Atmospheric Temperature FCDR from the MSU/AMSU-A/ATMS: Recent Progresses

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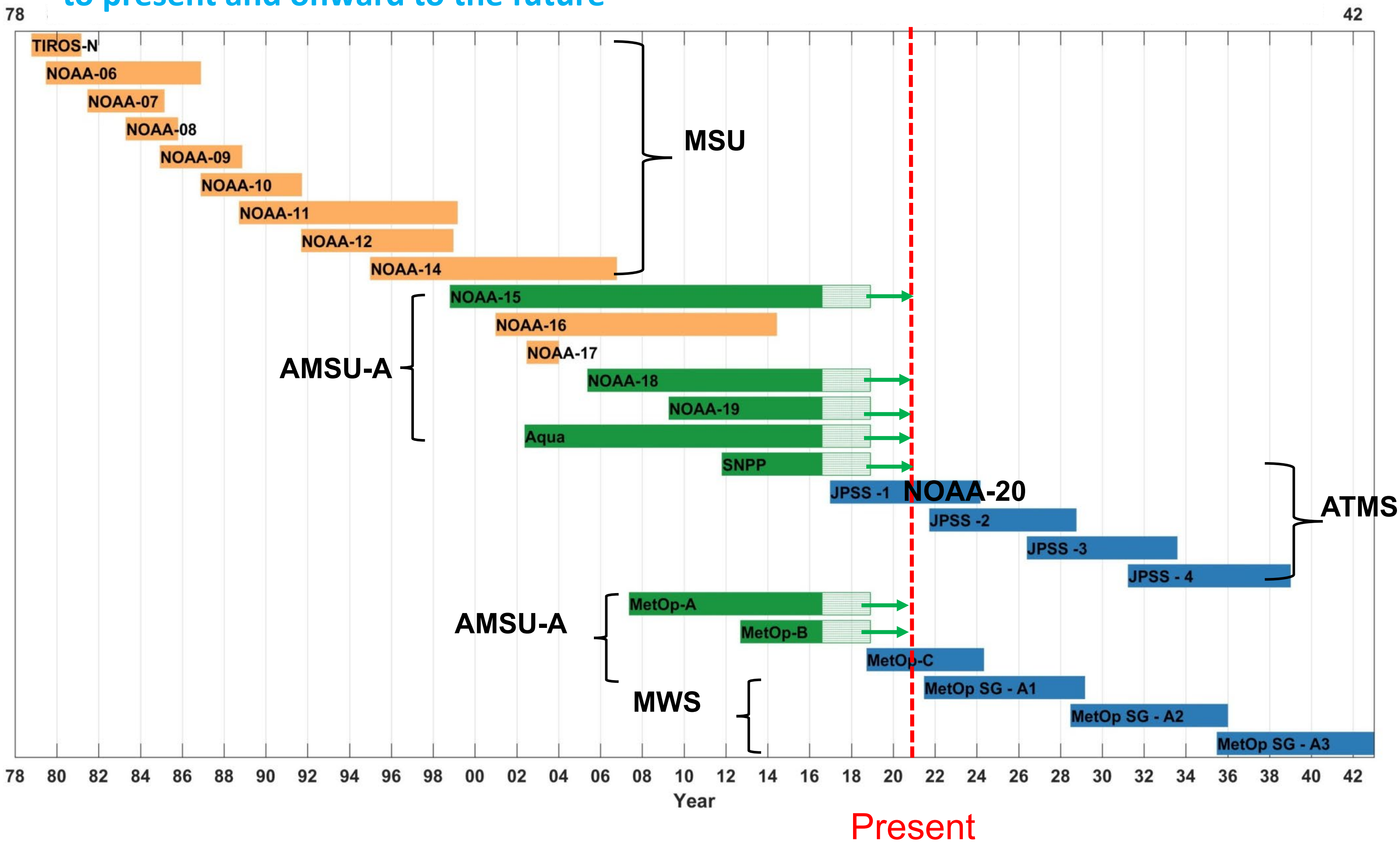
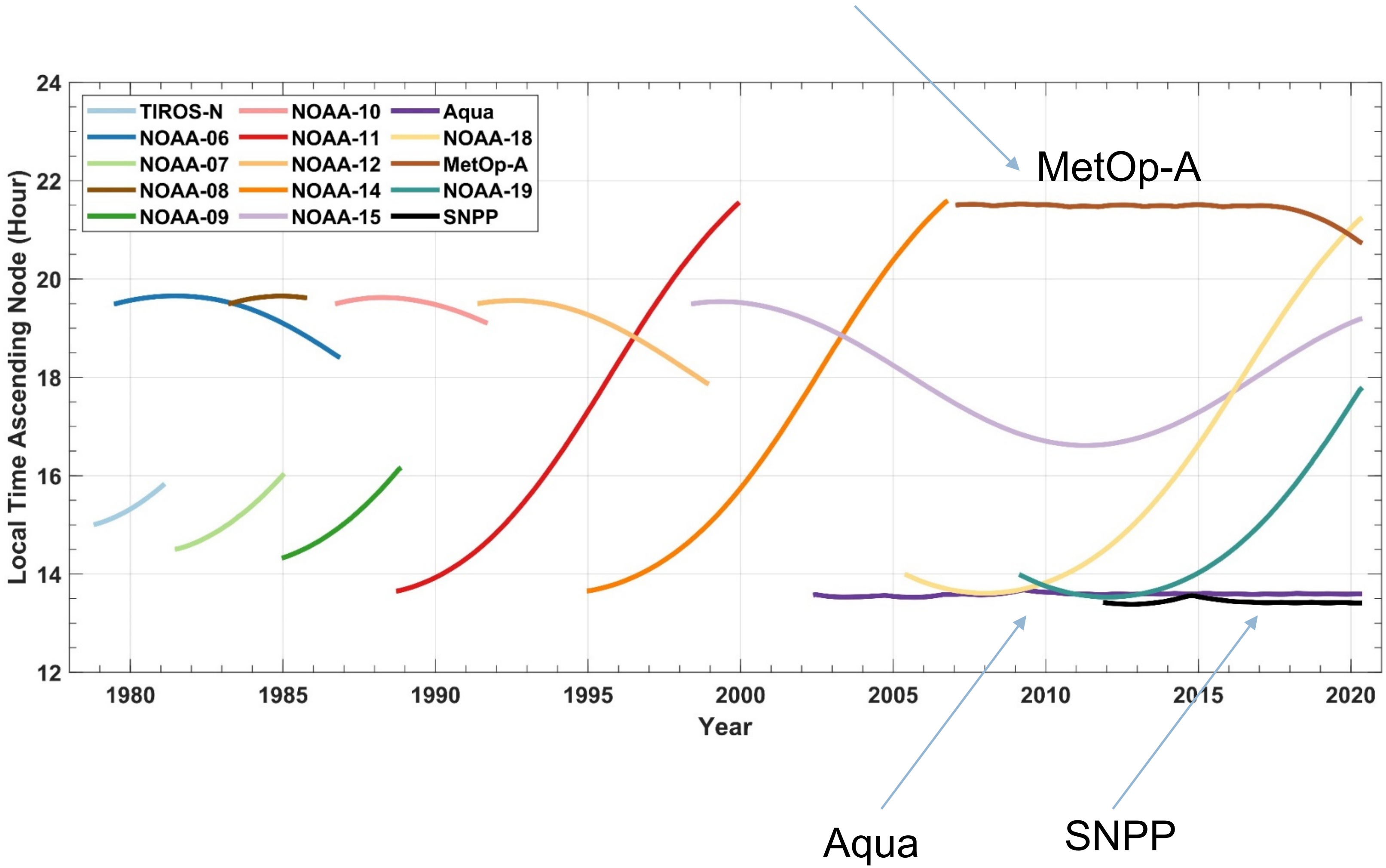
NOAA/NESDIS/Center for Satellite Applications and Research

GSICS Microwave Sub-Group Web Meeting, February 16, 2021

Atmospheric Temperature FCDR Development: Involving Microwave Sounders on NOAA/NASA/MetOp Satellite Series from 1978 to present and onward to the future



Satellite LECT



Recalibration/Inter-calibration Equations for FCDR Generation

Nonlinear Calibration Similar to Operational Calibration

$$R = R_L - \delta R + \mu Z$$

$$Z = S^2 (C_e - C_c)(C_e - C_w)$$

$R_L \rightarrow$ Linear part of the calibration

$\delta R = \alpha + \beta(t - t_0) \rightarrow$ Offset, allow to change over time

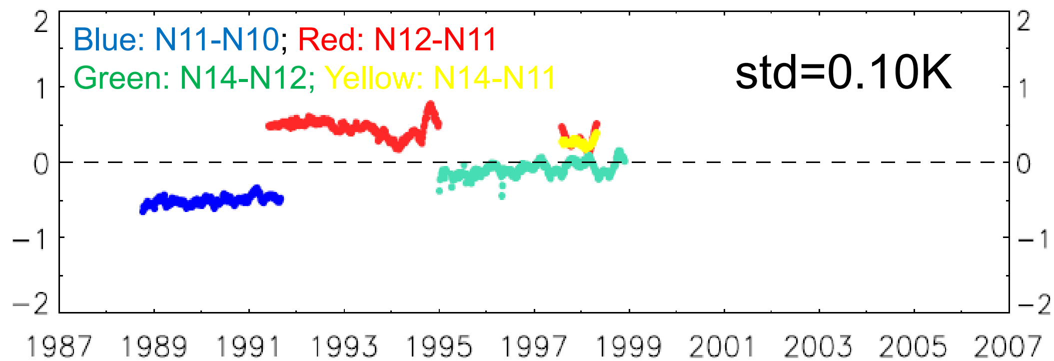
$\mu = \mu_0 + \kappa (t - t_1) \rightarrow$ nonlinear coefficient, allow to change over time

- Time varying offsets and nonlinear coefficients were obtained using SNOs and satellite overlap observations.
- Calibration offsets and nonlinear coefficients were not allowed to change with time for reference satellites
- Possible mechanisms causing the offset changes include the side-lobe efficiency changes due to reflector degradation and measurement leakage when the instrument antenna switches between the earth view and calibration target views
- Changes of nonlinear coefficient are not necessarily related to instrument temperature changes. It could be just the degradation of instrument amplifier's nonlinearity

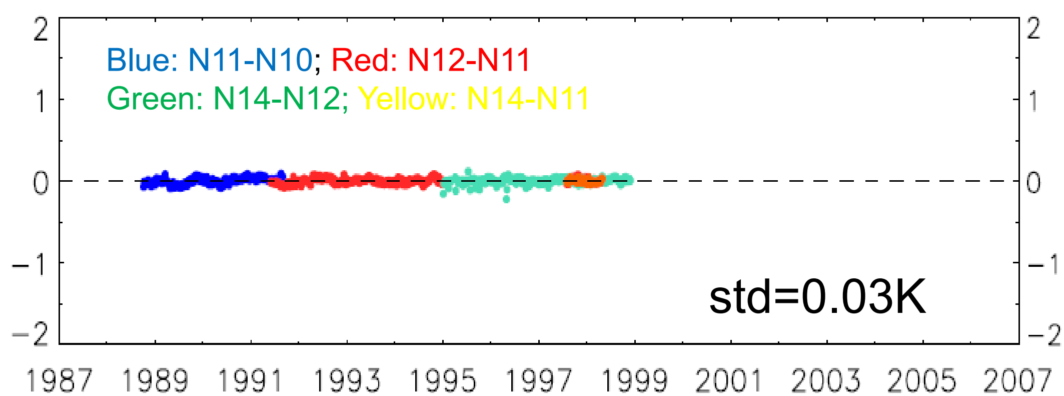
Earlier Version of the MSU/AMSU-A FCDR

- Developed around 2005-2009 (Zou et al. 2006, 2009, Zou and Wang 2011). MSU FCDR is archived in NOAA/NCEI data center. AMSU-A FCDR is still routinely delivered to NOAA/NCEI for archiving and distribution to users
- All MSU and most AMSU-A satellites had orbital drifts at that time
- MetOp-A were still short, Aqua did not provide raw counts for recalibration
- NOAA-10 and NOAA-15 were selected as references for MSU and AMSU-A recalibration/inter-calibration, respectively.
- Inter-satellites differences minimized

Before Recalibration (Operational Calibration)



After recalibration using SNOs



Global ocean mean inter-satellite difference time series for MSU channel 2 onboard NOAA-10 to NOAA-14 (plot from Zou et al. 2009)

Requirement on Microwave Sounder Reference

- **Requirements of reference measurements are different for weather prediction and climate change detection**

- Weather Requirement: absolute accuracy better than 0.1~0.2 K is required for satellite data to be assimilated into NWP models without a bias correction

  - Unless biases are absolutely zero, unstable small biases are no good for climate change detection--unstable bias of ±0.1K may still give a large non-climate trend signal of 0.2K/Dec.

- Climate Requirement: stability is the primary requirement for climate change detection

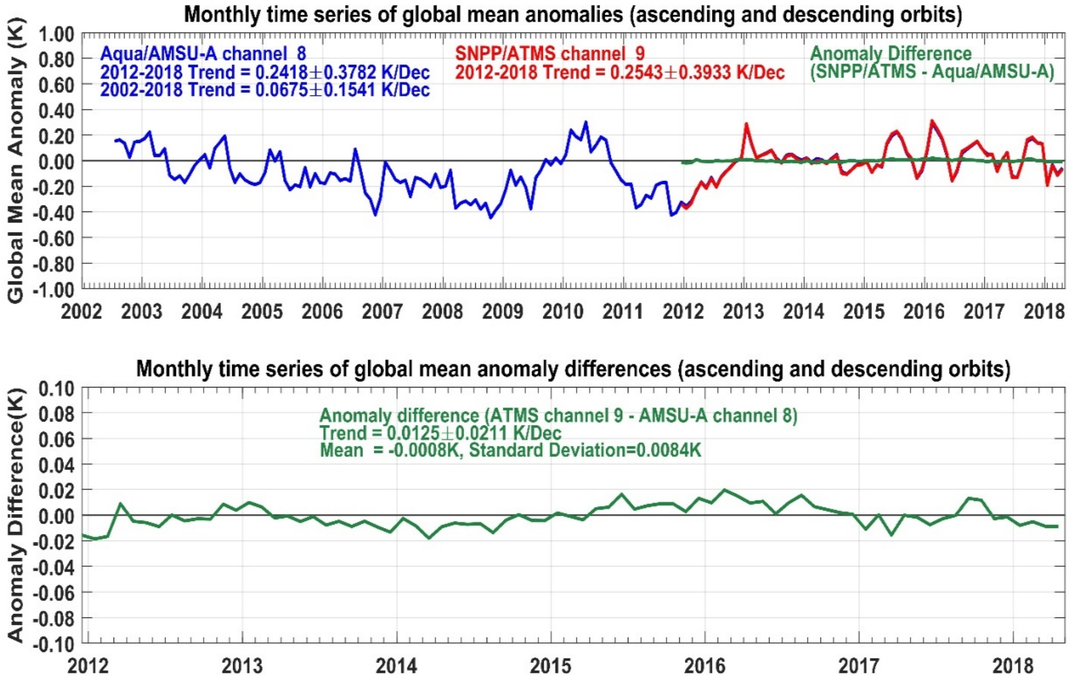
  - large bias is not a big concern as long as it is stable
  - Temperature measurement stability (Ohring et al. 2005):

    0.04K/Decade for tropospheric temperature

    0.08K/Decade for stratospheric temperature (Observations can do better than this)

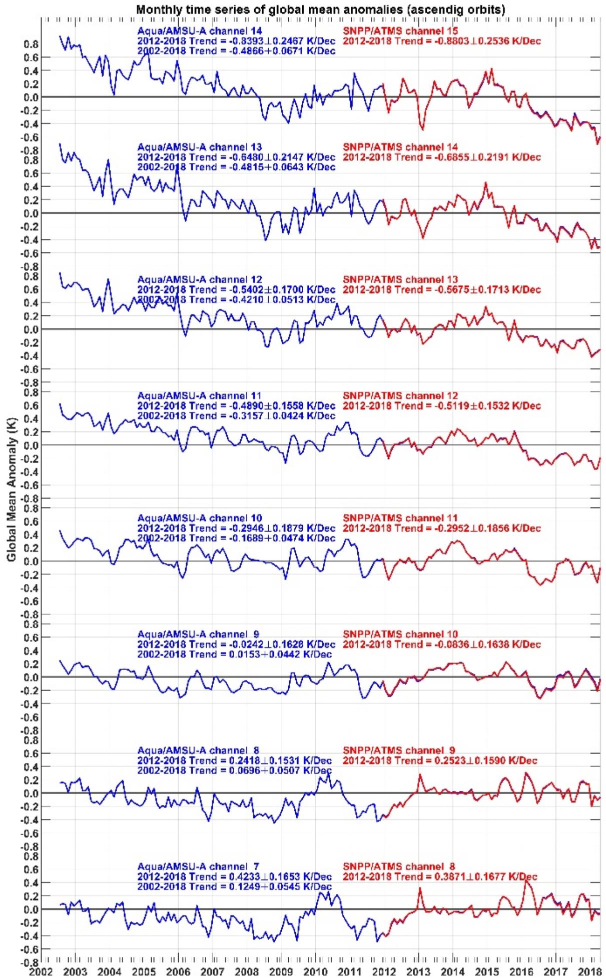
SNPP ATMS and Aqua/MetOp-A AMSU-A Achieves High Radiometric Stability

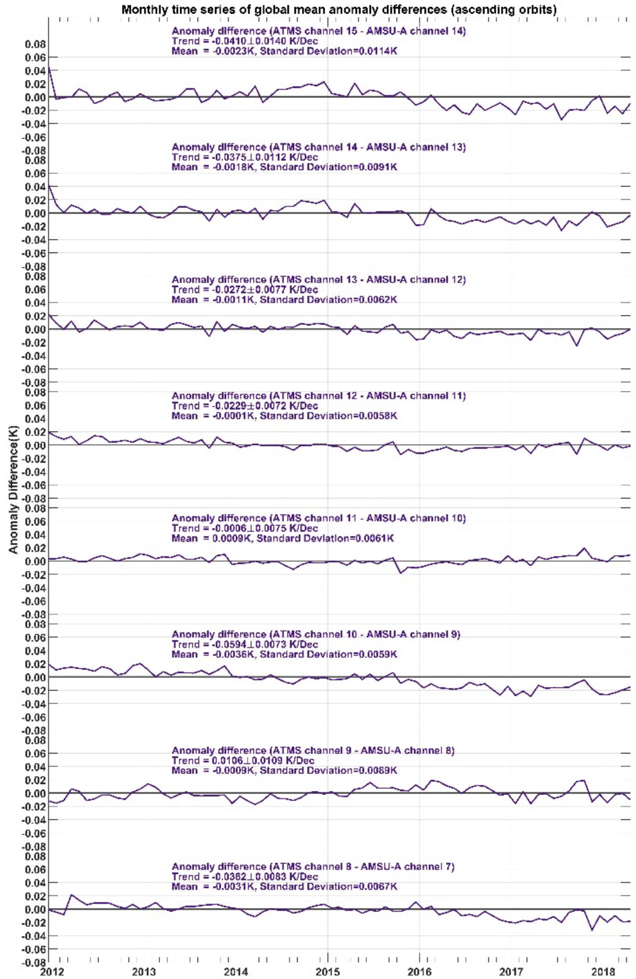
- Diurnal sampling difference is absent – diurnal sampling biases are naturally removed by satellites with stable orbits of the same overpass time
- Time series from different satellites match with each other nearly perfectly without applying any diurnal drift corrections or time-dependent inter-calibration
- Calibration drifts could be estimated quite accurately
- Small trend differences suggest absolute stability on either instruments
- Radiometric stability within 0.004K/Year for SNPP/ATMS and Aqua/AMSU-A for all analyzed channels



Monthly global mean anomaly time series of brightness temperatures for AMSU-A channel 8 onboard Aqua (blue, top panel) versus ATMS channel 9 onboard SNPP (red, top panel) and their difference time series (green, top and lower panels). The AMSU-A and ATMS data are respectively from June 2002 and December 2011 to April 2018. The AMSU-A anomaly time series are overlaid by ATMS during their overlapping period with their differences shown as nearly a constant zero line in the same temperature scale. Amplified scale of temperature is used in the bottom panel to show detailed features in the anomaly difference time series. Both ATMS and AMSU-A data are from limb-adjusted views and averaged over ascending and descending orbits (plot from Zou et al. 2018).

All analyzed channels

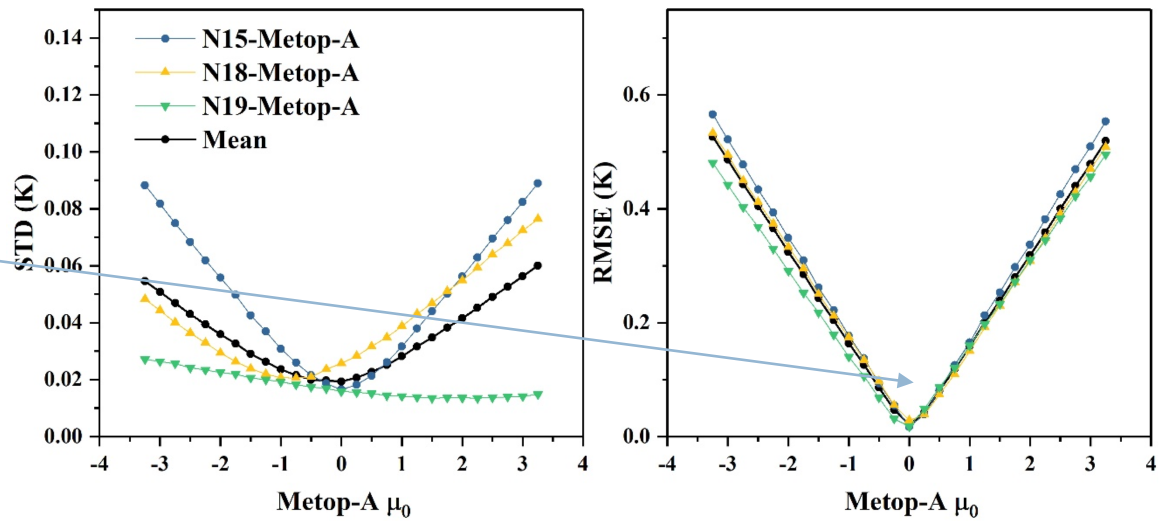




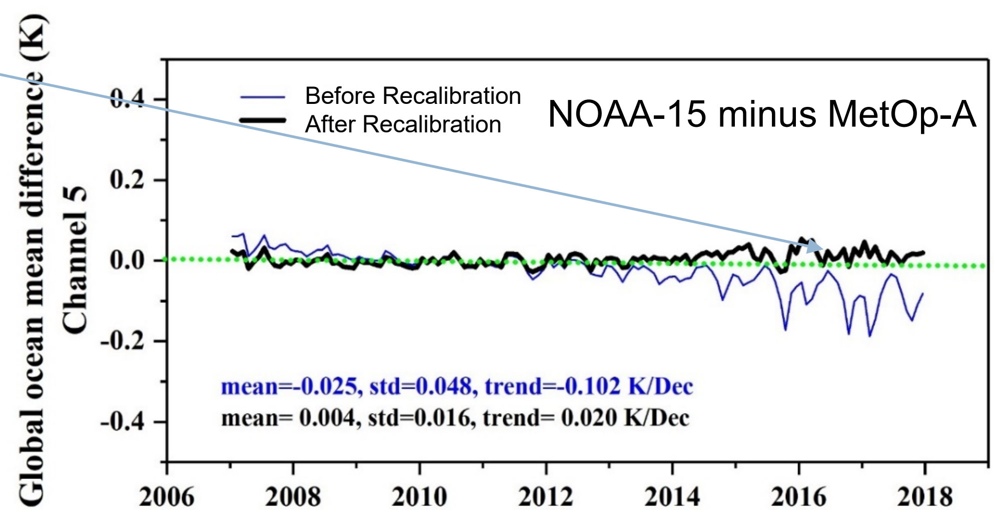
Radiometric stability achieves 0.004K/Year for most channels

Recalibration of AMSU-A Observations Using New Reference

- Using Integrated Microwave Inter-calibration Approach (IMICA), optimal calibration nonlinearity and offsets were obtained that minimized inter-satellite differences



- As a result, both trend and variability in inter-satellite difference time times were greatly reduced



Recalibration of Satellites and Channels of Interest— With MetOp-A As a Reference

	Satellite	δR_0	k	μ_0	λ
Channel 4	Metop-A	0.0	0.0	0.0	0.0
	NOAA-15	-0.043	1.000e-7	-1.088	0.026
	NOAA-18	0.178	0.0	0.426	0.0
	NOAA-19	0.456	0.0	0.750	0.0
Channel 5	Metop-A	0.0	0.0	0.0	0.0
	NOAA-15	-0.442	1.120e-6	-1.253	0.126
	NOAA-18	1.056	-7.100e-7	3.083	-0.150
	NOAA-19	0.617	0.0	0.752	0.0
Channel 6	Metop-A	0.0	0.0	0.0	0.0
	NOAA-15	1.646	-8.100e-7	1.089	-0.18
	NOAA-18	-0.274	0.0	0.120	0.0
	NOAA-19	-0.024	0.0	0.056	0.0
Channel 9	Metop-A	0.0	0.0	0.0	0.0
	NOAA-15	-0.390	1.100e-7	-0.657	-0.006
	NOAA-18	1.347	-1.050e-6	1.446	-0.091
	NOAA-19	0.555	-5.900e-7	0.837	-0.046
Channel 10	Metop-A	0.0	0.0	-0.25	0.0
	NOAA-15	0.519	0.0	-0.571	0.0
	NOAA-18	1.272	-1.080e-6	1.632	-0.089
	NOAA-19	-0.228	0.0	-0.297	0.0

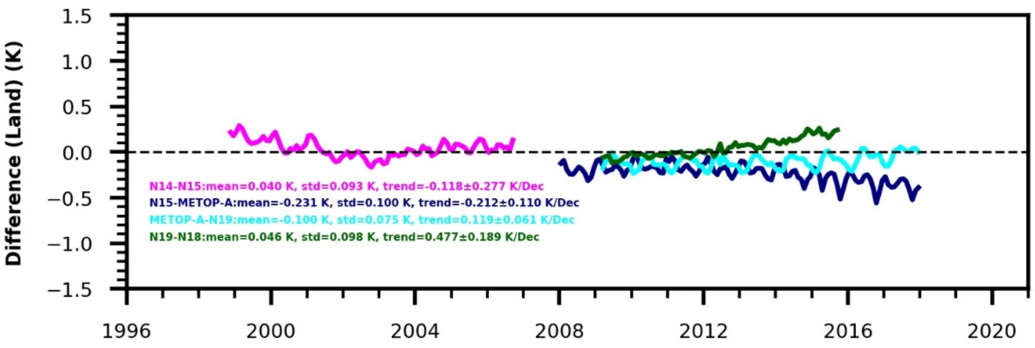
MetOp-A offset was set to be zero; nonlinear coefficient were obtained by IMICA method, but turned out to be zero for most channels

Diurnal Drift Correction For Developing TCDR

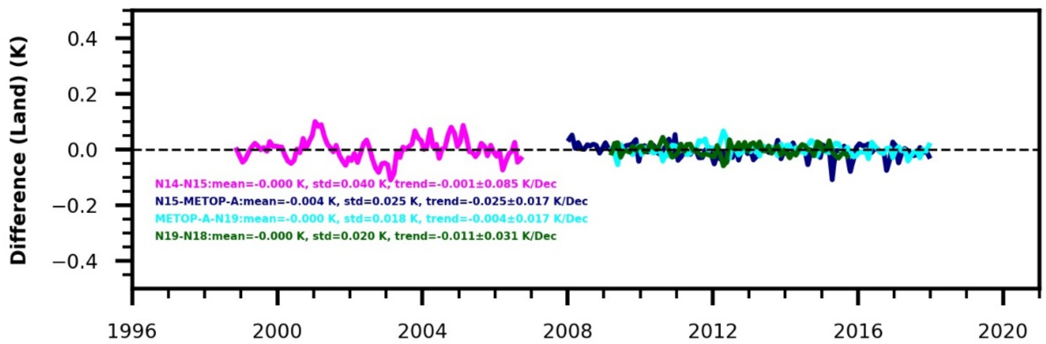
- Diurnal drift correction algorithms were developed and used to correct diurnal drifting errors for satellites with orbital drifts for TCDR development

- After diurnal drift correction, inter-satellite differences trends become zero

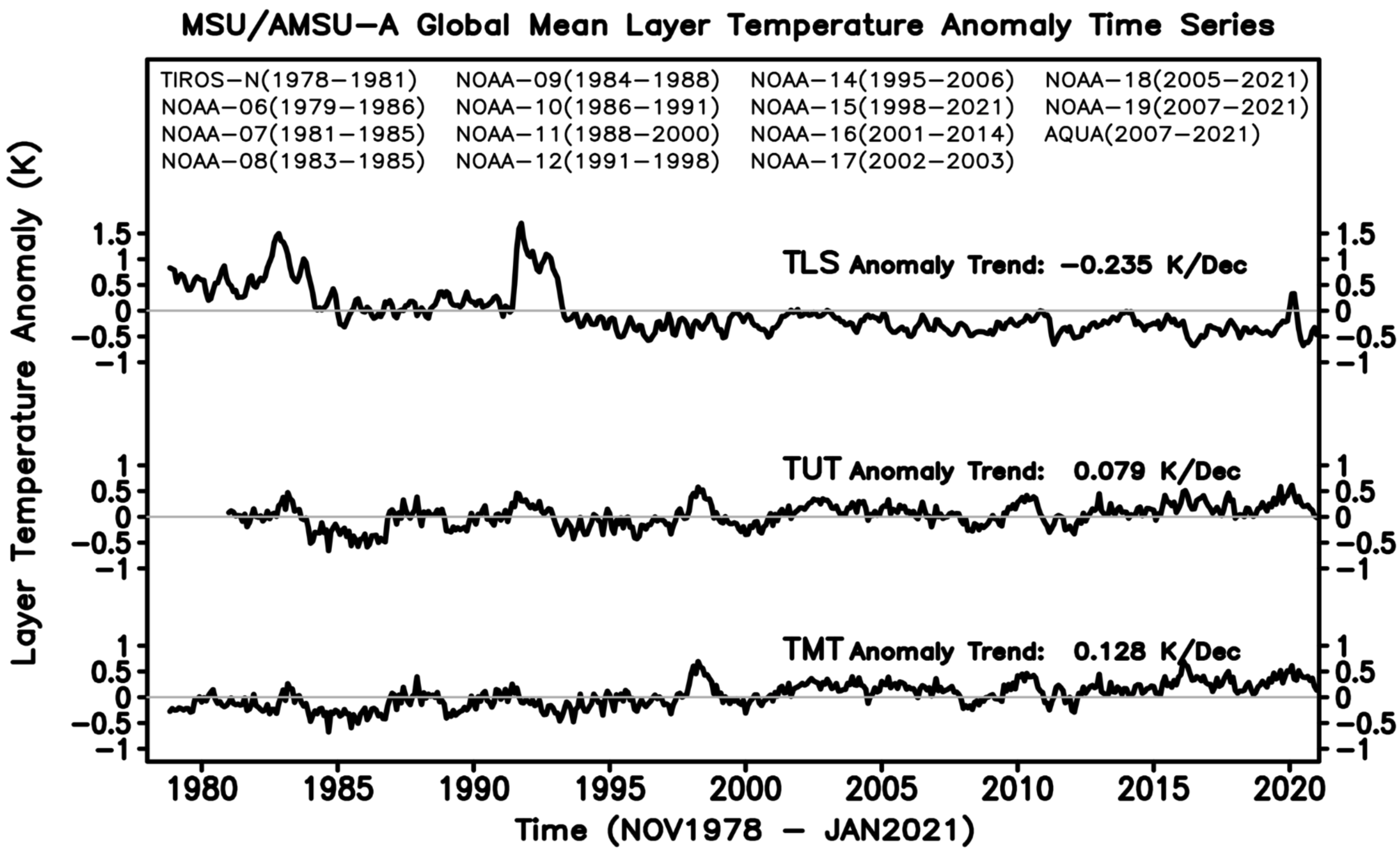
Inter-Satellite Differences Over Land for Satellites with Orbital Drifts
-- Before Diurnal Drift Correction



Inter-Satellite Differences Over Land for Satellites with Orbital Drifts
-- After Diurnal Drift Correction (note the temperature scale difference)



Near Term Goal – Upgrade STAR Layer Mean Atmospheric Temperature TCDR from Version 4.1 to Version 5.0



Summary

- Earlier version of the MSU/AMSU FCDR used references that may have drifted
- AMSU-A onboard Aqua and MetOp-A and ATMS onboard SNPP can be used as new references
- New AMSU-A/ATMS FCDR are developed using MetOp-A as a reference; TCDR trends will follow MetOp-A/AMSU-A and SNPP/ATMS trends
- More accurate diurnal corrections are developed
- More accurate TCDR is expected