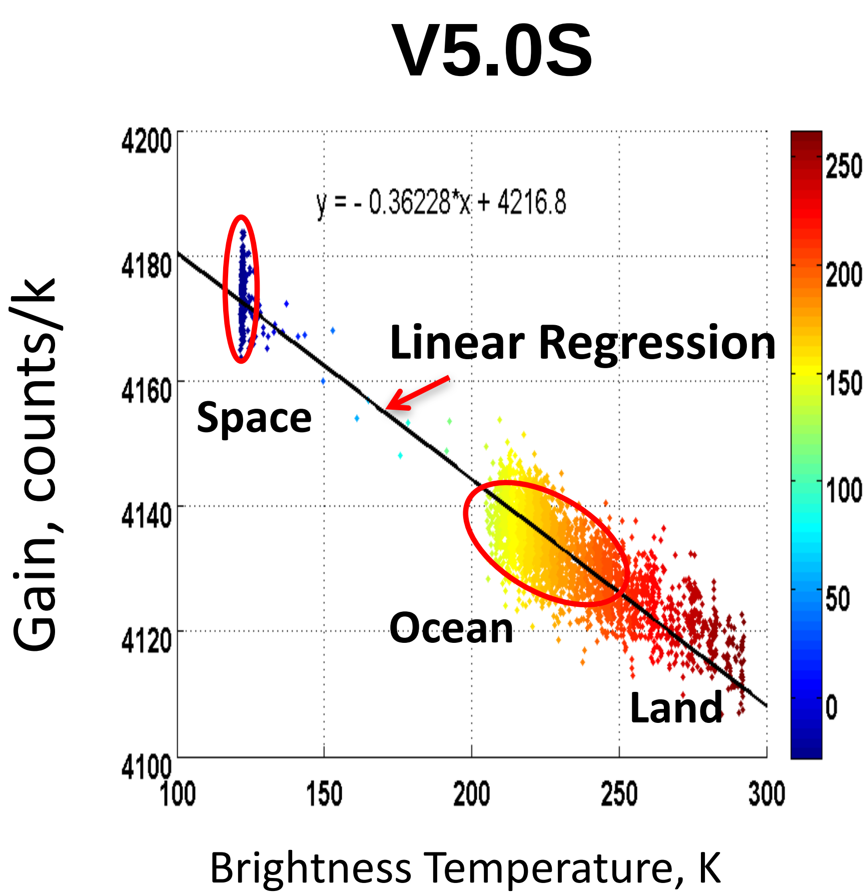
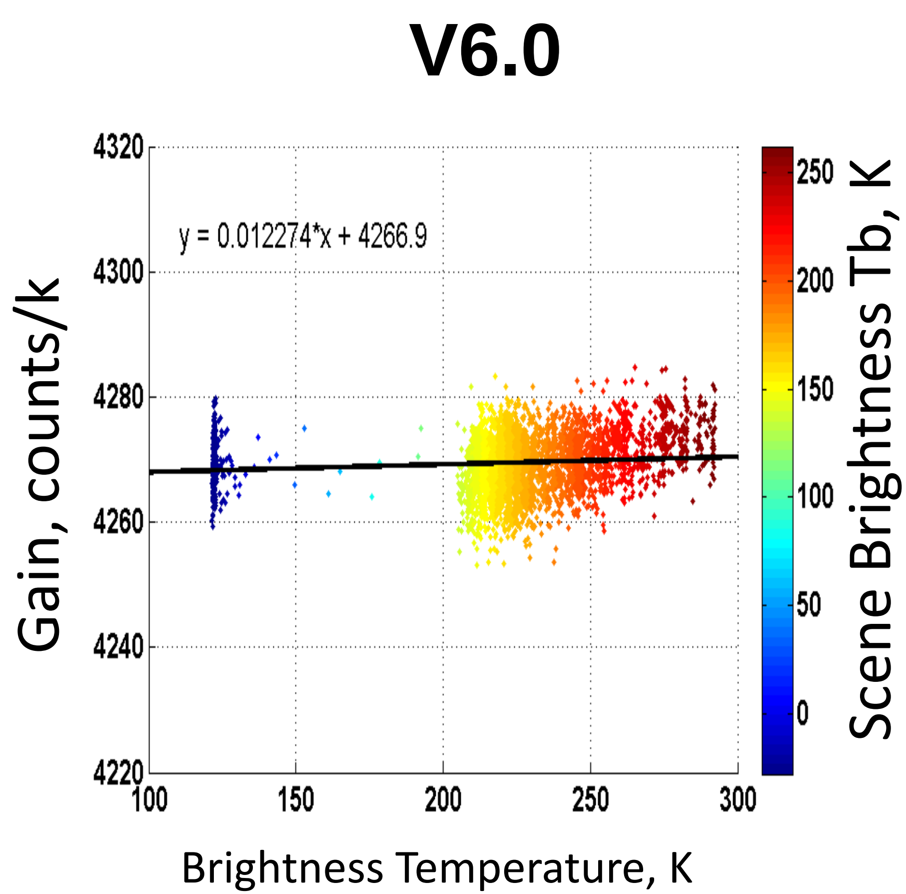
37GHz V-pol , One Orbit Noise Diode Deflection





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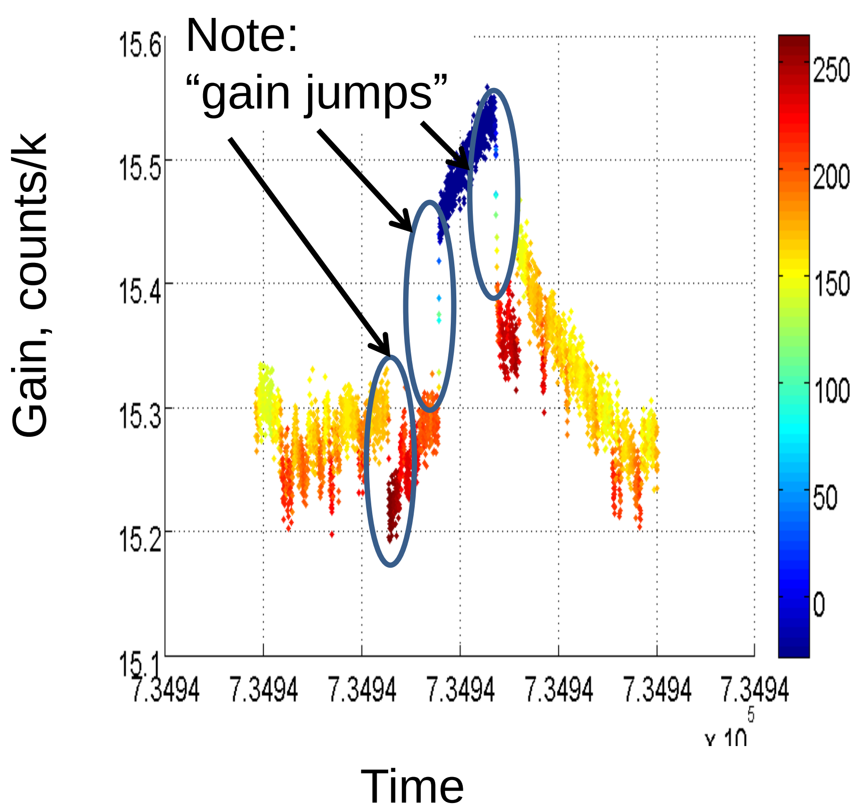
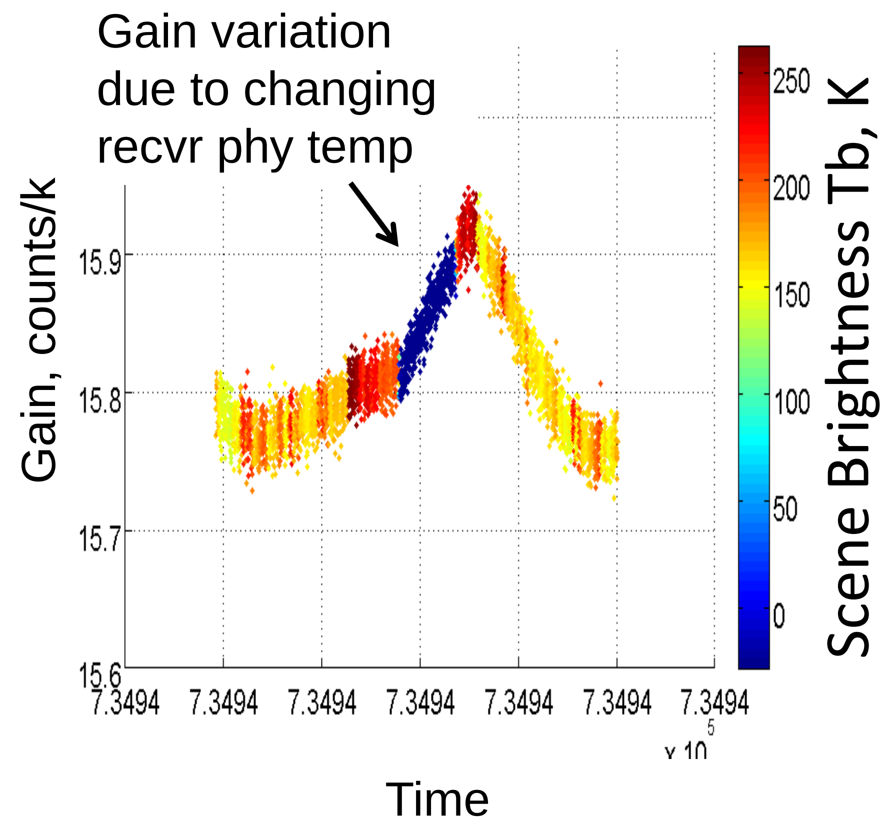
37GHz V-pol , One Orbit Radiometer Gain

V5.0S



V6.0



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Reanalysis of Prelaunch TV Calibration Test

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Pre-launch Data Analysis Objectives using Linearized Counts

- Characterization of injected noise diode temperature (T_N) over physical temperature
- Retrieve switch matrix loss coefficients
  - Empirical method (regression model) was applied
  - Assumption: All transmission and reflection coeff's are constant and are NOT expected to change during MWR's mission life time

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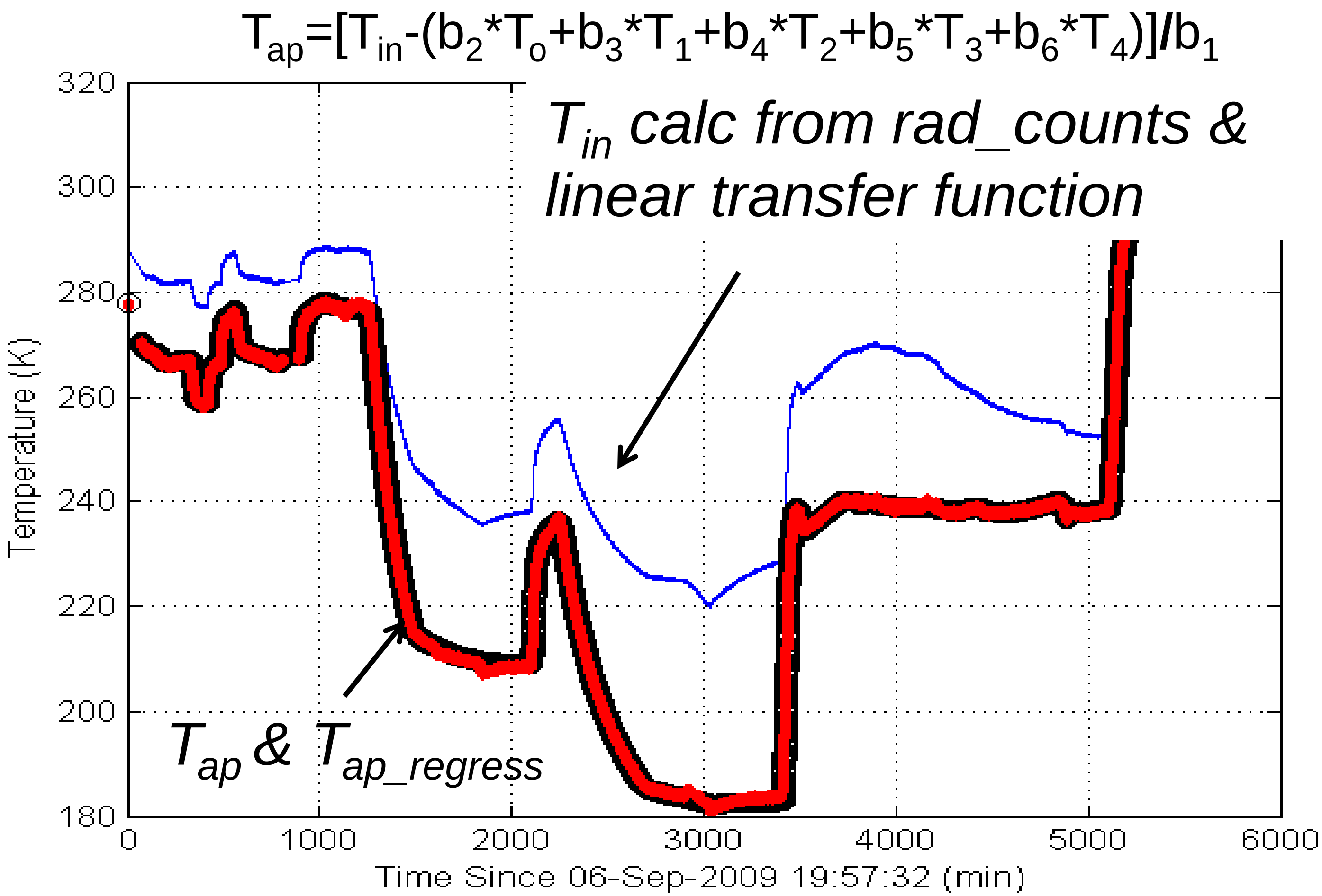
37GHz V-pol, Computed Apparent Temperature using V6.0 Regression Model



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Inversion Model for Apparent Brightness Temperature (T_{ap})

$$T_{ap}=[T_{in}-(b_2*T_o+b_3*T_1+b_4*T_2+b_5*T_3+b_6*T_4)]/b_1$$

- where
  - T_{ap} is the scene brightness temp at horn aperture
  - T_{in} is the input brightness temperature to antenna port of Dicke switch
  - T_o , T_1 , T_2 , T_3 ,& T_4 are MWR physical temps
  - b_1, b_2, b_3, b_4, b_5 and b_6 are coefficients derived using the regression model

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