Suomi NPP ATMS SDR Provisional Product Highlights

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Suomi NPP EDR Product Review
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ATMS Calibration Requirements

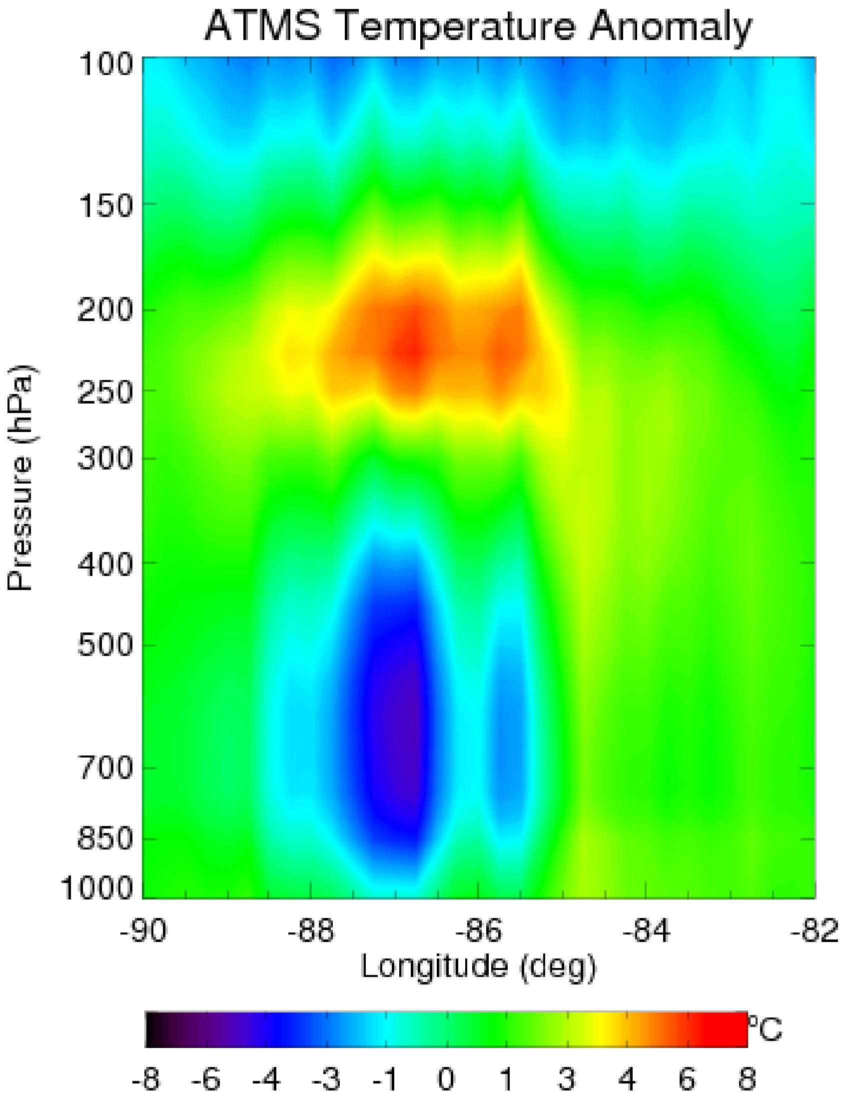
#	Channel Freq.(MHz)	Polarization	Bandwidth Max. (MHz)	Freq. Stability (MHz)	Calibration Accuracy	Nonlinearity Max. (K)	NEΔT (K)	3-dB BW* (deg)
1	23800	QV	270	10	0.83	0.1	0.5	5.2
2	31400	QV	180	10	0.83	0.1	0.6	5.2
3	50300	QH	180	10	0.67	0.075	0.7	2.2
4	51760	QH	400	5	0.67	0.075	0.5	2.2
5	52800	QH	400	5	0.67	0.075	0.5	2.2
6	53596±115	QH	170	5	0.67	0.075	0.5	2.2
7	54400	QH	400	5	0.67	0.075	0.5	2.2
8	54940	QH	400	10	0.67	0.075	0.5	2.2
9	55500	QH	330	10	0.67	0.075	0.5	2.2
10	f_o=57290.344	QH	330	0.5	0.67	0.075	0.75	2.2
11	f_o ± 217	QH	78	0.5	0.67	0.075	1.0	2.2
12	f_o ±322.2±48	QH	36	1.2	0.67	0.075	1.0	2.2
13	f_o ±322.2±22	QH	16	1.6	0.67	0.075.	1.5	2.2
14	f_o ±322.2±10	QH	8	0.5	0.67	0.075	2.2	2.2
15	f_o ±322.2±4.5	QH	3	0.5	0.67	0.075	3.6	2.2
16	88200	QV	2000	200	0.95	0.1	0.3	2.2
17	165500	QH	3000	200	0.95	0.1	0.6	1.1
18	183310± 7000	QH	2000	30	0.95	0.1	0.8	1.1
19	183310± 4500	QH	2000	30	0.95	0.1	0.8	1.1
20	183310± 3000	QH	1000	30	0.95	0.1	0.8	1.1
21	183310± 1800	QH	1000	30	0.95	0.1	0.8	1.1
22	183310± 1000	QH	500	30	0.95	0.1	0.9	1.1

ATMS TDR/SDR Provisional Product Highlights

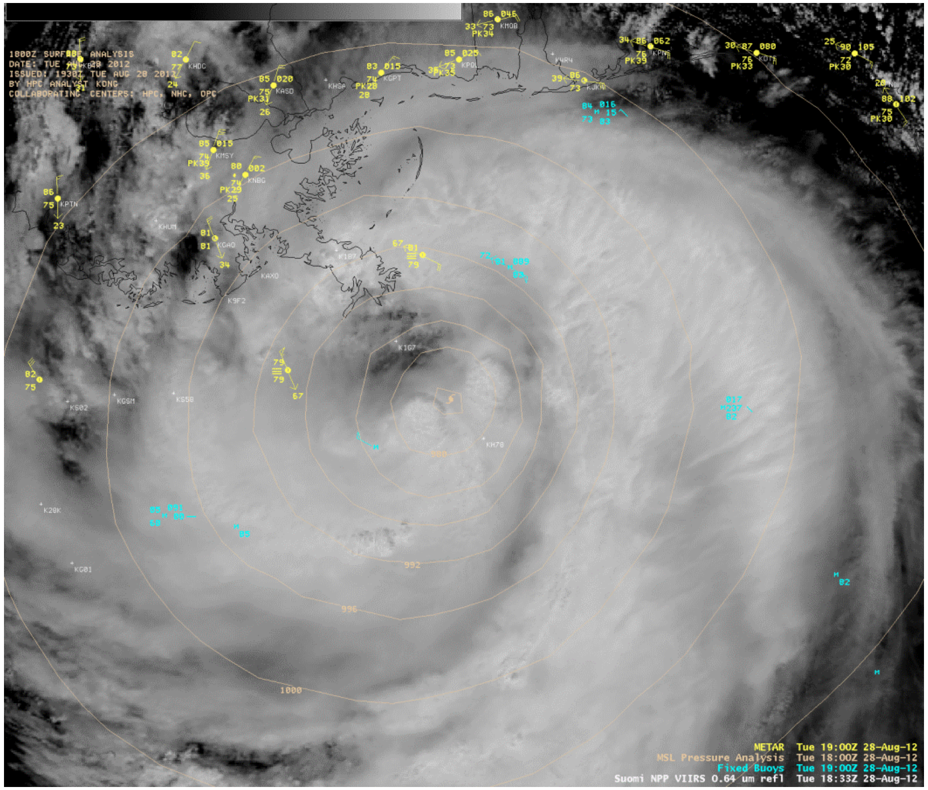
- Stable instrument performance and calibration
- All the ATMS channels have noises much lower than specification
- ATMS processing coefficients table (PCT) were updated with nominal values
- Quality flags (e.g. spacecraft maneuver and scanline, calibrations) were completely checked out and will be updated in the MX7.0
- Geolocation errors for all the channels are quantified and meet specification
- Remap SDR coefficients were updated using on-orbit CrIS data (e.g. CrIMSS now fully synchronized) and RSDR biases are assessed
- On-orbit calibration is explored using GPS RO data, LBLRTM and ATMS SRF. All the sounding channels have biases much less than the specification of accuracy

NPP ATMS and VIIRS Imager and Products

Warm Core Cross section along 26.0 N

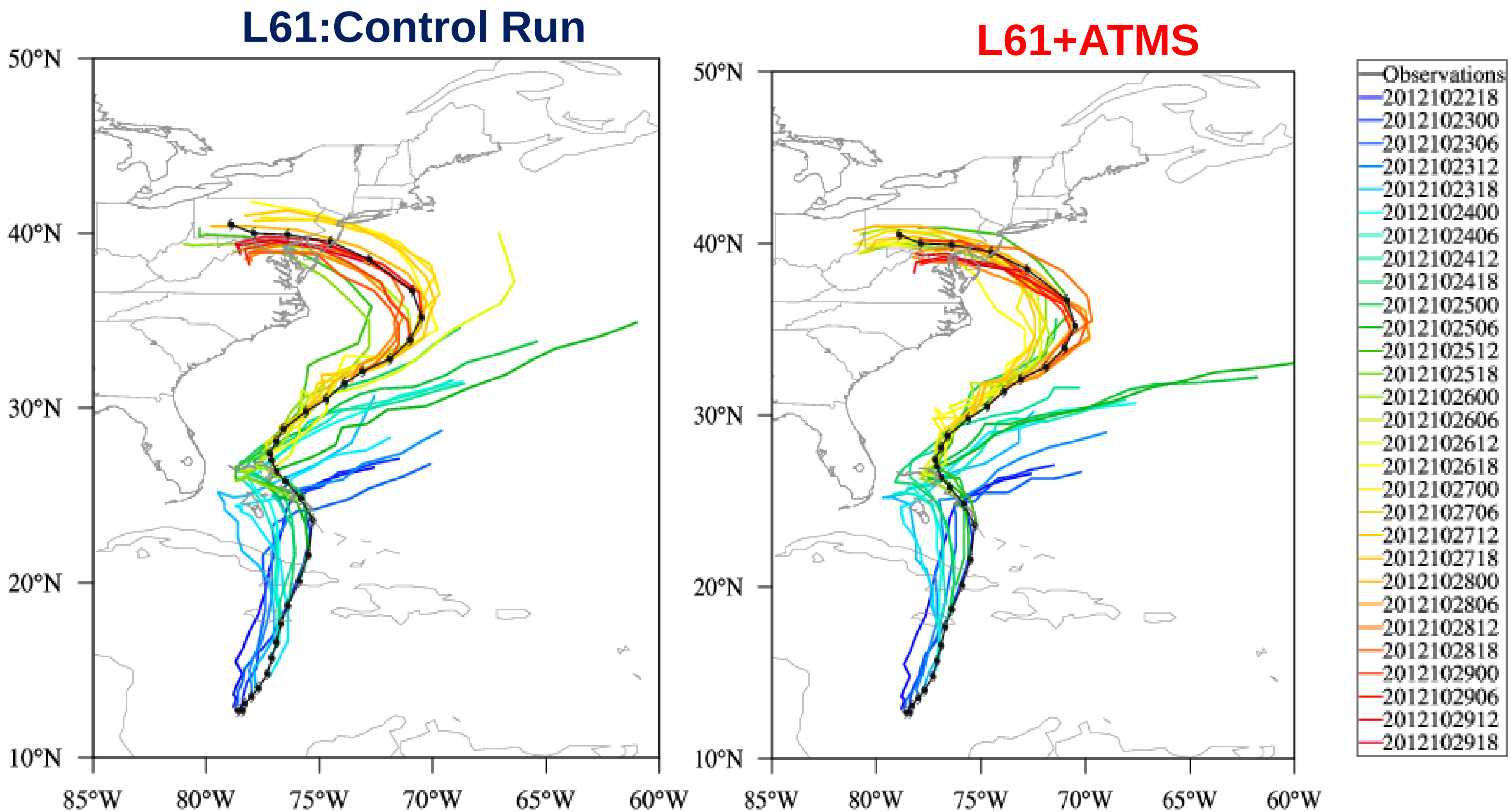


VIIRS 0.64 μm visible and 11.45 μm IR images at 18:33 UTC, 28 Aug 2012



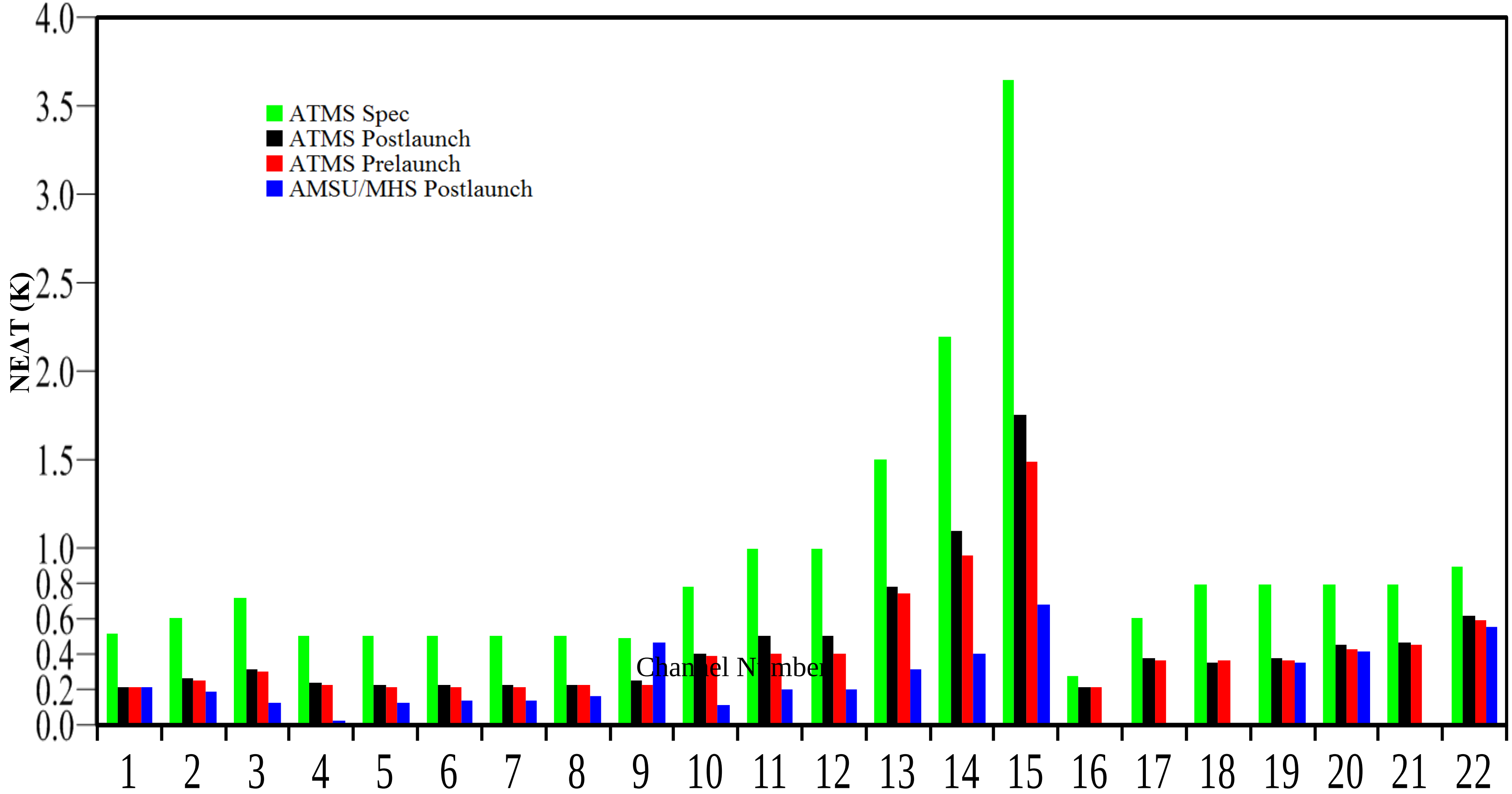
METAR, MSL Pressure, and Buoys information included

Impacts of Direct Assimilation of Suomi NPP ATMS Radiances on Hurricane Sandy's Track



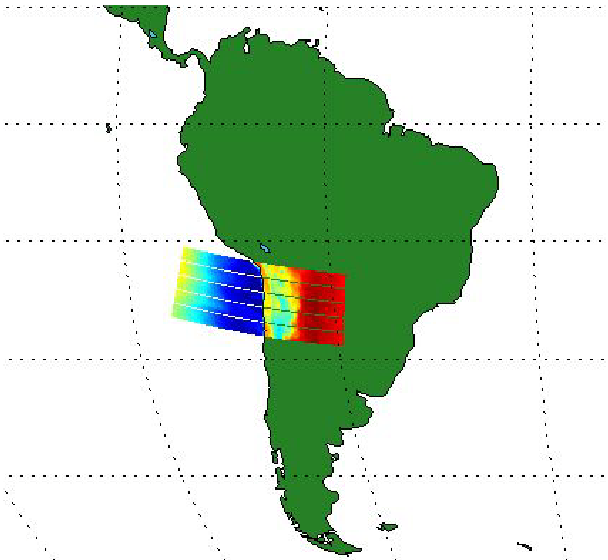
Predicted vs. observed track for Hurricane Sandy during October 22 to 29. NCEP 2012 HWRF is revised with a high model and 6 forecast as background for direct satellite radiance assimilation in GSI. Control Run: All conventional data and NOAA/METOP/EOS/COSMIC. It is clearly demonstrated that assimilation of Suomi NPP ATMS radiance data reduce the forecast errors of Hurricane Sandy's track .

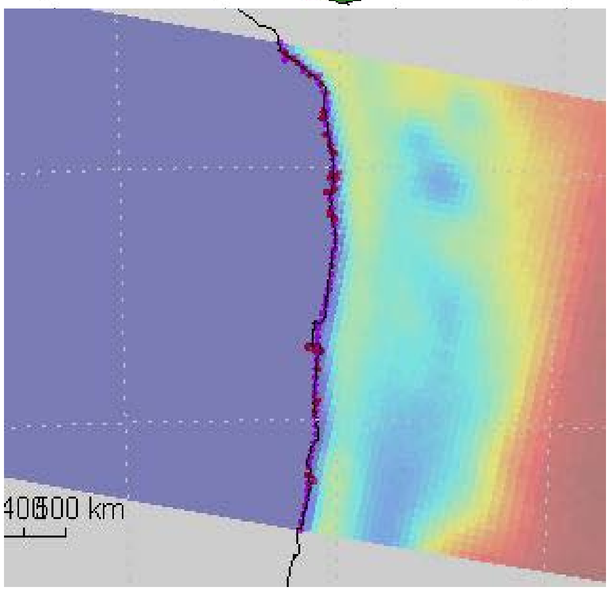
Channel Noise Characterization



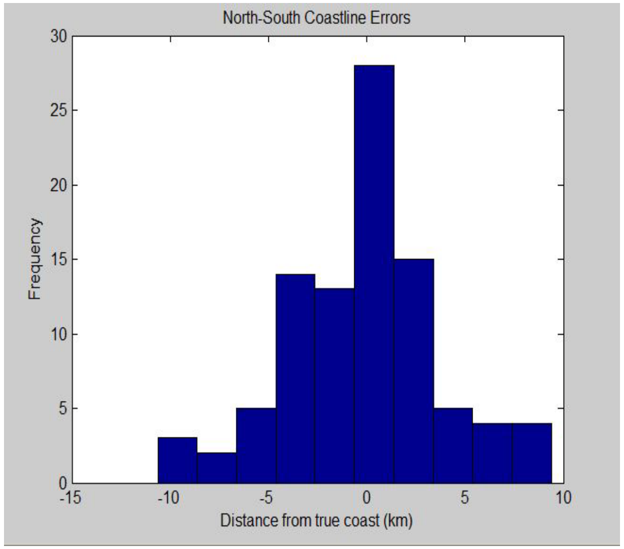
All Channels are within Specifications

Geolocation Verification

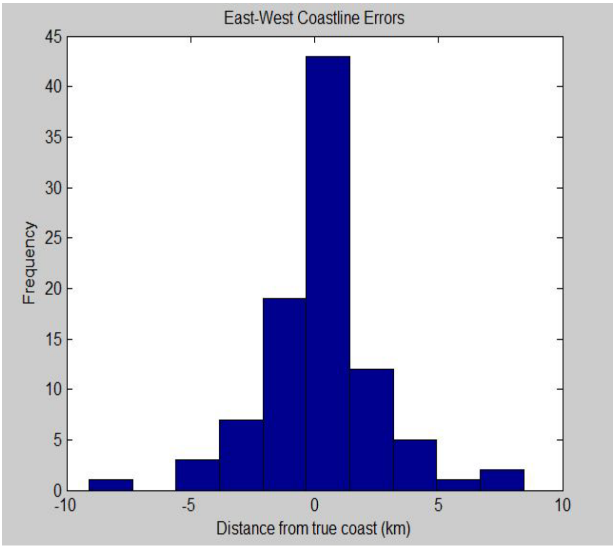




North – South
Mean -0.15km
0.01°
Std. Deviation
3.98km 0.28°

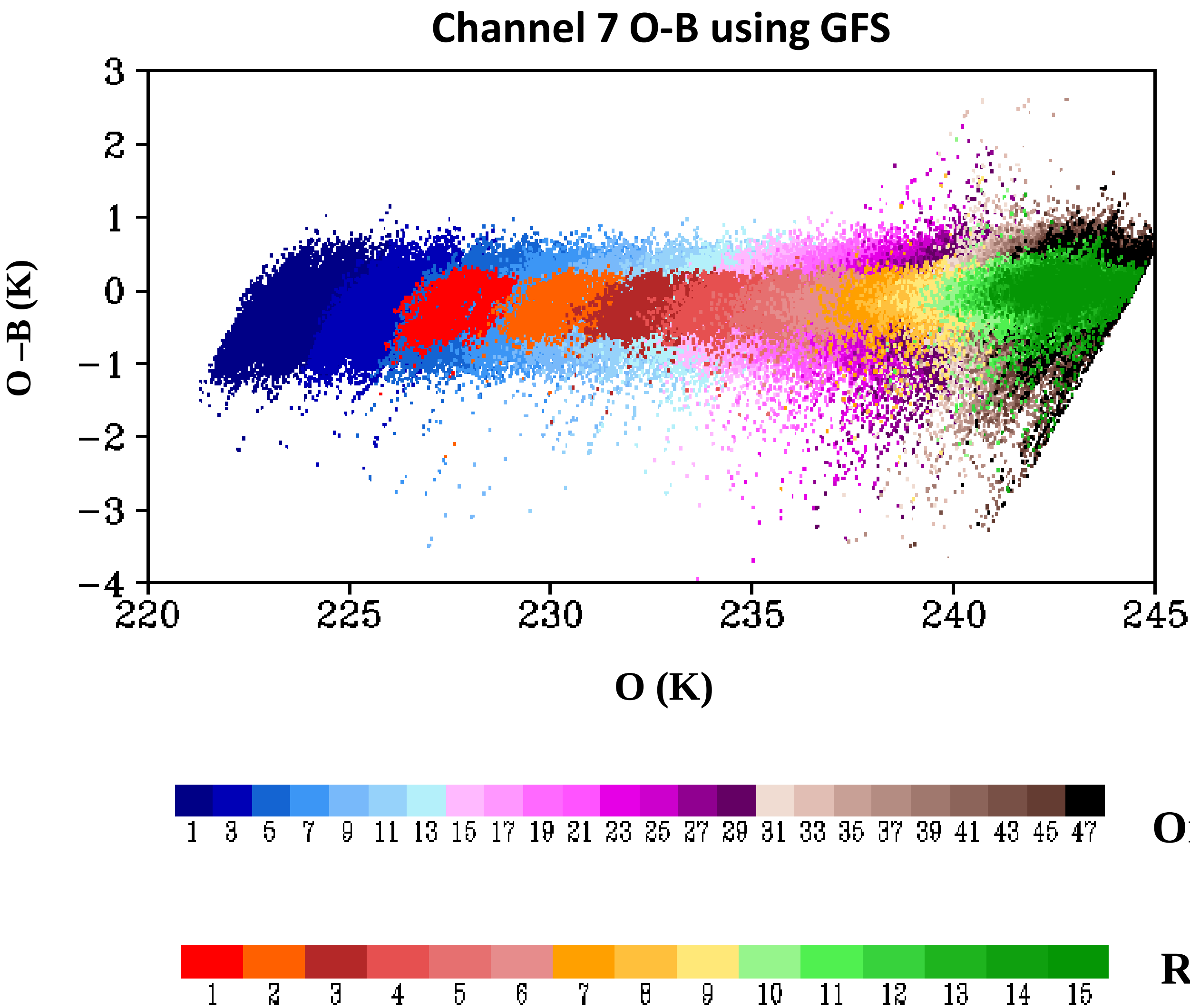


East – West
Mean -.027km
0.02°
Std. Deviation
2.34km 0.16°



Slide courtesy of SDL

Assessments of ATMS Remap SDR (RSDR)



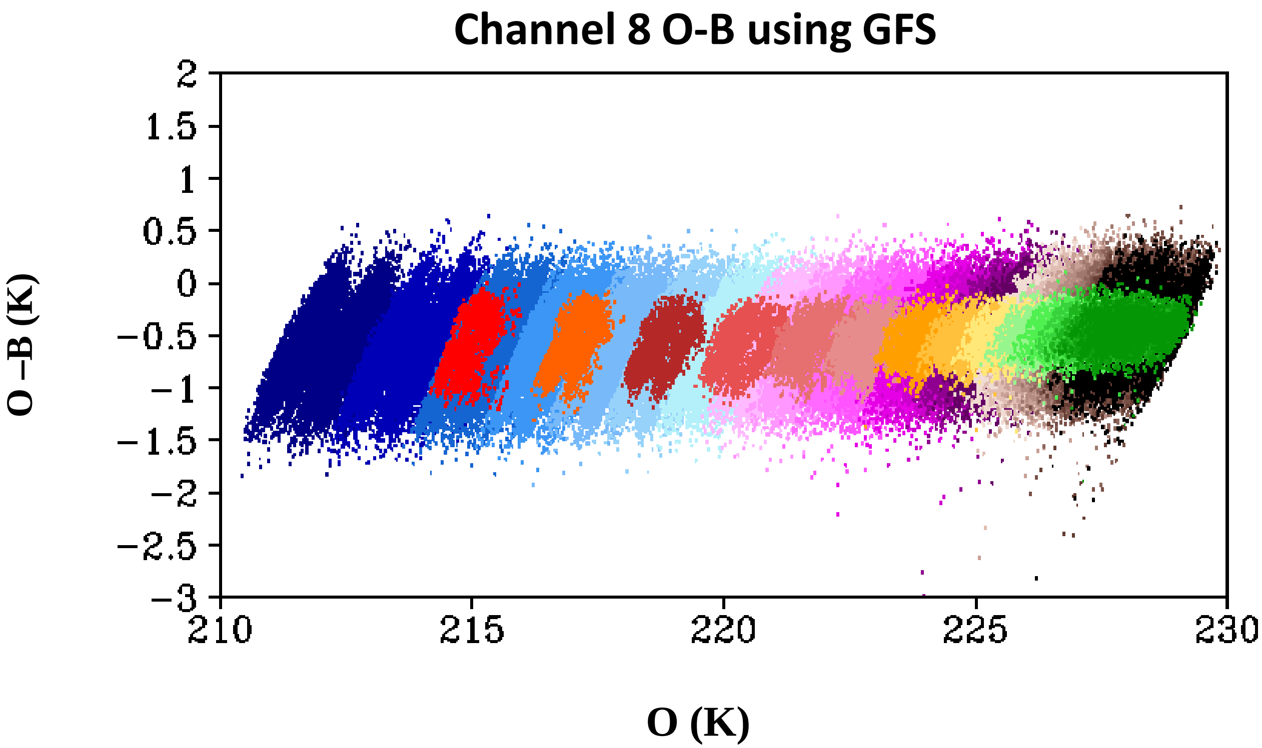
Original ATMS

Remap ATMS

Resampled ATMS has the same bias at all brightness temperatures but much smaller spread (high innovation)

Slide courtesy of STAR

Assessments of ATMS Remap SDR (RSDR)



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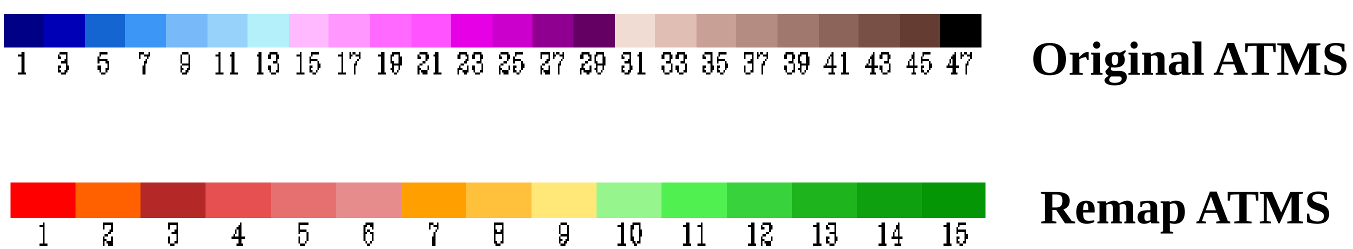
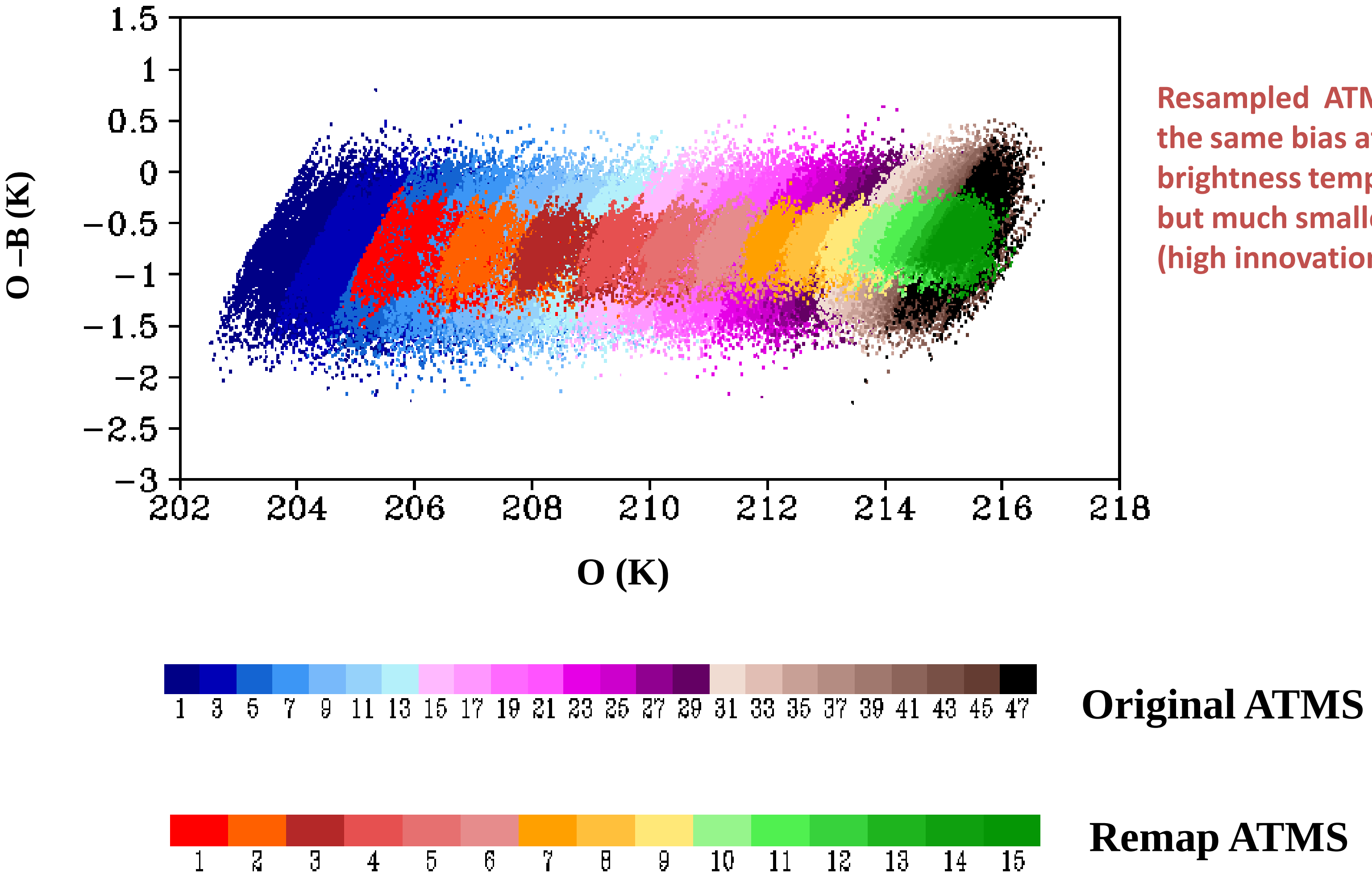


Assessments of ATMS Remap SDR (RSDR)

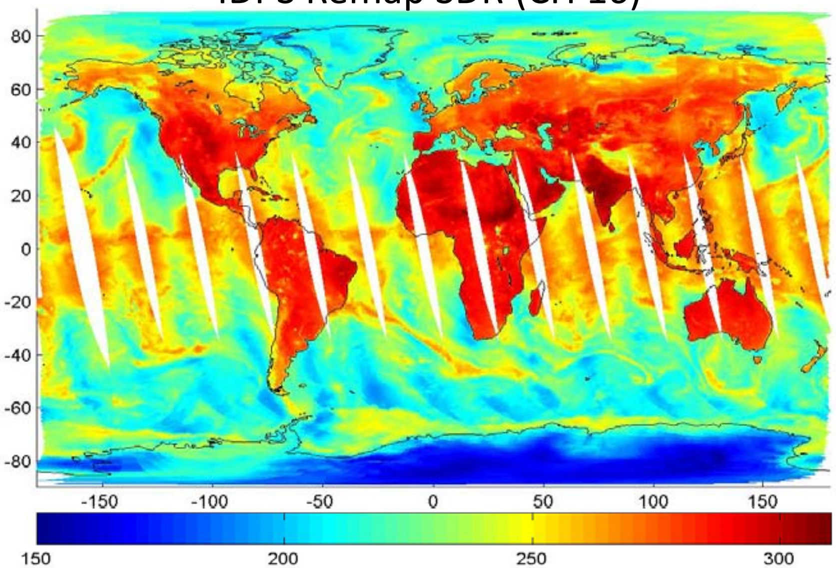
Channel 9 O-B using GFS



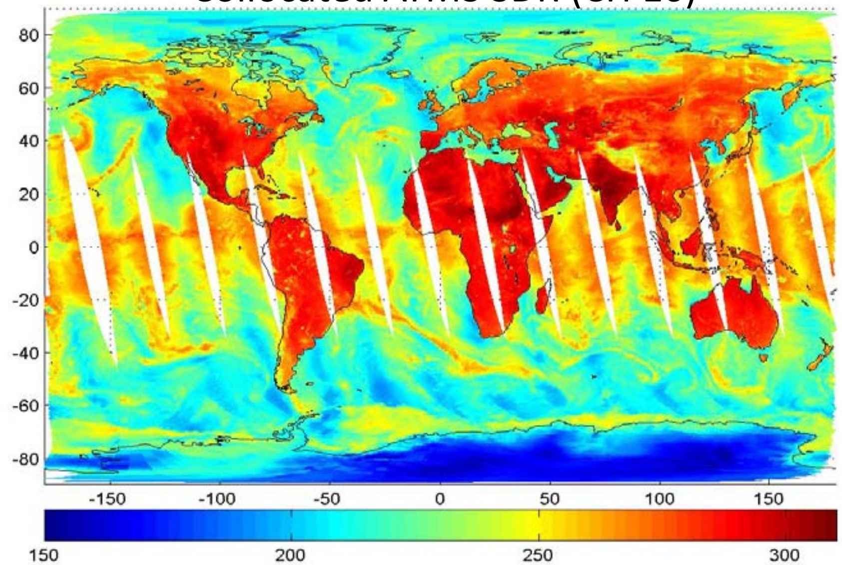
Resampled ATMS has the same bias at all brightness temperatures but much smaller spread (high innovation)

ATMS Remap SDR Evaluation

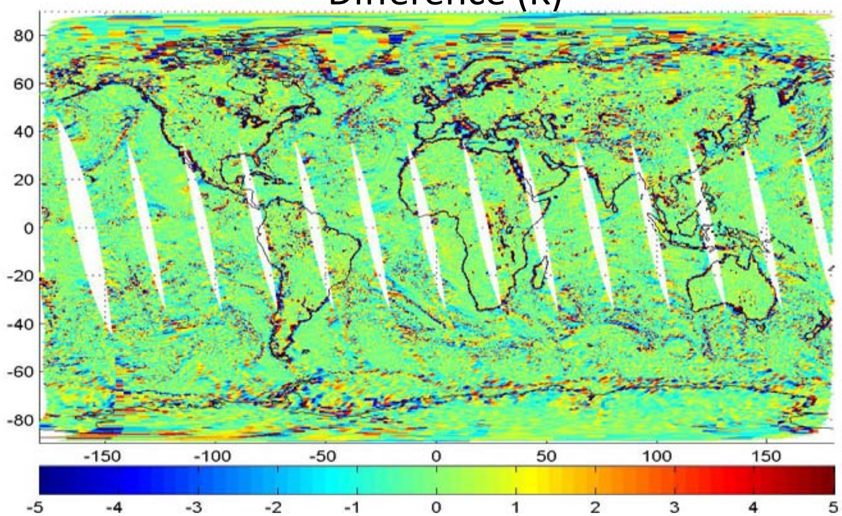
IDPS Remap SDR (CH 16)

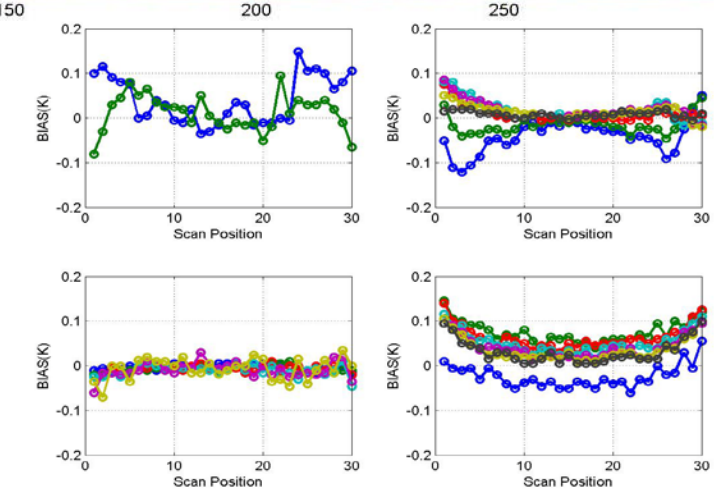


Collocated ATMS SDR (CH 16)



Difference (K)

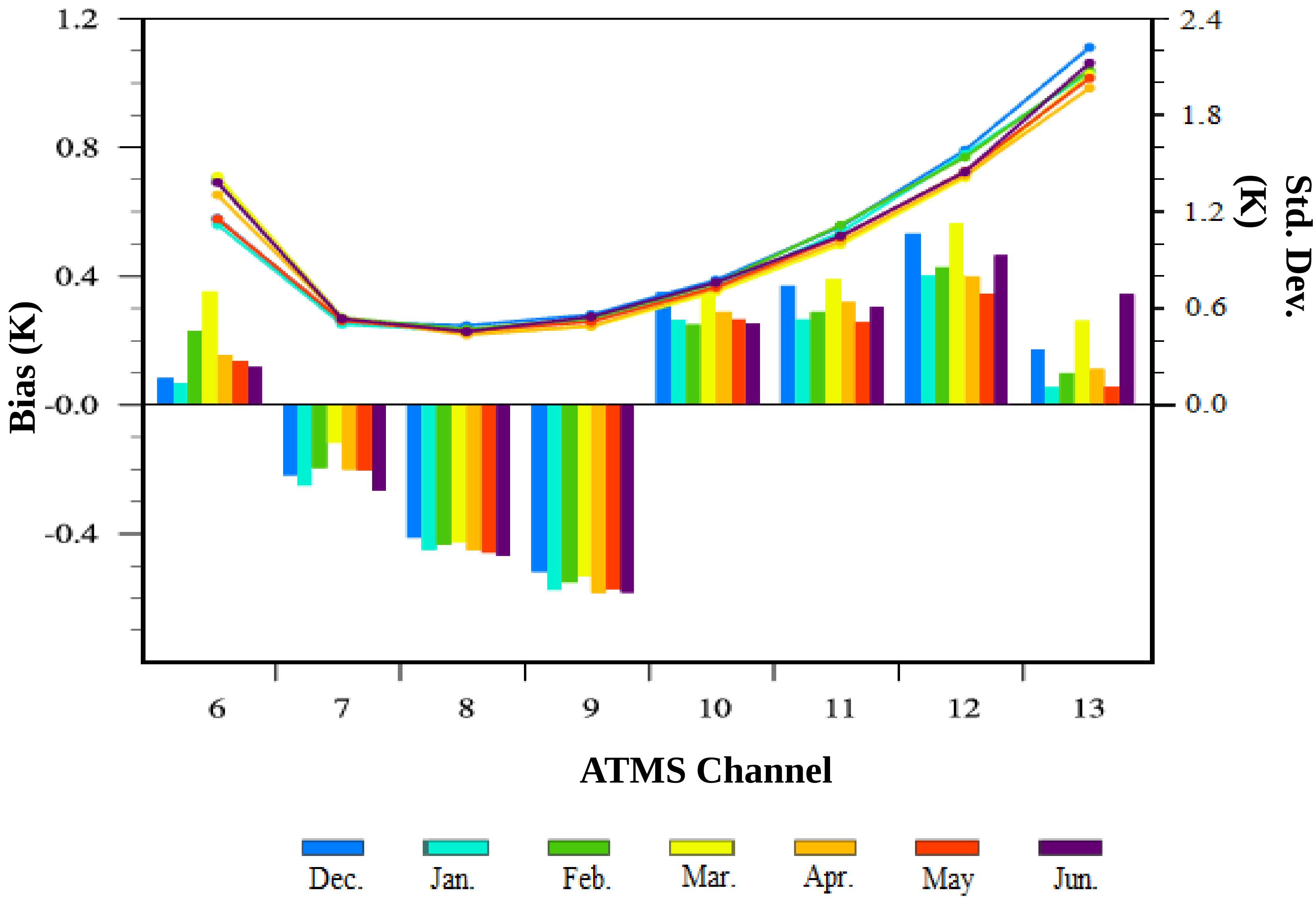




No Significant Biases Between Remapped SDRs and Collocated ATMS SDRs

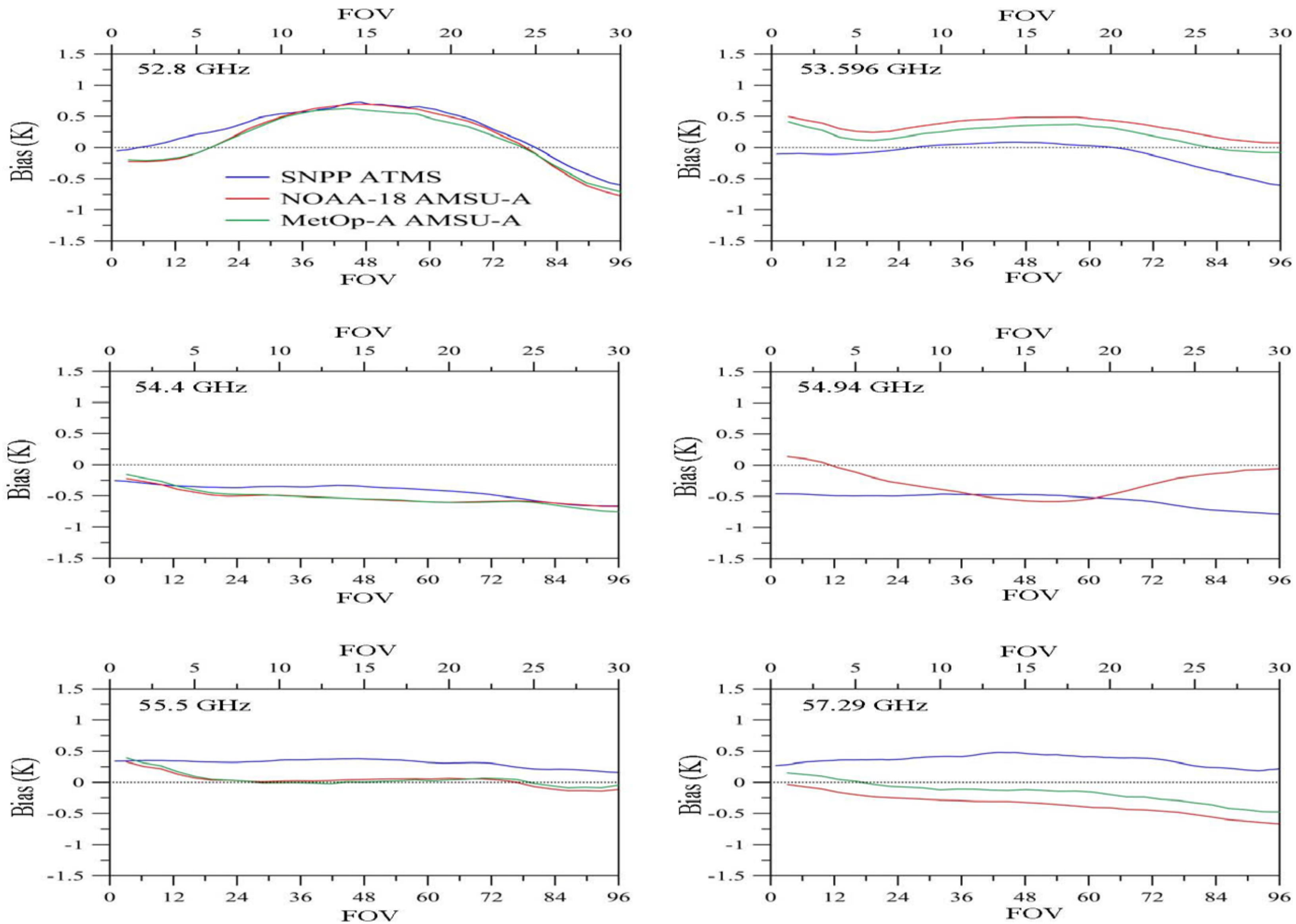
Slide courtesy of NGAS

ATMS Bias Obs - Sim (GPSRO)



Slide courtesy of STAR

ATMS Bias Compared to AMSU-A



Slide courtesy of STAR

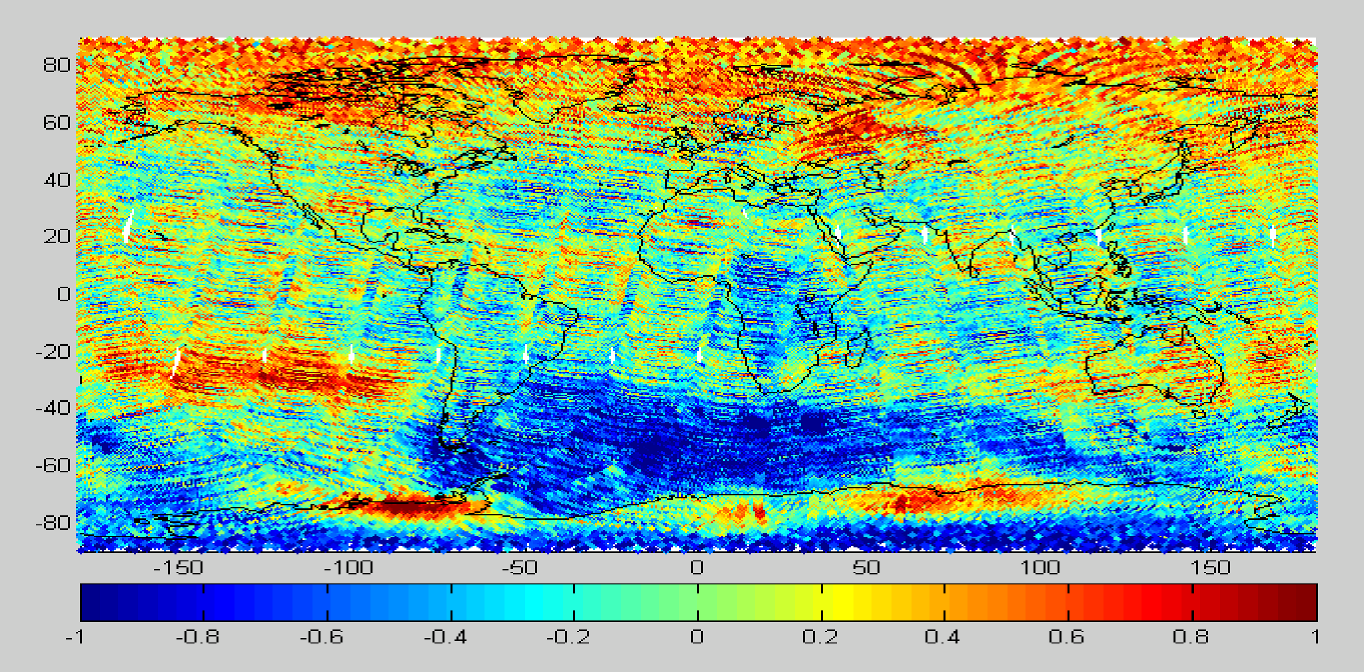
Major Issues

- Channel dependent calibration procedure for reducing the striping
  - Need to further reduce the ATMS striping for the upper-level channels
- Slope and intercept in ATMS TDR to SDR conversion
  - Uncertainty in computing antenna main, side lobe and cross-pol efficiency
  - Current ATMS antenna has 1 to 2% cross-polarization spill-over for some channels. Over oceans where the surface is polarized, TDR to SDR conversion would have a large uncertainty due to neglecting cross-pol spill-over
- Uncertainty in the current ATMS radiometric calibration
  - Uses of Rayleigh-Jeans approximation result in significant uncertainty in calibration although empirical corrections are applied
- Uses of Backus-Gilbert for channel 1 to 2 enhancement
  - ATMS noise is very low and the FOV enhancements for ch 1 and 2 seem to be likely for better depicting the storm structure

ATMS TDR Stripping Noise

- Striping is caused by ATMS SDR calibration noise, specifically the noise in the warm counts. Contributions to the overall calibration noise from cold counts and PRT readings are much smaller
- The level of the striping noise is insignificant and well within ATMS SDR noise spec level

ATMS Brightness Temperature Difference: Simulated – Observed



Slide courtesy of NGAS

ATMS Calibration Equation in IDPS

$$R_s = \underbrace{R_c + (R_w - R_c)\left(\frac{C_s - \overline{C_c}}{\overline{C_w} - \overline{C_c}}\right)}_{R_L} + Q$$

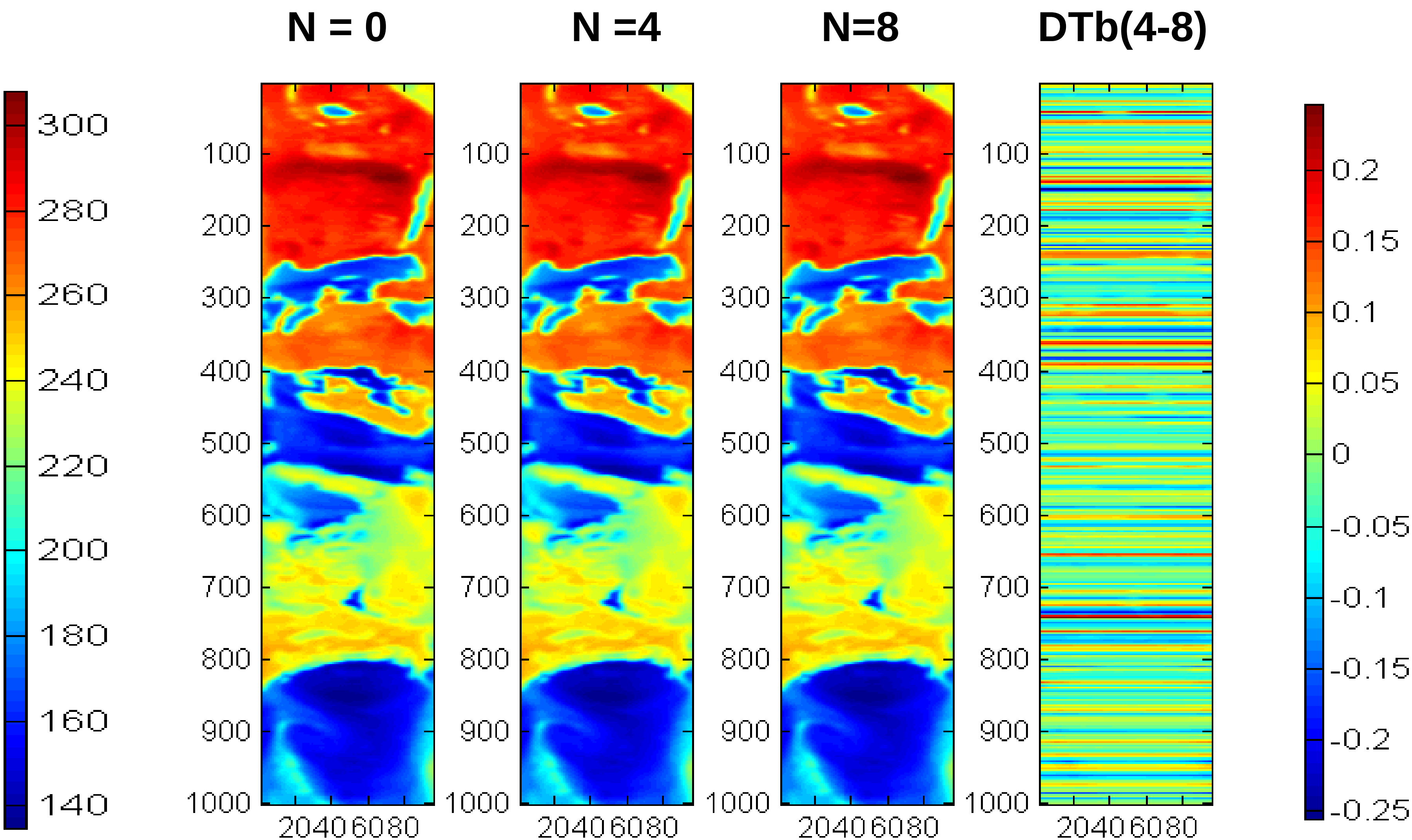
$$Q = \mu(R_w - R_c)^2 \frac{(C_s - \overline{C_w})(C_s - \overline{C_c})}{(\overline{C_w} - \overline{C_c})^2}$$

$$G = \frac{\overline{C_w} - \overline{C_c}}{R_w - R_c}$$

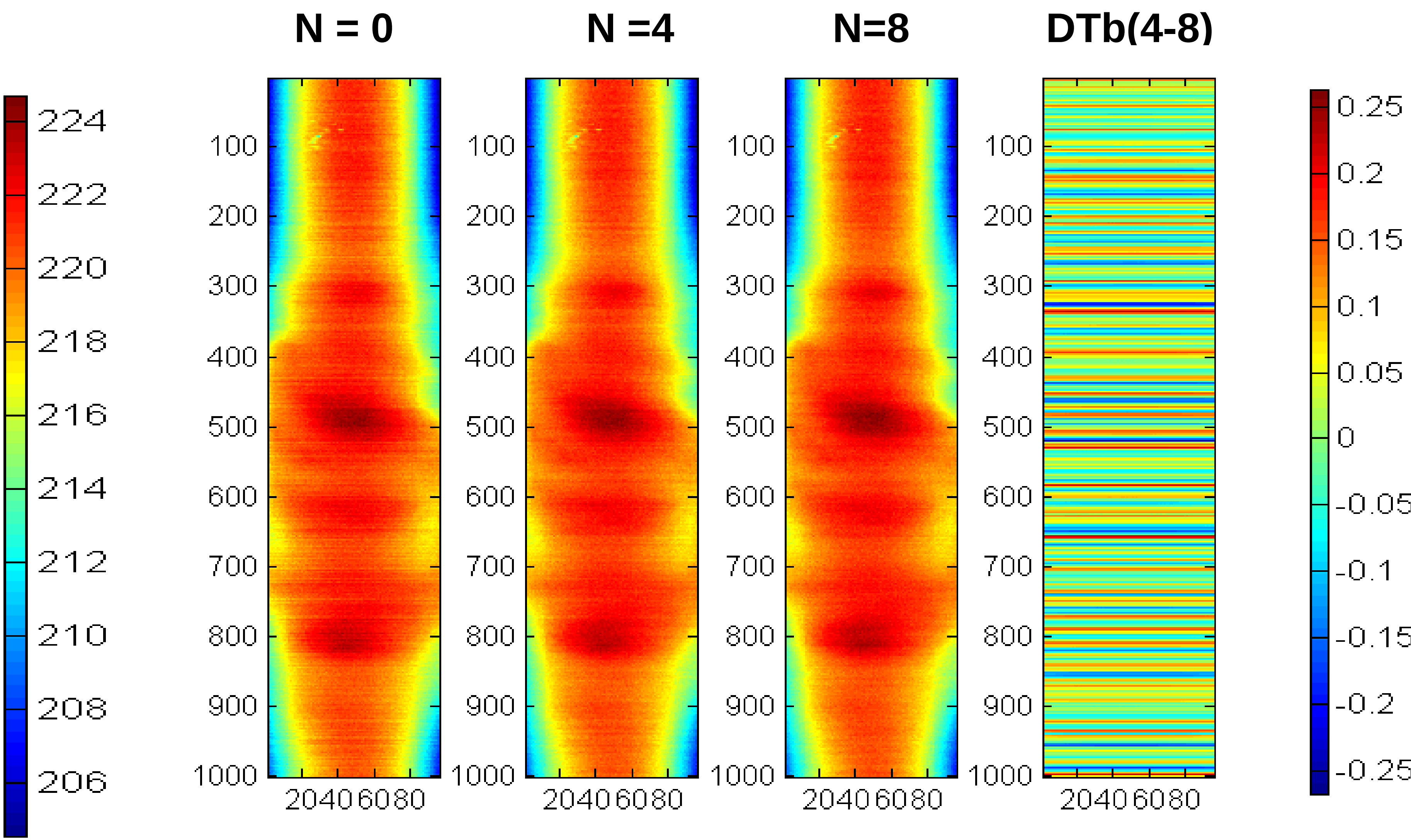
$$\overline{C_x} = \frac{1}{N+1}\sum_{i=-N}^{N}\left(1 - \frac{|i|}{N+1}\right)C_x, x = w \; or \; c$$

For ATMS, N = 4 in the current IDPS processing

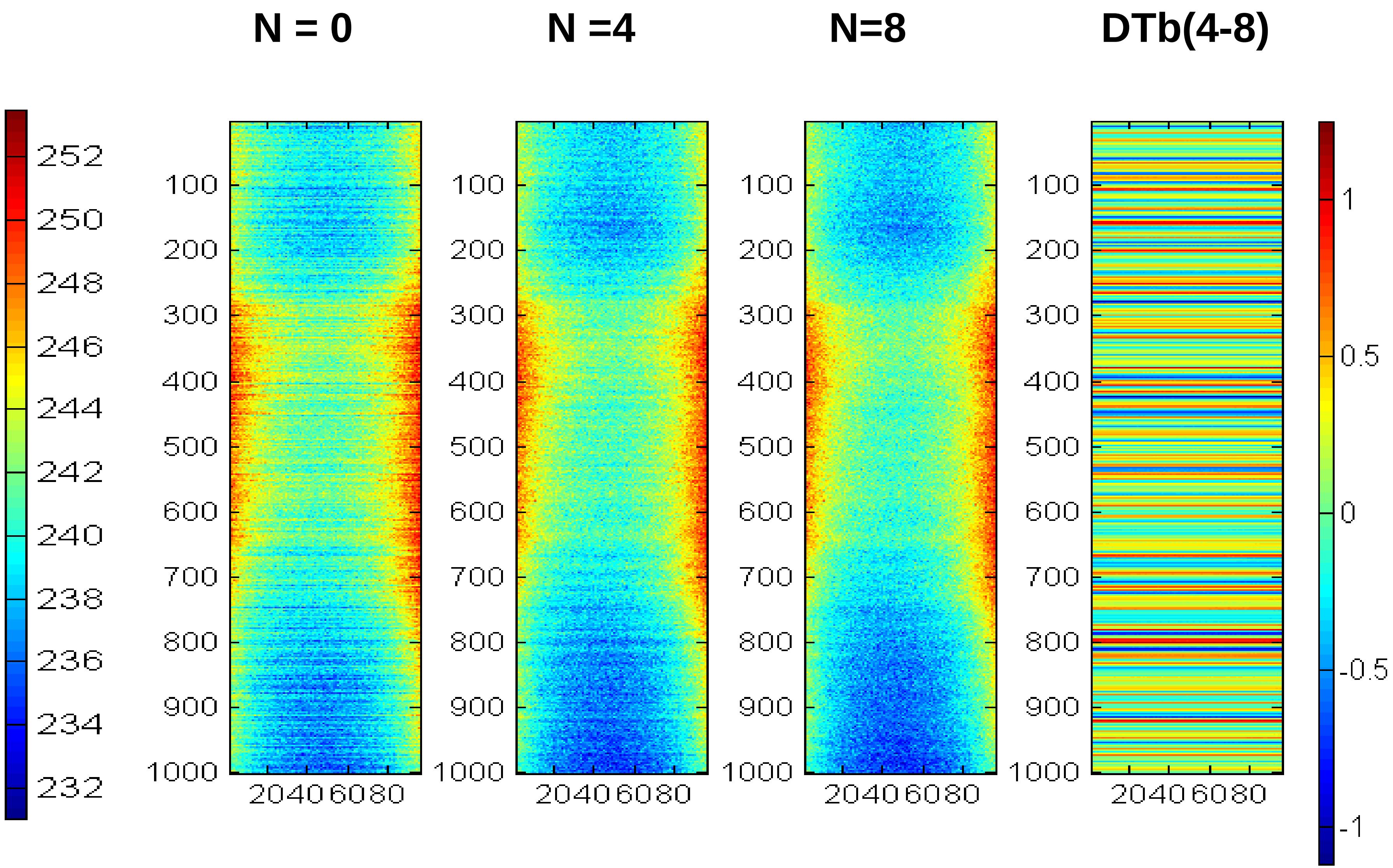
ATMS Averaging for Reducing Stripping using Earth Scene Data (Channel 1)



ATMS Averaging for Reducing Stripping using Earth Scene Data (Channel 8)



ATMS Averaging for Reducing Stripping using Earth Scene Data (Channel 14)



ATMS SDR Algorithm Formulation

SDR

TDR

$$T_a^{Qv} = \eta_{me}^{vv} T_b^{Qv} + \eta_{me}^{hv} T_b^{Qh} + \eta_{se}^{vv} E_b^{Qv} + \eta_{se}^{hv} E_b^{Qh} + \eta_{sc}^{vv} C_b^{Qv} + \eta_{sc}^{hv} C_b^{Qh} + S_a^{Qv}$$

SDR

$$T_a^{Qh} = \eta_{me}^{hh} T_b^{Qh} + \eta_{me}^{vh} T_b^{Qv} + \eta_{se}^{hh} E_b^{Qh} + \eta_{se}^{vh} E_b^{Qv} + \eta_{sc}^{vv} C_b^{Qv} + \eta_{sc}^{hv} C_b^{Qh} + S_a^{Qh}$$

Weng et al., 2012, GRSL

The first two terms are Quasi-V and Quasi-H brightness temperature from earth in the main beam (main lobe earth), the 3rd/4th terms are those from the side-lobe earth, the 5/6th terms are the side-lobe cold space, the last term is the near-field satellite radiation

$$T_b^{Qv} = T_b^{v} \cos^2\theta + T_b^{h} \sin^2\theta \qquad T_b^{Qh} = T_b^{v} \sin^2\theta + T_b^{h} \cos^2\theta$$

Under a polarized earth scene, the side lobe together with cross-polarization term can result in large errors in computing SDR from TDR data if the antenna has a significant spill-over effect and the cross-polarization term is neglected.

Convertibility Issues from TDR to SDR

- Need to correct side-lobe radiation from far-field earth and near-field satellites

- For un-polarized surface and atmospheric conditions, the inversion from TDR to SDR is possible with a single polarization measurement.

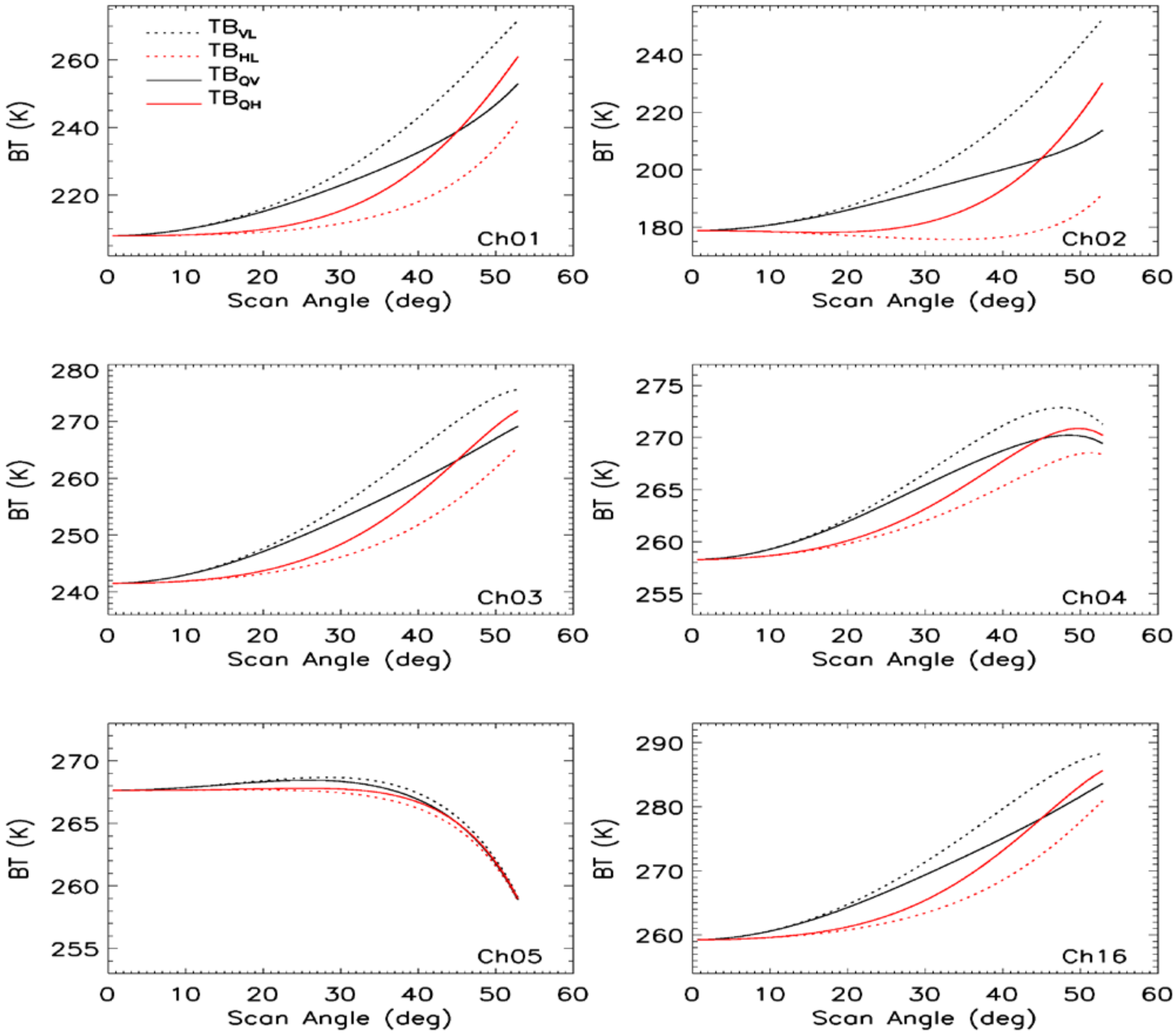
- For an instrument with a significant cross-polarization spill-over, an inversion from TDR to SDR is problematic if a single polarization measurement is available.

ATMS Antenna Beam Efficiency

Frequency (GHz)	θ_{3dB} (degree)	η_{me}^{pp} (%)			η_{me}^{pq} (%)			$\eta_{se}^{pp}+\eta_{sc}^{pp}+\eta_{ss}^{pp}$ (%)		
		B1	B48	B96	B01	B48	B96	B01	B48	B96
23.8	5.25	99.48	99.61	99.53	0.52	0.39	0.46	0.003	0.0002	0.0025
31.4	5.35	99.59	99.60	99.60	0.40	0.40	0.39	0.003	0.0003	0.0024
50.3	2.20	99.43	99.39	99.56	0.57	0.61	0.44	0.001	0.0006	0.0008
51.8	2.25	99.45	99.47	99.73	0.55	0.53	0.27	0.001	0.0004	0.0007
52.8	2.25	99.48	99.46	99.36	0.51	0.54	0.64	0.001	0.0004	0.0010
53.6	2.20	99.49	99.43	99.31	0.51	0.57	0.68	0.001	0.0004	0.0008
54.4	2.15	99.51	99.51	99.55	0.49	0.49	0.44	0.001	0.0006	0.0006
54.9	2.20	99.48	99.49	99.21	0.51	0.51	0.78	0.001	0.0004	0.0007
55.5	2.15	99.50	99.52	99.54	0.50	0.48	0.46	0.001	0.0004	0.0007
57.3	2.20	99.48	99.49	99.48	0.52	0.51	0.52	0.001	0.0006	0.0007
88.2	2.05	97.73	97.70	97.92	2.27	2.30	2.07	0.002	0.0012	0.0035
166.5	1.16	98.00	97.77	96.92	1.98	2.21	3.06	0.013	0.0147	0.0085
176.31	1.10	97.92	97.77	96.17	2.07	2.21	3.81	0.009	0.0115	0.0075
183.31	1.10	97.69	98.48	98.86	2.29	1.50	1.12	0.009	0.0108	0.0083
190.31	1.07	98.23	97.94	97.80	1.75	2.03	2.18	0.011	0.0138	0.0111

From STAR' calculation

Brightness Temperatures Simulated over Oceans



For a scan angle ranging from 15 to 45 degrees, ATMS brightness temperatures at ch1, 2, 3,4 and 16 are polarized over oceans. A conversion from TDR to SDR is also ill-posted problem if the antenna has a significant spill-over effect

Slide courtesy of STAR

ATMS SDR Algorithm

For Quasi-V :

$$T_b^{Qv} = (T_a^{Qv} - \beta_0^v - \beta_1^v \sin^2\theta) / \eta_m^{vv}$$

For Channels 1, 2, 16

For Quasi-H:

$$T_b^{Qh} = (T_a^{Qh} - \beta_0^h - \beta_1^h \cos^2\theta) / \eta_m^{hh}$$

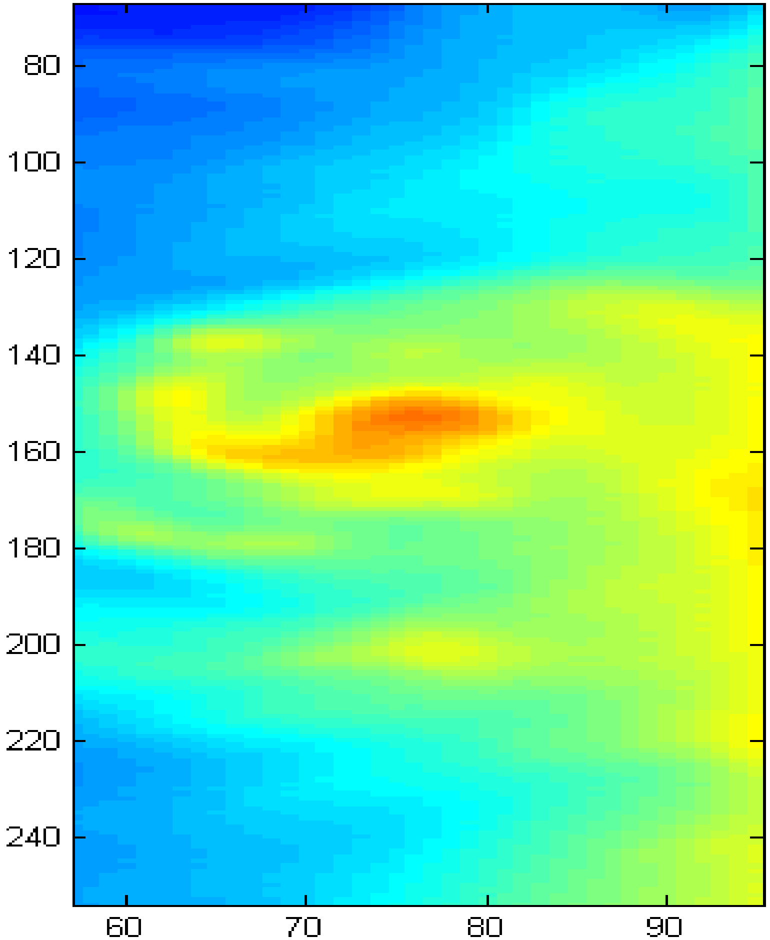
For Channels 4~15, and 17~22

$$\eta_m^{pp} = \eta_{me}^{pp} + \eta_{se}^{pp}$$

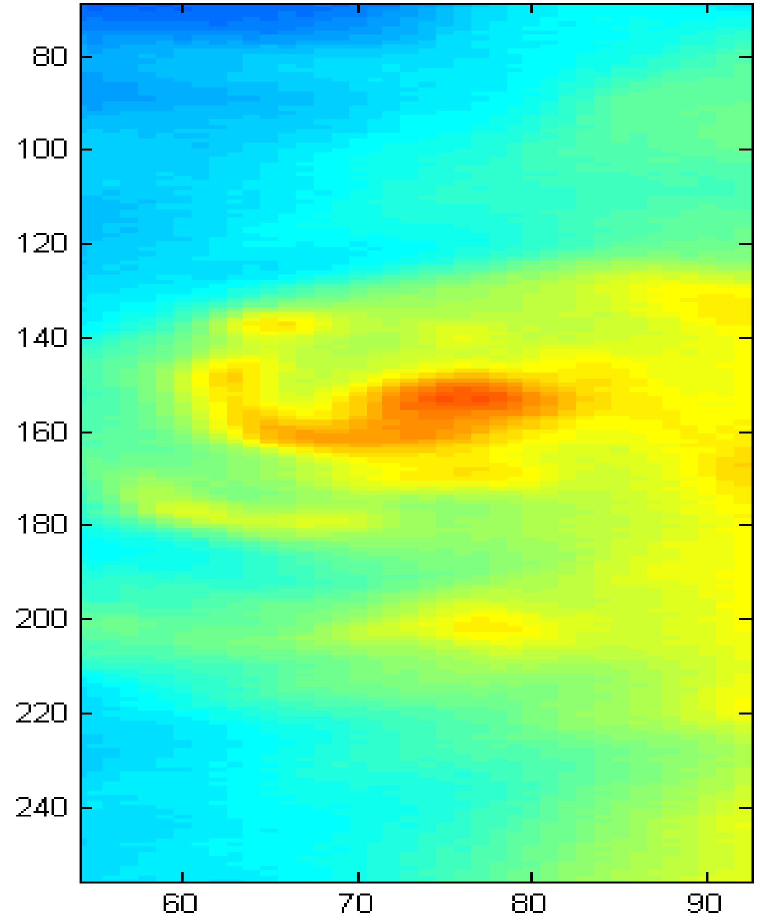
Caveats: Cross-polarization spill-over is neglected. The main contribution from the side-lobe earth is next to the main beam. Atmosphere is also unpolarized and both side-lobe earth and spill-over are included in the main beam efficiency which is close to 1.0

ATMS De-convolution from Low to High Resolution

Raw 23 Tb (5.2 degree)

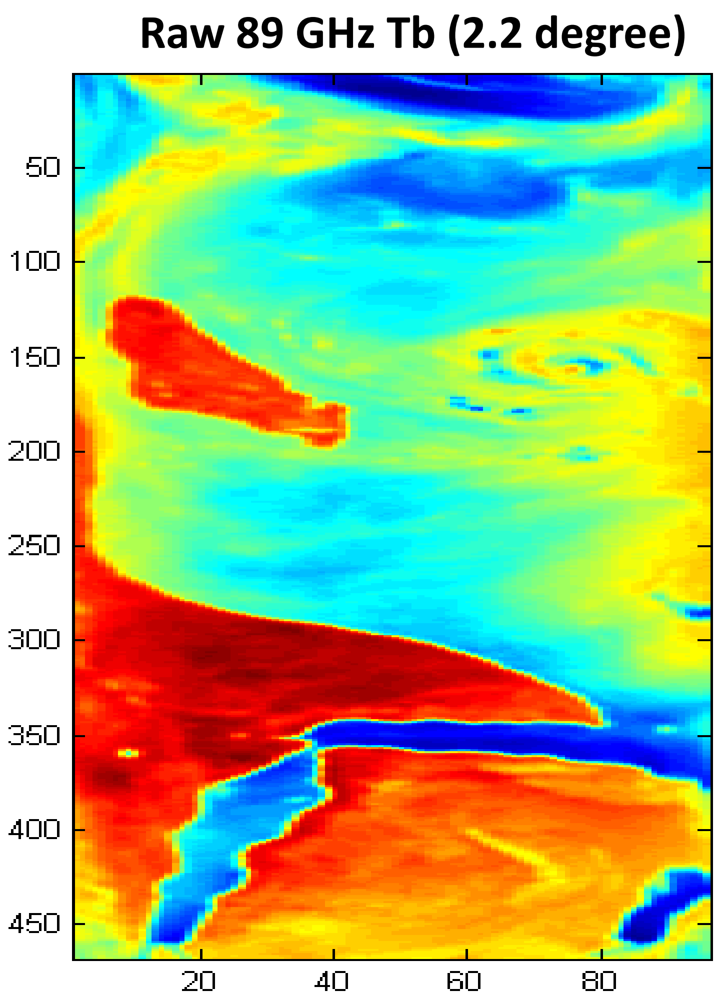


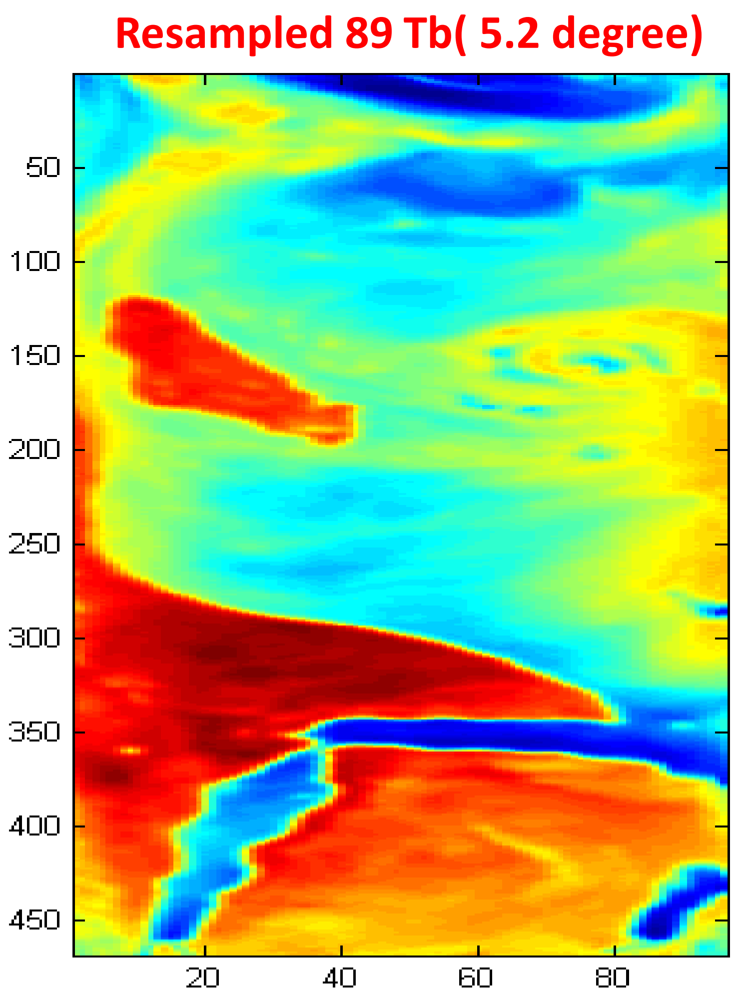
Resampled 23 Tb(2.2 degree)



Slide courtesy of STAR

ATMS Convolution from High to Low Resolution





Slide courtesy of STAR

Summary

- ATMS TDR/SDR data was approved for provisional status.
  - NEDT (precision) at 22 channels meet specification
  - Bias (accuracy) at channels 5 to 13 are better than specification
- ATMS TDR to SDR conversion theory is well developed and applied for TDR to SDR conversion
  - Caveats : xpol spill-over is neglected for window channels. Performance is not optimal for clear oceans where there is significant polarization
- ATMS striping in TDR radiances as shown in NWP O-B was analyzed and the root-cause is identified.
- ATMS radiometric calibration theory needs to be further improved with full radiance processing

Path Forward

- Produce beta version of ATMS striping reduction algorithm and create new ATMS datasets for NWP experiments
- Update ATMS scan bias corrections for TDR to SDR conversion using the ATMS antenna efficiency and pitch maneuver data
- Work with NGES to better characterize ATMS antenna (side-lobe, xpol spill-over, polarization twist angle) for J1/J2 mission
- Revise ATMS radiometric calibration in full radiance to make the SDR data consistent with NOAA heritage approach