Assessing the Long-Term Stability of ATMS through Cross-Calibration

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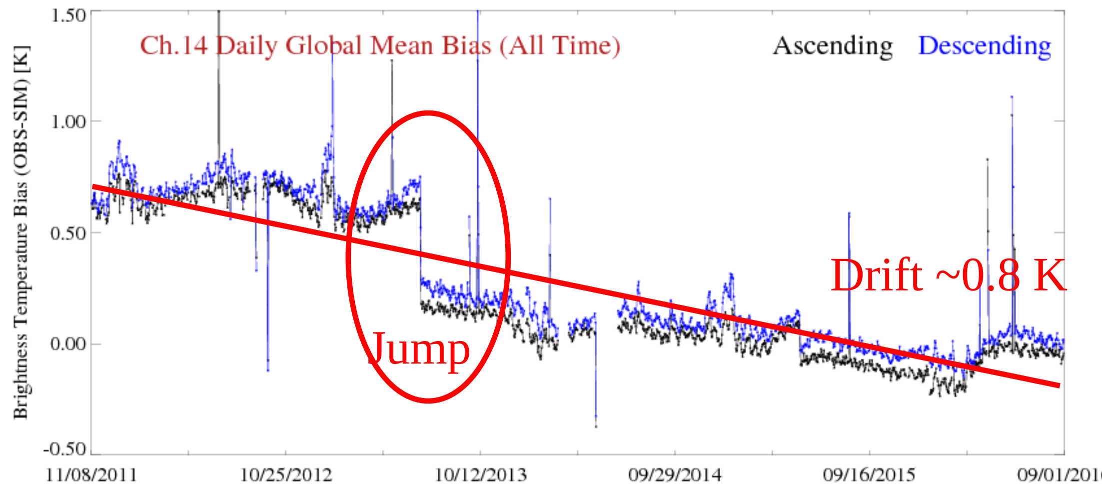
Motivation

- Suomi NPP ATMS was launched in 2011 with a designed lifetime of 5-year, and it is critical to assess the long-term stability of ATMS
- Cross-calibration uses independent sensors as the reference rather than RTM and can exclude pseudo drift due to simulation errors in O-B
- To obtain inter-sensor biases between ATMS and other instruments for constellation
- To develop a reliable cross-calibration algorithm for imagers/sounders, and cross-tracking/conical scanning sensors

Example: Is Drift/Jump Real?

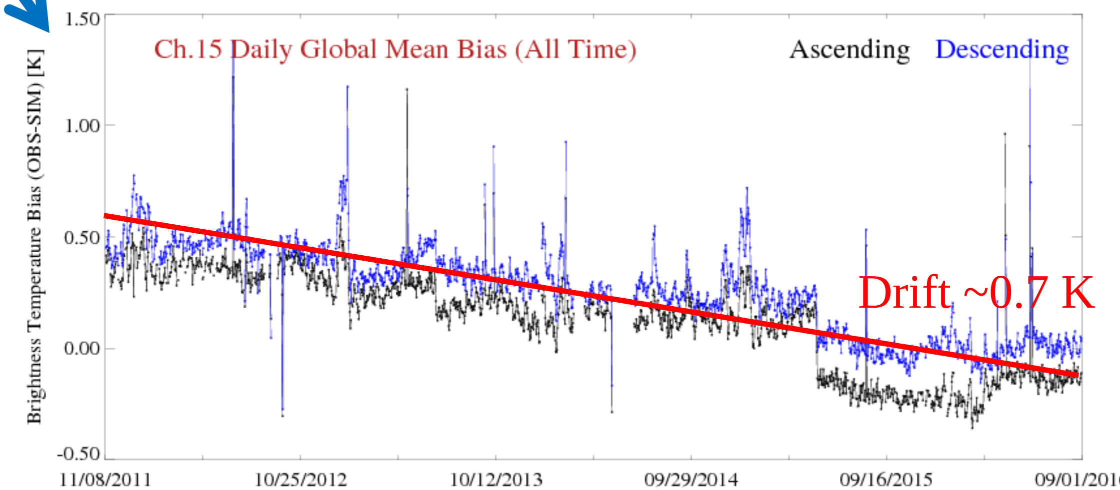
ATMS Chan 14 (O-B)



While drift

and jump are shown in O-B on NOAA STAR monitoring site, verification is necessary

ATMS Chan 15 (O-B)

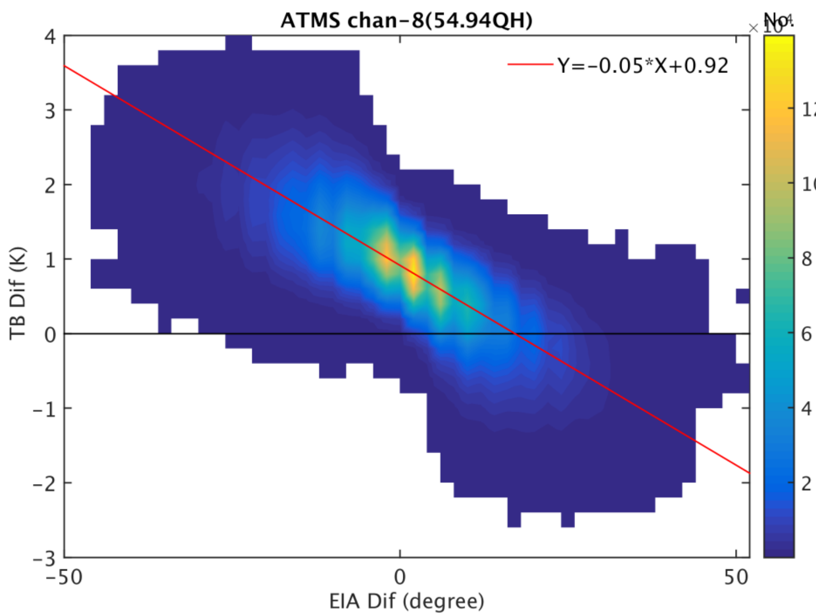


Data and Method

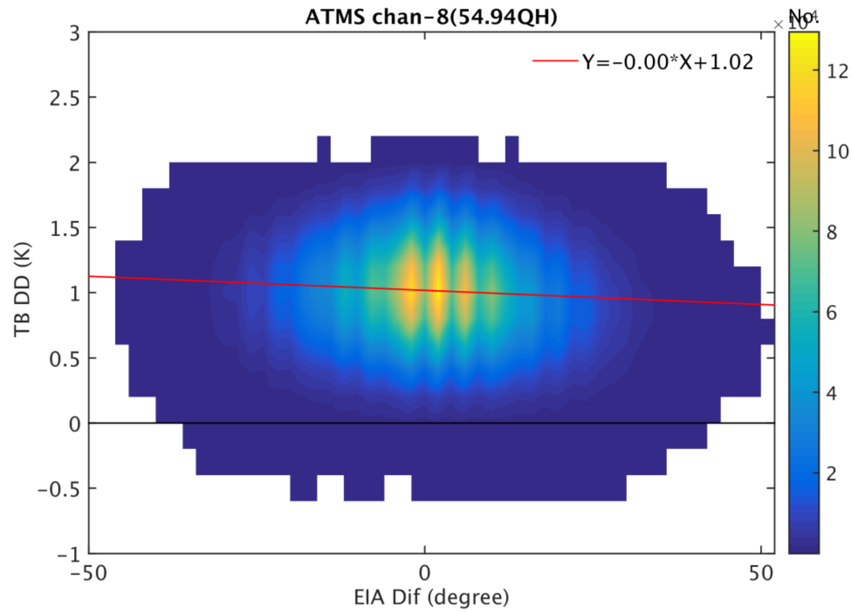
- Data
  - ATMS, GMI, TMI, AMSU-A, MHS (NOAA 18)
  - ERA interim, NCEP-FNL (GDAS)
- Simulation
  - A 1D RTM (Yang et al, 2015, 2016), including modules of Rosenkranz atmospheric absorption model (Rosenkranz 1993), Remote Sensing System (RSS) surface emissivity model (Meissner and Wentz, 2014)
  - Each band is divided into an effective 100-subband with a box-cut spectra response function (SRF), which has a ~0.001K mean difference compared to that with 200 subband. In contrast, using a single center frequency can have difference as large as several K
  - Collocate FOV of two sensor within 0-km & 2-hour, cloud screening, all scan positions (both nadir and off-nadir)
  - Inter-sensor biases, or double difference (DD), is obtained $(O_2\text{-}B_2)\text{-}(O_1\text{-}B_1)$

Reconciling Sensor Differences in EIAs, Frequencies, Polarization and Bandwidths

Direct TB Comparison
between ATMS and AMSU-A

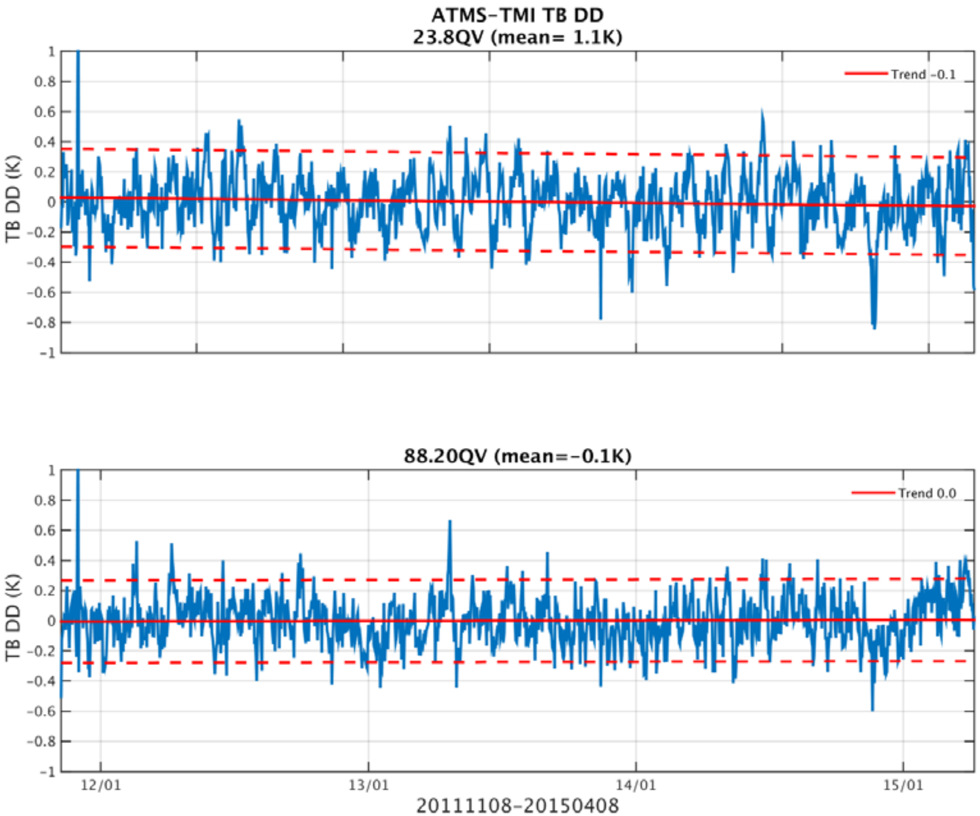


Comparison through Cross-Calibration
between ATMS and AMSU-A



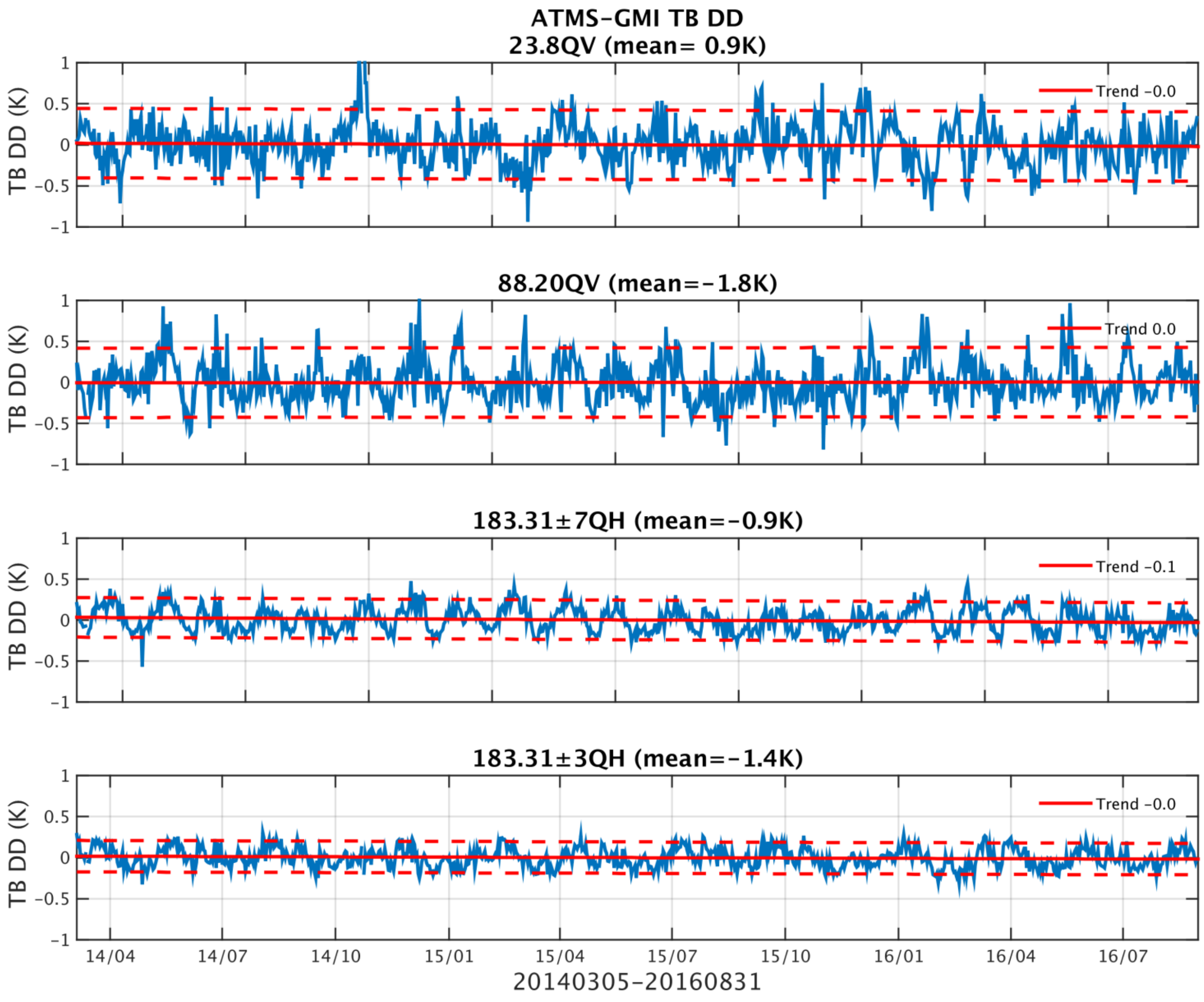
- Comparison with only nadir view has very limited samplings
- Direct comparison of TB results in difference depending on EIAs, frequencies, polarization (e.g. QV Vs V) and bandwidth, which can be accounted in cross-calibration with RTM

ATMS/TMI Bias
(Daily Mean)



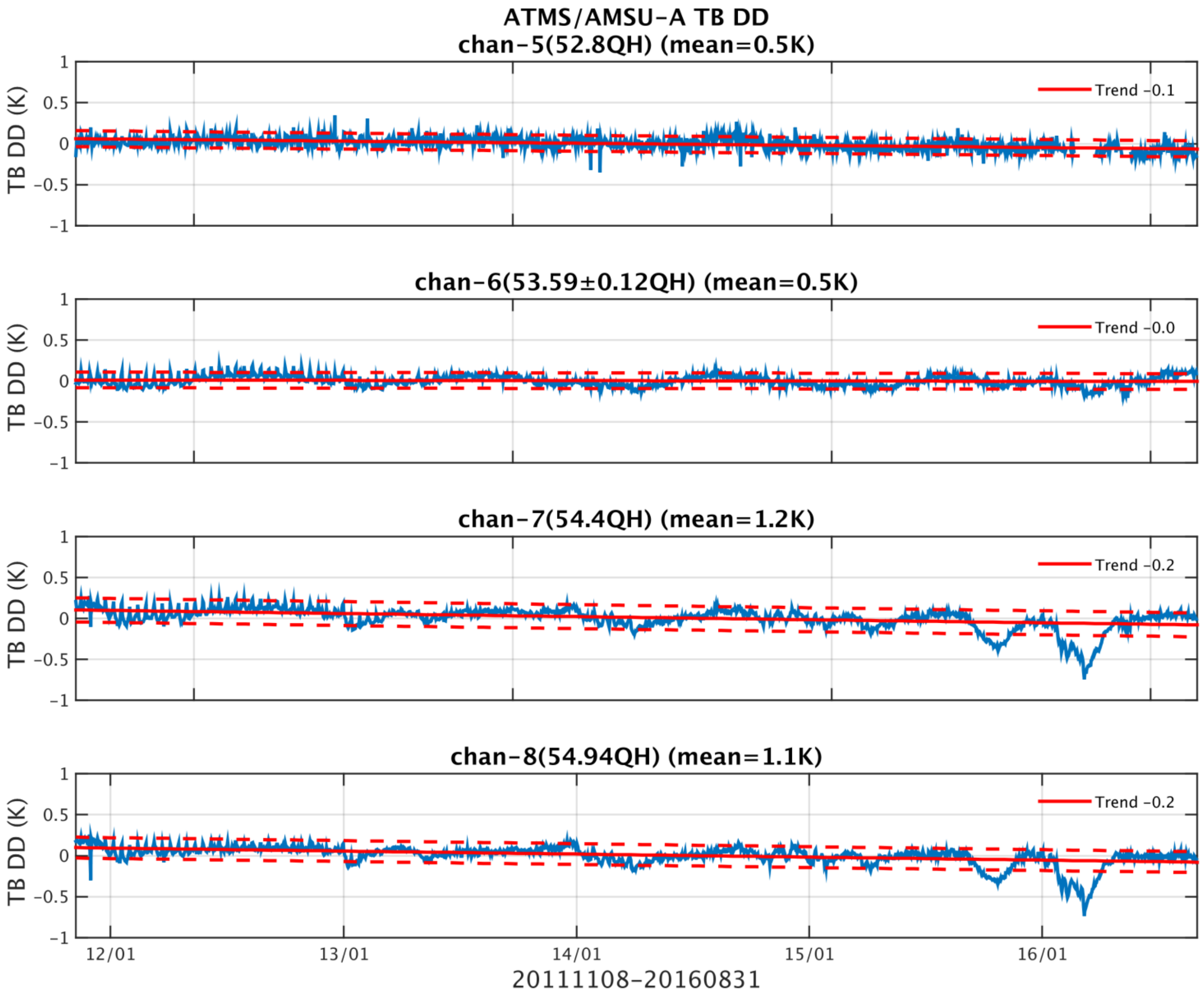
- Continuous daily monitoring
- No noticeable jump/drift
- Moderate fluctuation with small standard deviation and regression interval level

ATMS/GMI

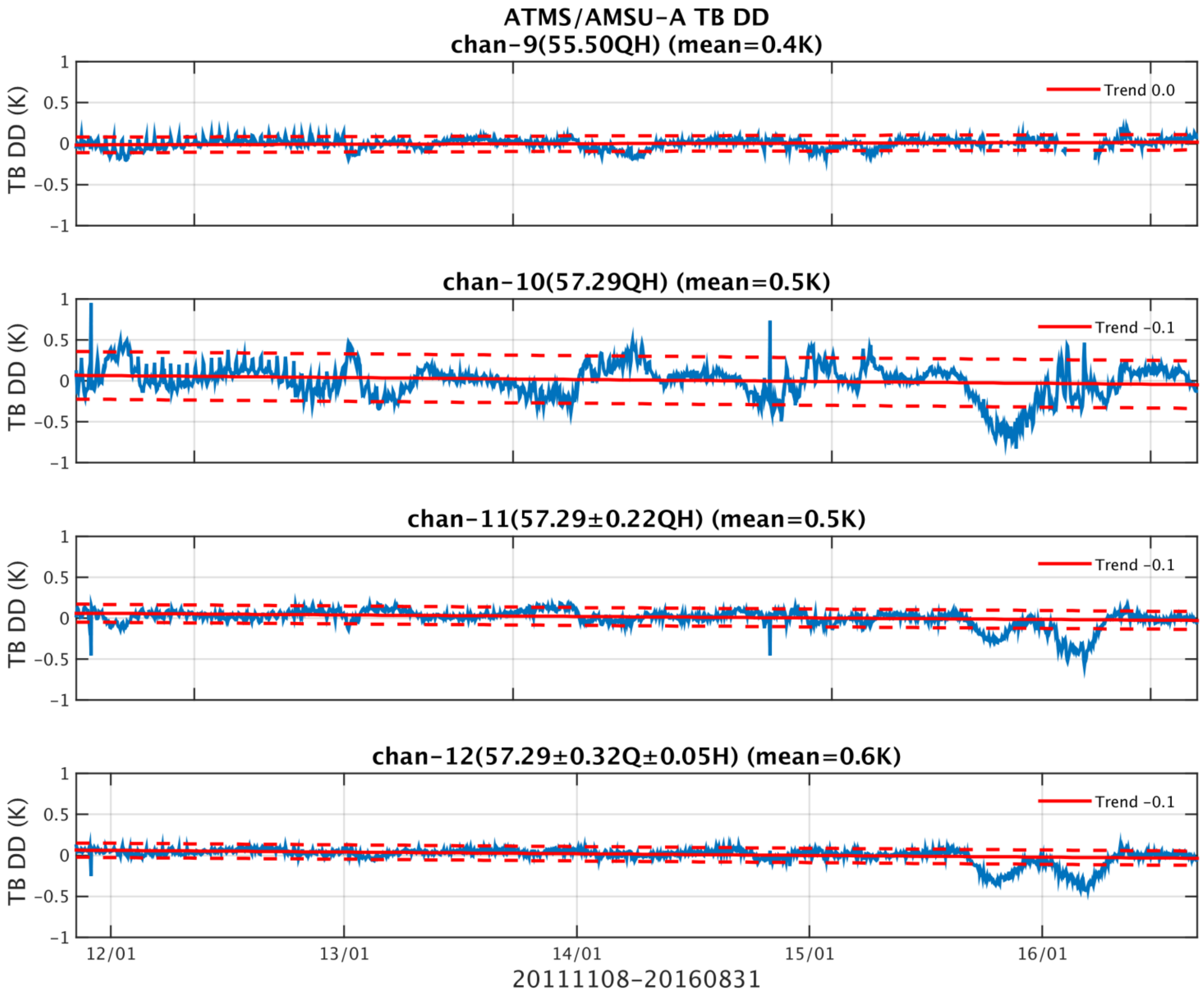


ATMS-GMI TB DD
23.8QV (mean= 0.9K)
Trend -0.0
88.20QV (mean=-1.8K)
Trend 0.0
183.31±7QH (mean=-0.9K)
Trend -0.1
183.31±3QH (mean=-1.4K)
Trend -0.0
TB DD (K)
14/04
14/07
14/10
15/01
15/04
15/07
15/10
16/01
16/04
16/07
20140305-20160831

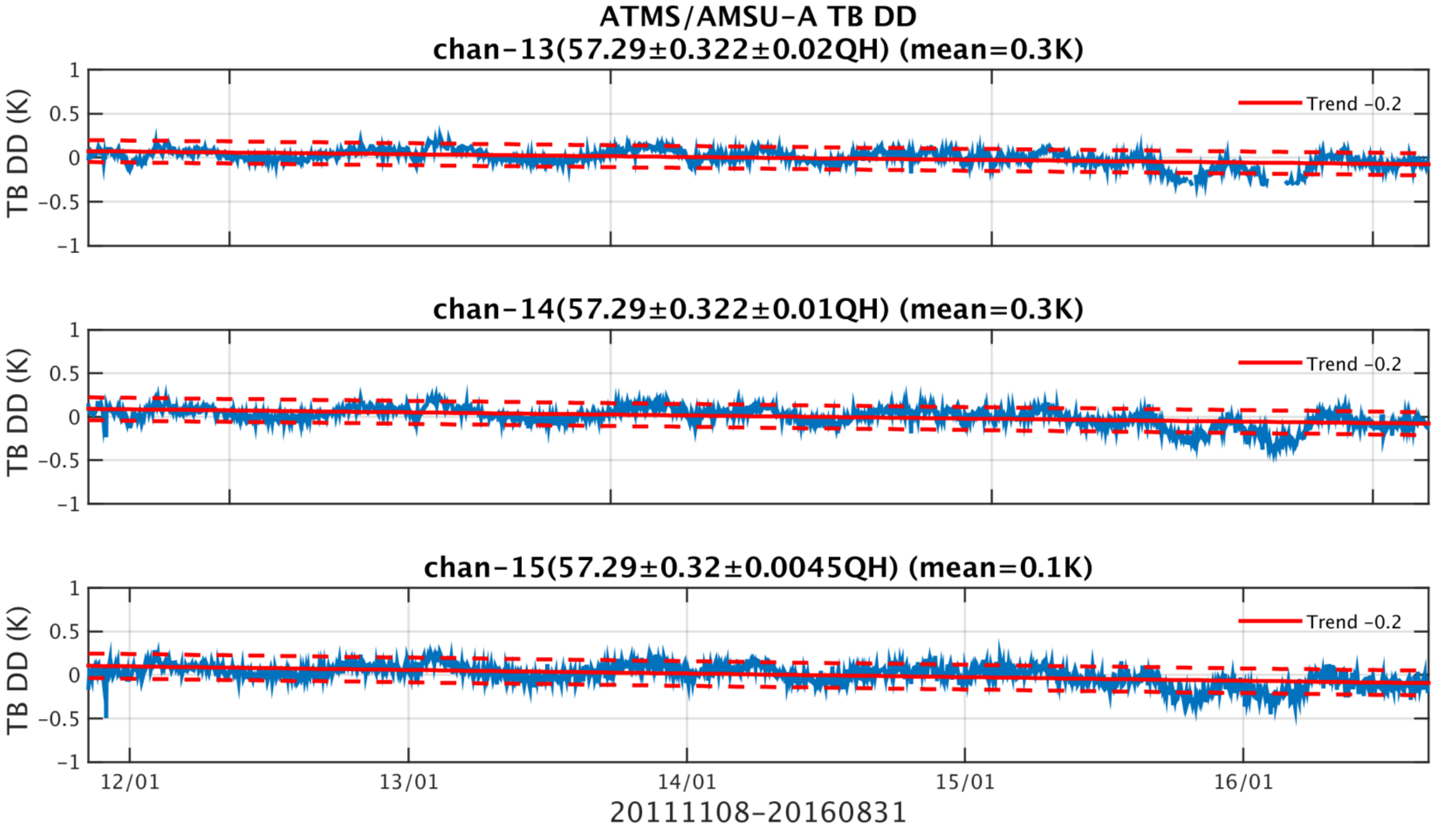
ATMS/AMSU-A (NOAA 18) Channels 5-8



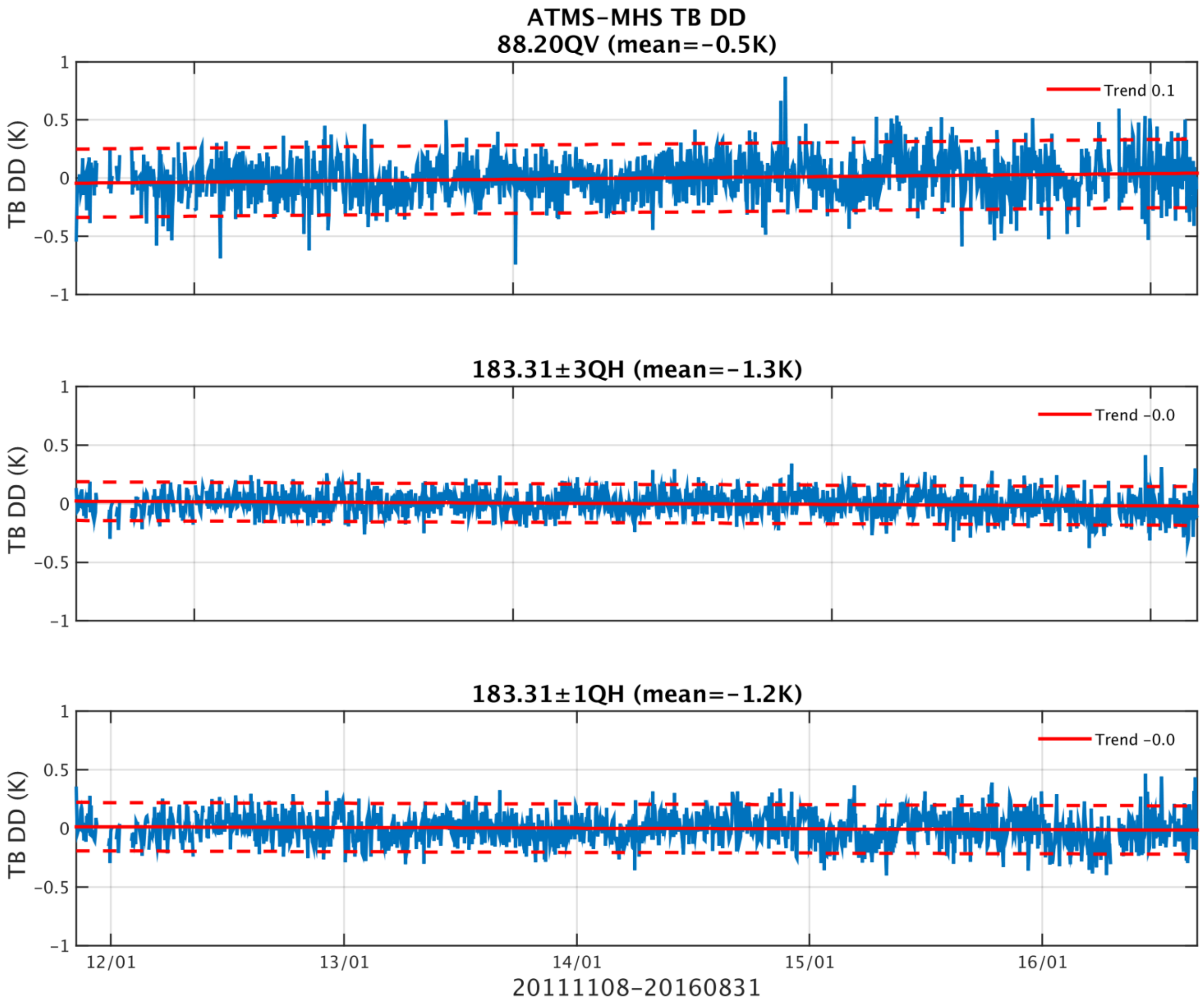
Channels 9-12



Channels 13-15

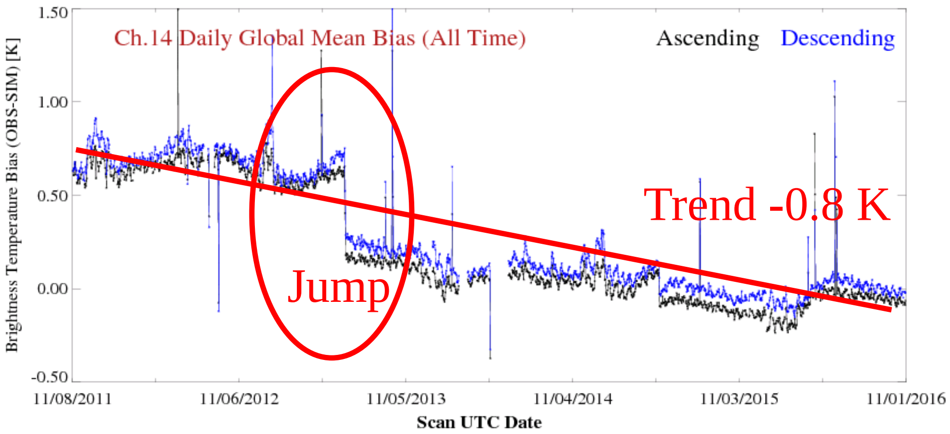


ATMS/MHS (NOAA 18)

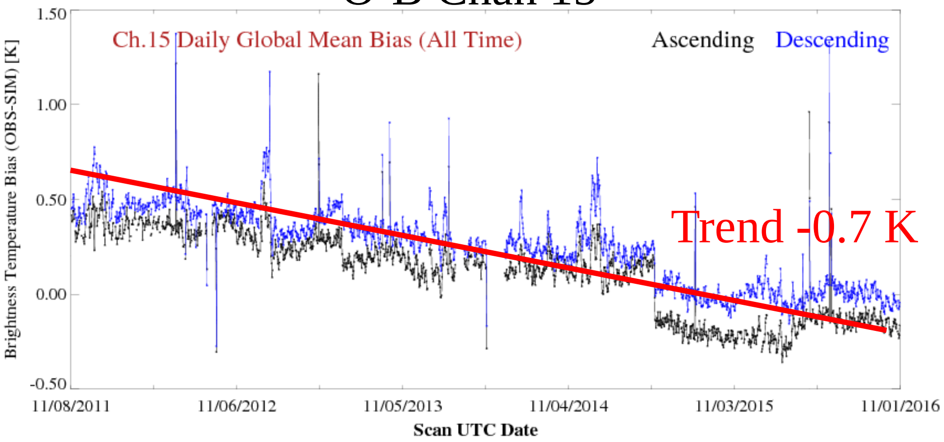


Comparing Cross-Calibration and O-B

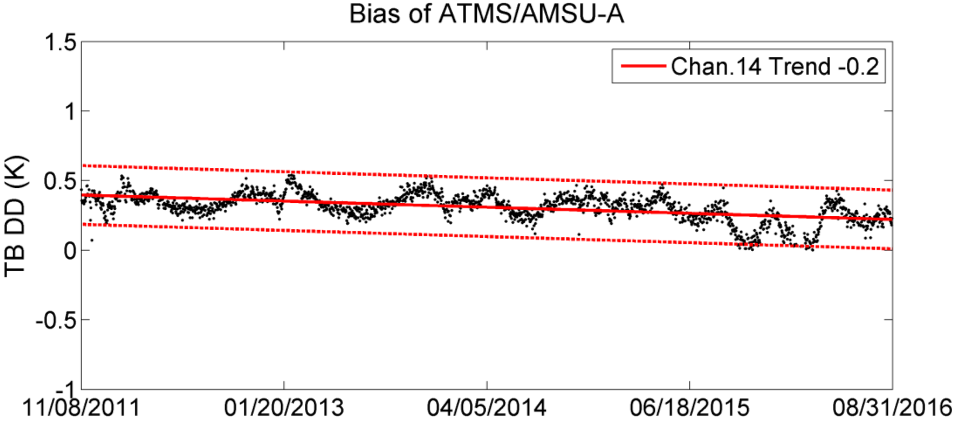
O-B Chan 14



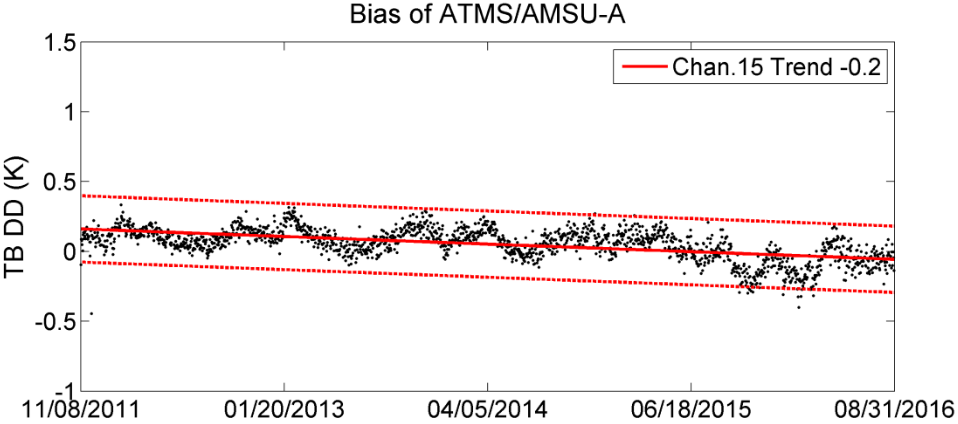
O-B Chan 15



Cross-Calibration Chan 14



Cross-Calibration Chan 15

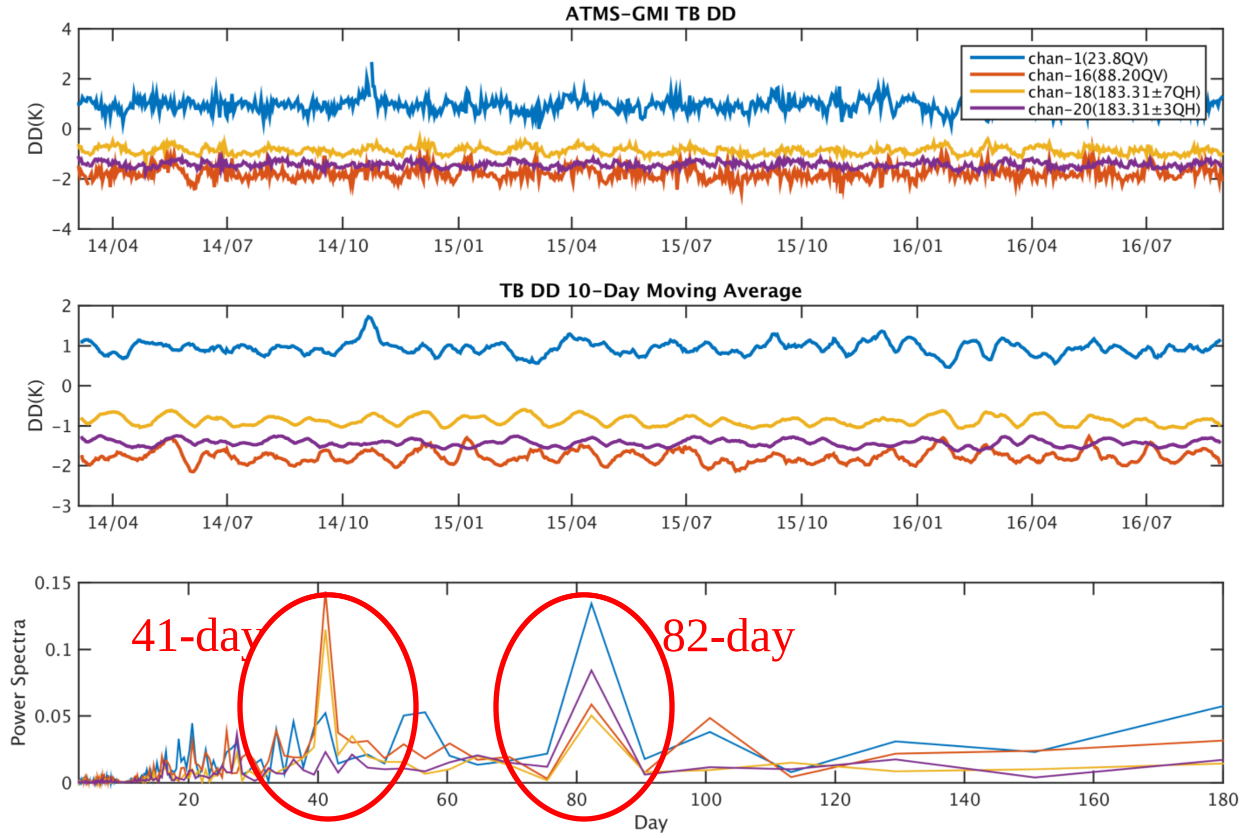


- No jump is found with much less drift according to cross-calibration, implying that O-B can be vulnerable to simulation biases and sampling issues

Table of Cross-Calibration

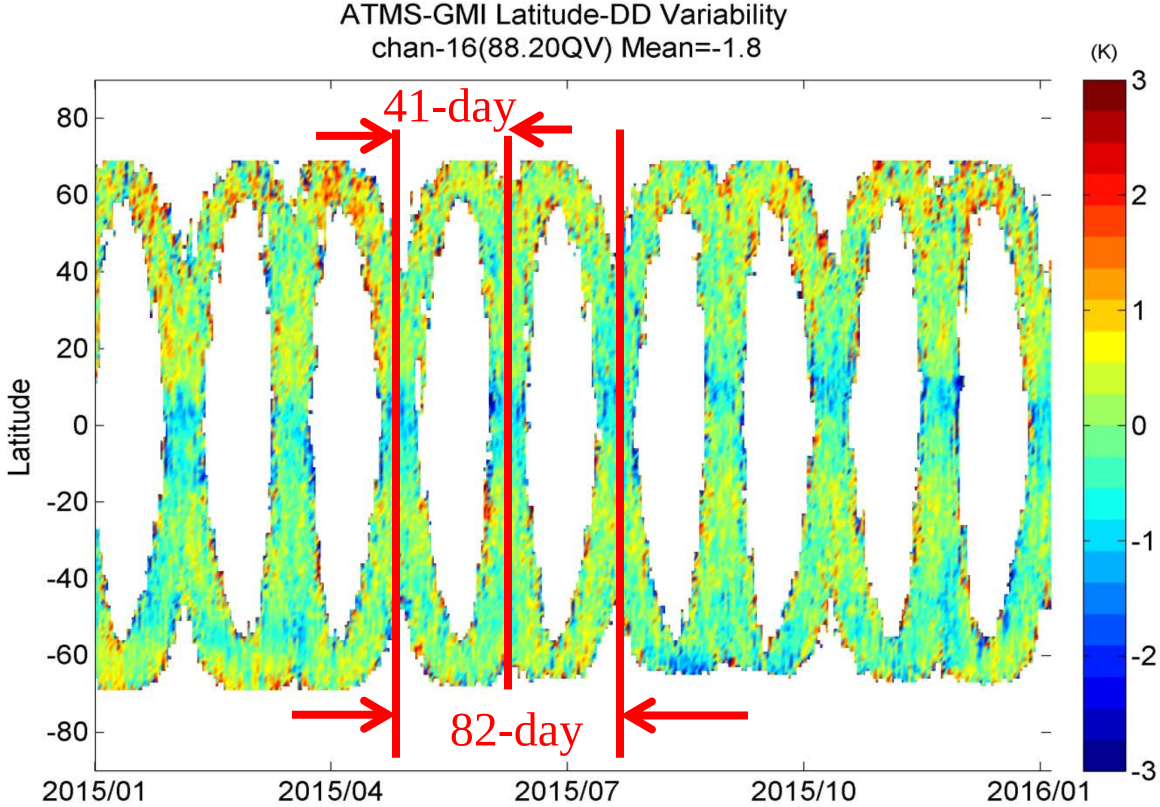
Channel	Freq	Pol	Bias	Bias STD	Trend
	ATMS		AMSU-A/MHS/GMI/TMI	AMSU-A/MHS/GMI/TMI	AMSU-A/MHS/GMI/TMI
1	23.8	QV	0.9/1.1	2/1.9	0/-0.1
5	52.8	QH	0.4	1.1	-0.1
6	53.596±0.115	QH	0.5	0.5	0
7	54.4	QH	1.1	0.4	-0.2
8	54.94	QH	1.0	0.4	-0.2
9	55.5	QH	0.3	0.4	0
10	57.29034	QH	0.4	0.6	-0.1
11	57.29034±0.217	QH	0.4	0.5	-0.1
12	57.29034±0.322±0.048	QH	0.5	0.5	-0.1
13	57.29034±0.322±0.022	QH	0.2	0.8	-0.2
14	57.29034±0.322±0.010	QH	0.2	1.1	-0.2
15	57.29034±0.322±0.0045	QH	0.0	1.7	-0.2
16	88.2	QV	-0.6/-2/-1.1	4.2/2.3	0.1/0/0
18	183.31±7	QH	-1	0.9	0.1
20	183.31±3.0	QH	-1.4/-1.5	1.8/1.1	0/0
21	183.31±1.8	QH	-1.2	2.3	0

Oscillation



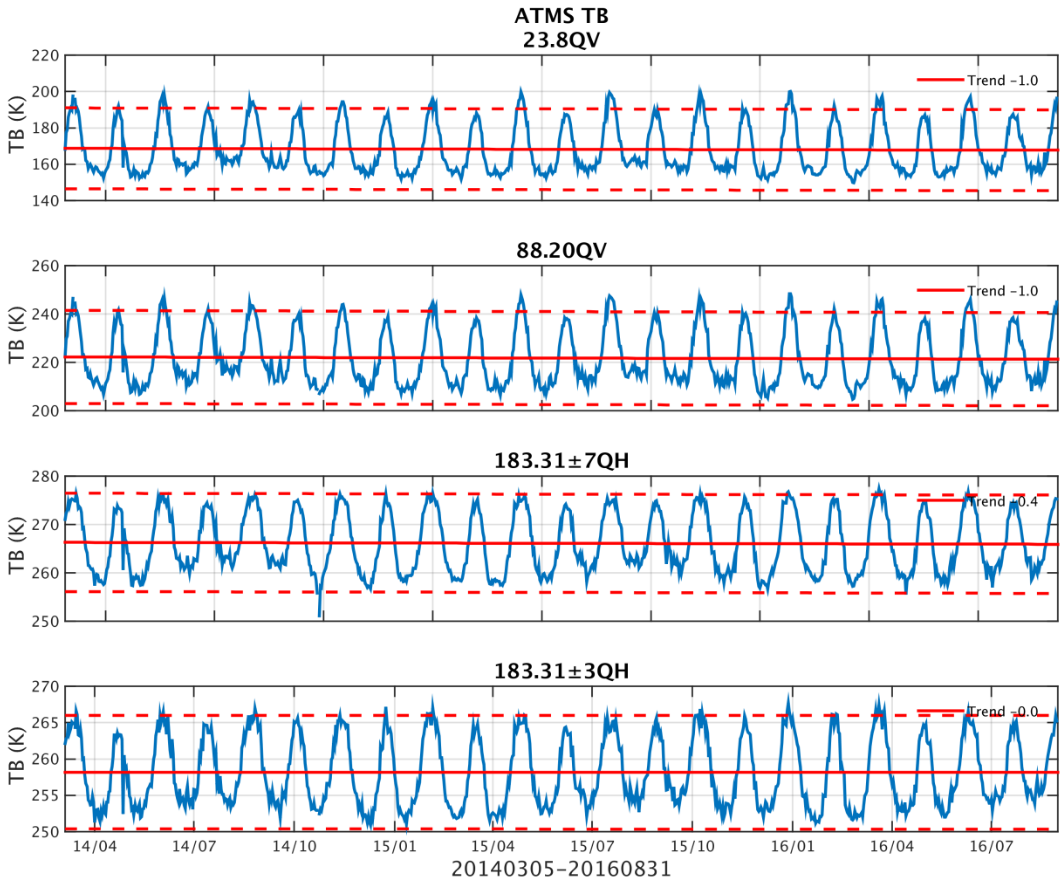
- A ubiquitous oscillation is found in inter-sensor biases, e.g., 41 and 82 days for ATMS/GMI

Latitudinal Oscillation



- The geolocation in cross-calibration oscillates latitudinally
- Two sinusoid-like waves overlap, each of which has a 82-day period. The symmetry reduces the overall period to half of 82-day. But some 82-day signals remain due to imperfect symmetry

Oscillation of Brightness Temperature



- TB oscillates with latitudes and affect cross-calibration
- The magnitude is ~1K, which affects O-B but can be canceled out in cross-calibration

A Physical Model Accounting for Oscillation Period

$$T = \frac{360}{2 \times 6.529 \times 10^{24} \left| a_1^{-3.5} \cos i_1 - a_2^{-3.5} \cos i_2 \right|}$$ (Yang et al. 2016 JGR)

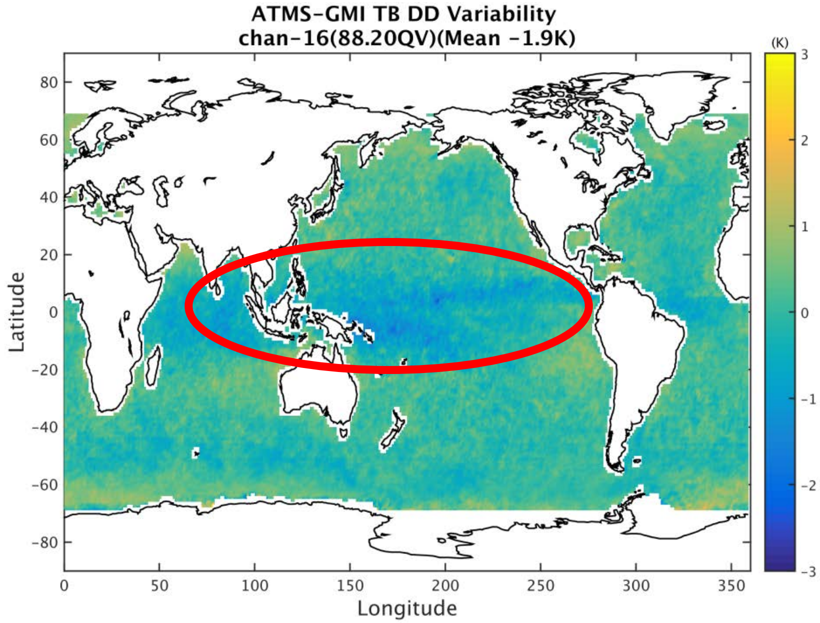
- a = distance of satellite orbit to Earth center, i=orbit inclination angle, T=oscillation period in days

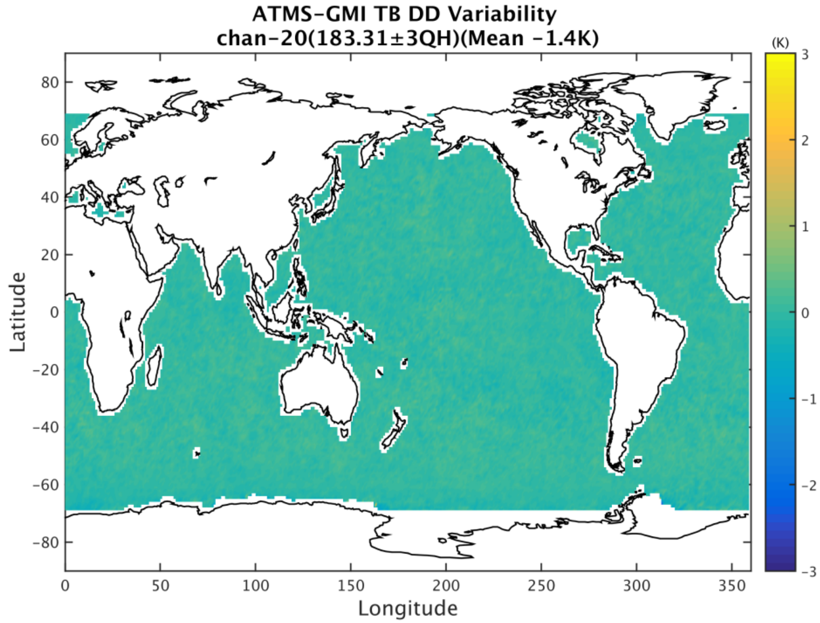
Model Vs. Observation

Instrument Pair	Oscillation Period from Analytic Calculation (day)	Oscillation Period from Observational Calculation (day)
ATMS-GMI	41	41
ATMS-TMI	24	24
GMI-AMSR2	40	41
GMI-F16	40	41
GMI-F17	40	41
GMI-F18	40	41
GMI-TMI	52	56
GMI/WindSat	40	41
TMI/WindSat	24	23

- The oscillation period is determined by the spacecraft orbit characteristics and precession
- ATMS/AMSU-A/MHS collocate mainly in poles and thus the model does not apply

Regional Difference





- Regional difference of inter-sensor biases are noticeable in window channels, but insignificant in sounding channels

Conclusion and Future Work

- Long-term cross-calibration shows stable performance of ATMS without noticeable drift
- Oscillation is found due to orbit variability
- Our techniques work for comparing cross-track and conical scanning instruments, allowing for continuous daily monitoring
- The cross-calibration codes are developed and can be used for upcoming JPSS
- Document the results and submit a paper to IEEE Transaction on Geo. Remo. Sens.

References

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- Rosenkranz, P. W. (1998), Water vapor microwave continuum absorption: A comparison of measurements and models, Radio Sci., 33(4),919–928
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- **Yang, J. X**., D.S. McKague and C. S. Ruf, 2015, Boreal, temperate, and tropical forests as vicarious calibration sites for spaceborne microwave radiometry, IEEE Transactions on Geoscience and Remote Sensing, 54(2), 1035-1051,
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- **Yang, J. X.**, D.S. McKague and C. S. Ruf, 2014, Land contamination correction for passive microwave radiometer data: demonstration of wind retrieval in the Great Lakes using SSM/I, Journal of Atmospheric and Oceanic Technology, 31, 2094-2113.

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Tables of Cross-Calibration

ATMS			AMSU-A			MHS			GMI			TMI		
Channel	Freq	Pol	Bias	STD	Trend	Bias	STD	Trend	Bias	STD	Trend	Bias	STD	Trend
1	23.8	QV							0.9	2.0	0.0	1.1	1.9	-0.1
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18	183.31±7	QH							-1.0	0.9	-0.1			
20	183.31±3.0	QH				-1.4	1.8		-1.5	1.1	0.0			
21	183.31±1.8	QH				-1.2	2.3							

	AMSU-A	MHS	GMI	TMI
Cross-Calibration to ATMS Start	2011/11/08	2011/11/08	2014/03/05	2011/11/08
Cross-Calibration to ATMS End	2016/08/31	2016/08/31	2016/08/31	2015/04/08

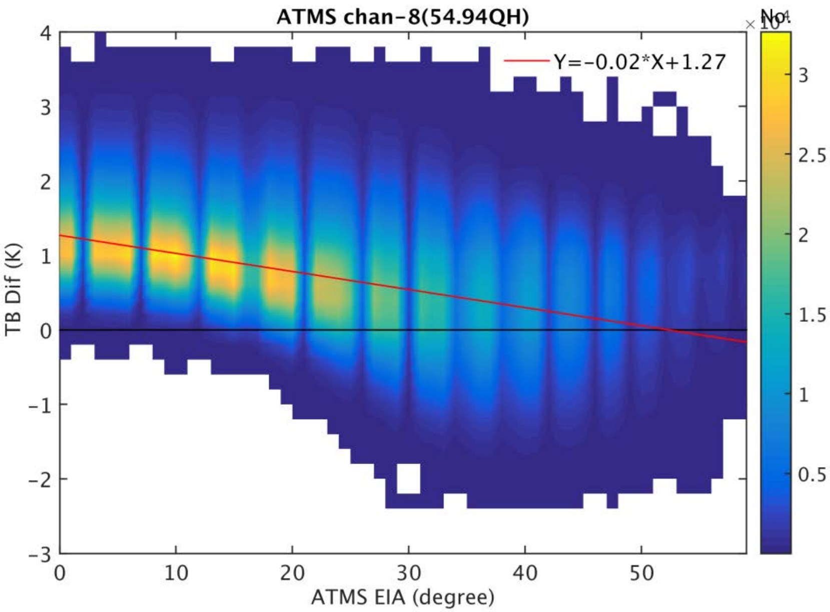
ERAI Vs NCEP-FNL

AMSU-A		MHS		GMI		TMI	
ERAI	NCEP-FNL	ERAI	NCEP-FNL	ERAI	NCEP-FNL	ERAI	NCEP-FNL
Bias	Bias	Bias	Bias	Bias	Bias	Bias	Bias
0.4	0.4	-0.6	-1.1	0.9	0.8	1.1	1.0
0.5	0.4	-1.4	-1.3	-2.0	-1.1	-1.1	-0.2
1.1	1.0	-1.2	-1.2	-1.0	-1.3		
1.0	0.9			-1.5	-1.8		
0.3	0.3						
0.4	0.4						
0.4	0.4						
0.5	0.5						
0.2	0.4						
0.2	0.4						
0.0	0.1						

*ATMS cross-calibration

Example: Account for EIA Dependence

Direct TB Comparison
between ATMS and AMSU-A



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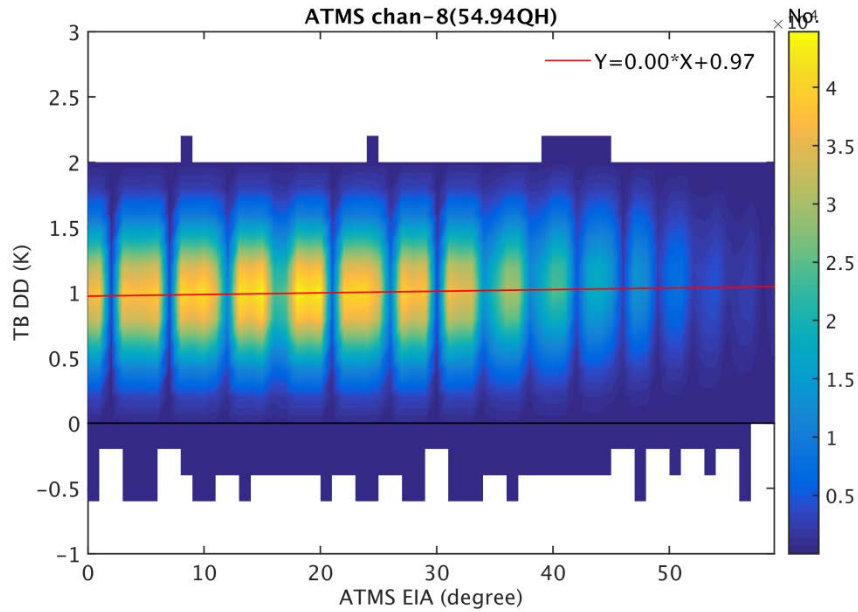
between ATMS and AMSU-A



- Comparison with only nadir view has limited samplings
- Direct comparison of TB results in difference depending on EIAs, frequencies and bandwidth, which can be accounted in cross-calibration with RTM

DD Dependence on TB