Toward Improved Climate Data Record Using Stable SNPP/ATMS Observations As References

Cheng-Zhi Zou

NOAA/NESDIS/Center for Satellite Applications and Research

With contributions from Hui Xu, Xianjun Hao and Mitch Goldberg

ITSC-22, October 31 – November 6, 2019, Saint-Sauveur, Québec, Canada

Outline

❑ Requirement for Satellite Microwave Sounder for Climate Change Detection

❑ Satellite calibration drift and diurnal drift

❑ Recent findings on radiometric stability of ATMS, Aqua, and MetOp-A

❑ Perspective on how the new findings will improve the science of climate trend measurement

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

  - Unstable small biases are no good for climate change detection--unstable bias of ±0.1K may still give a large non-climate trend signal   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

  - Need at least 33 years of measurement for the uncertainty of the global mean temperature trend to be within 20%

  - Satellite merging can produce longer time series

  - Continuity in channel frequency in instrument design

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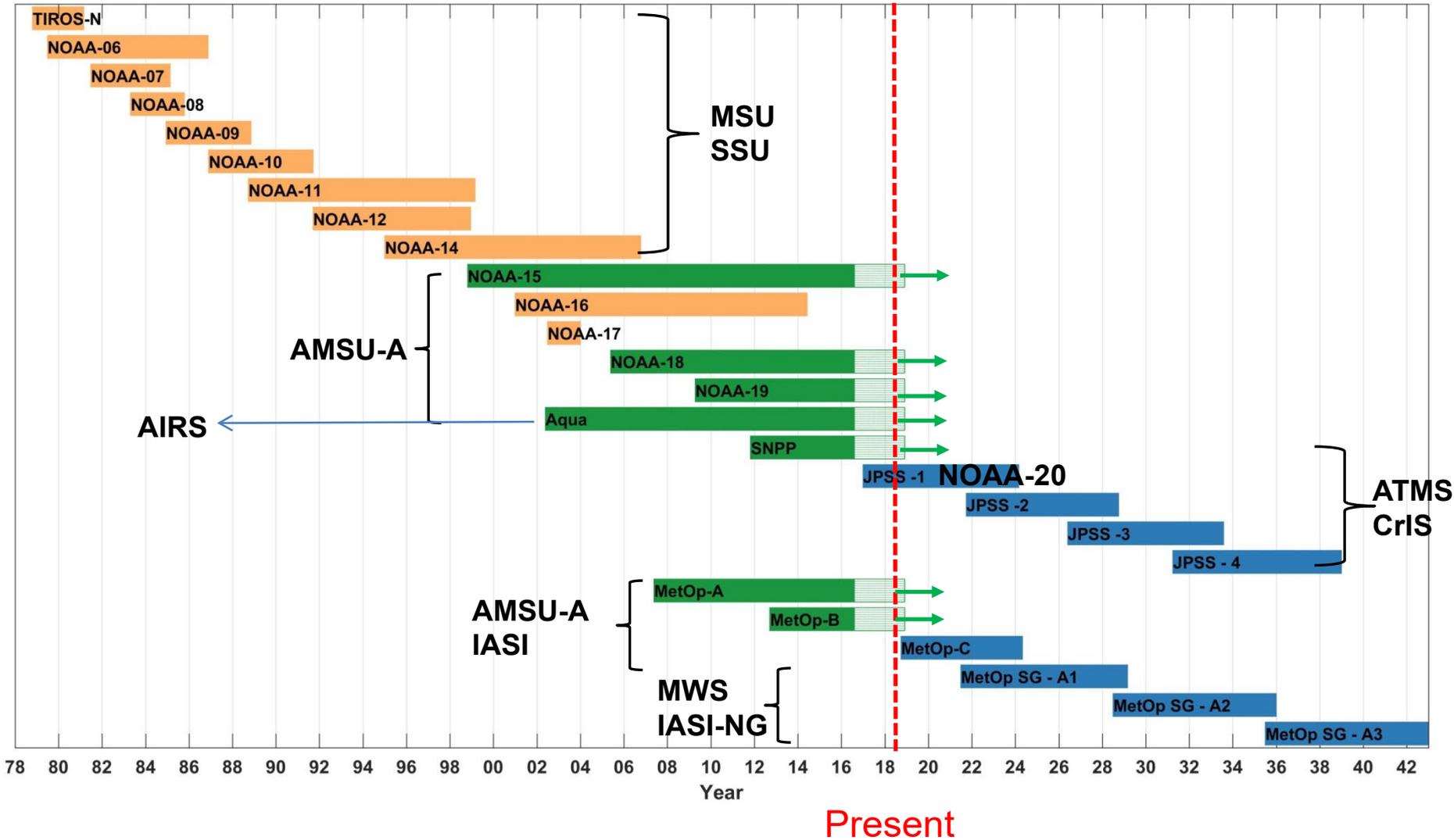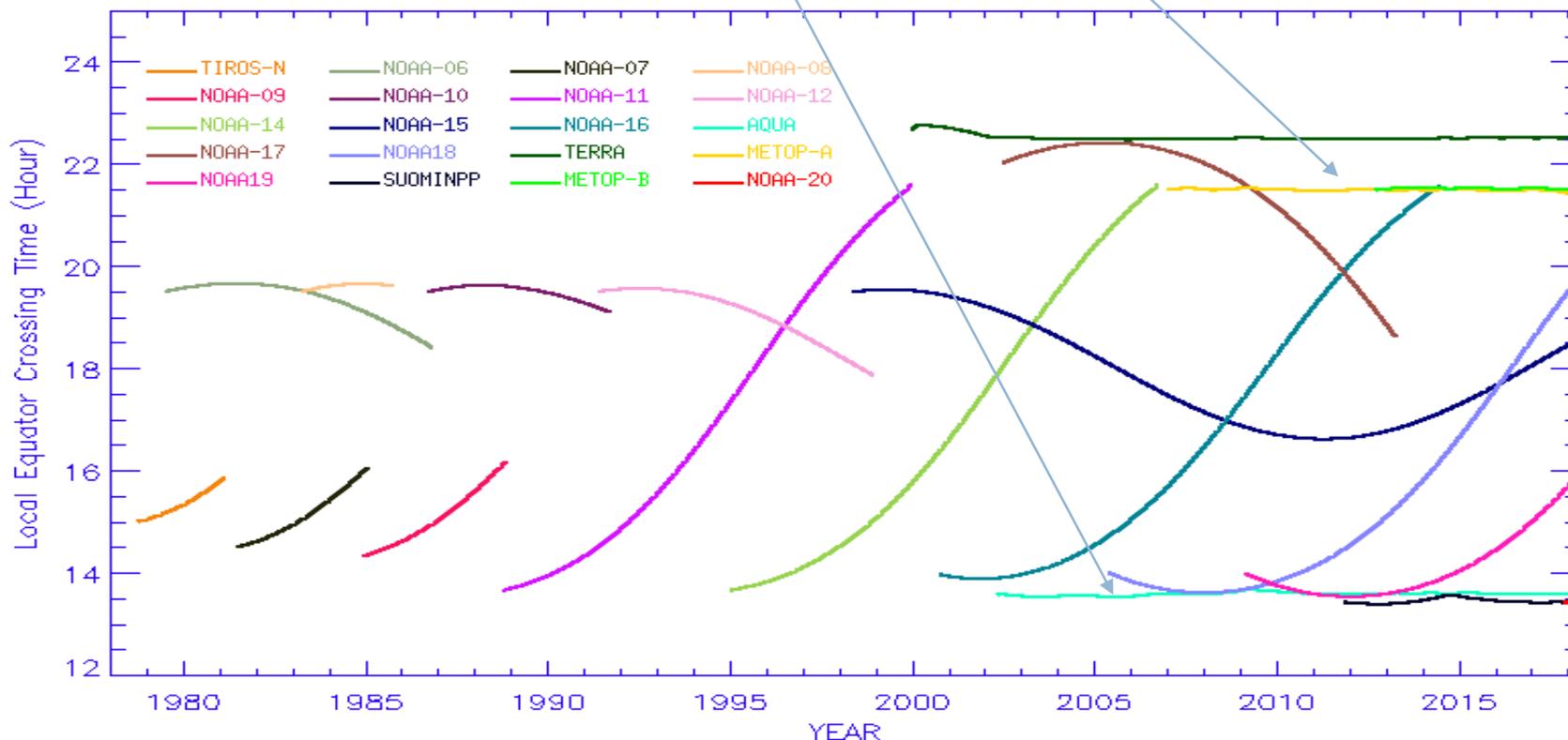
Satellite Orbital Drifts

- MetOp-A, -B, and future –C have close to the same 9:30am stable morning orbits
- Aqua, SNPP, NOAA-20, and future JPSS have close to the same 13:30pm stable afternoon orbits
- Terra has a stable 10:30am morning orbit
- All other satellite's orbits drifted with time

Satellite local equator crossing time (LECT) for ascending orbits
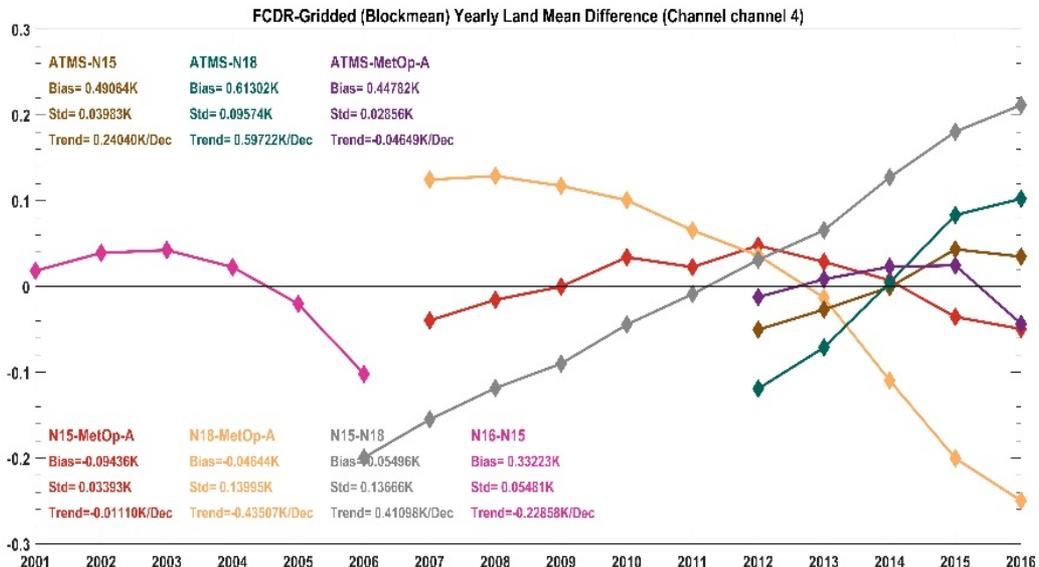(Plot is provided by STAR calibration team)

Challenges in Defining Reference Satellites —Satellite Orbital Drifts Induce Bias Drifts

- **Satellite Orbital Drifts Cause**

➢ Changes with time in diurnal Sampling

➢Biases change with time

➢Need complicated bias correction algorithms to remove these time-varying biases
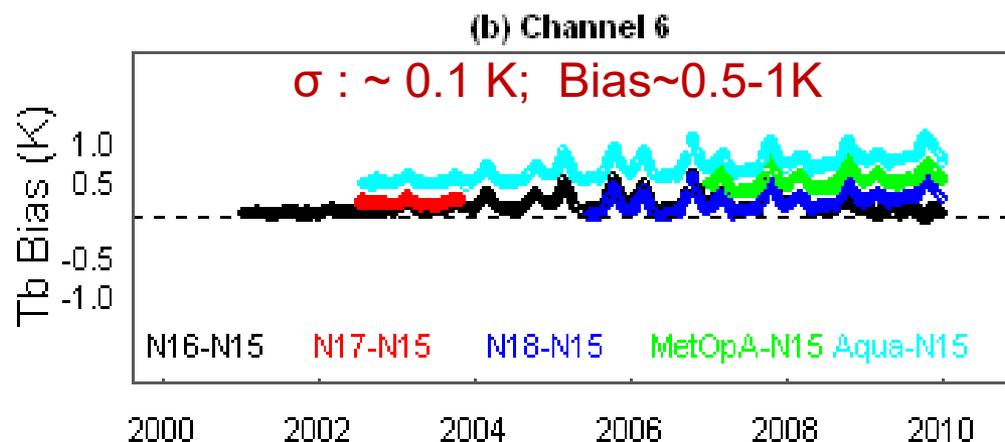

Inter-satellite difference time series for AMSU-A satellite pairs

Challenges in Defining Reference Satellites —Calibration Drift

➢ Inaccurate instrument calibration could result in time-varying biases between satellite pairs

➢ Need complicated inter-calibration/recalibration algorithms to remove these time-varying biases

(b) Channel 6

$\sigma : \sim 0.1\ K;\ Bias \sim 0.5\text{-}1K$

Tb Bias (K)

N16-N15   N17-N15   N18-N15   MetOpA-N15 Aqua-N15

2000   2002   2004   2006   2008   2010

Inter-satellite difference time series for AMSU-A satellite pairs showing calibration drifting errors (plot from Zou and Wang 2011)
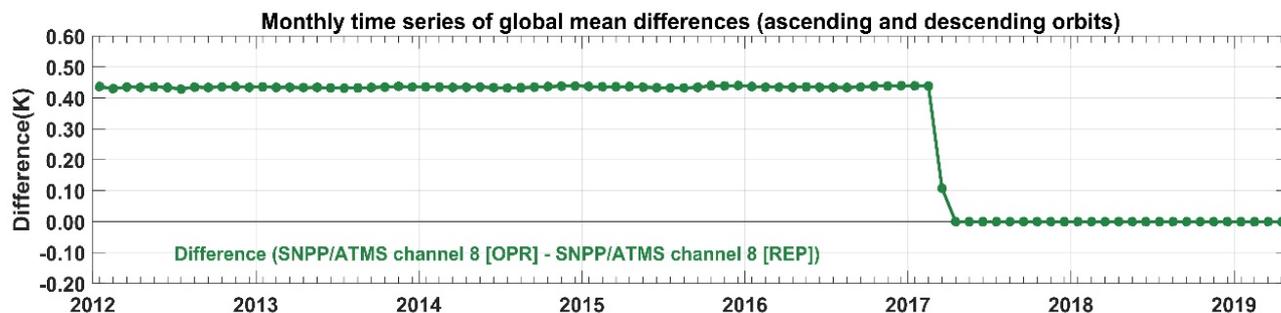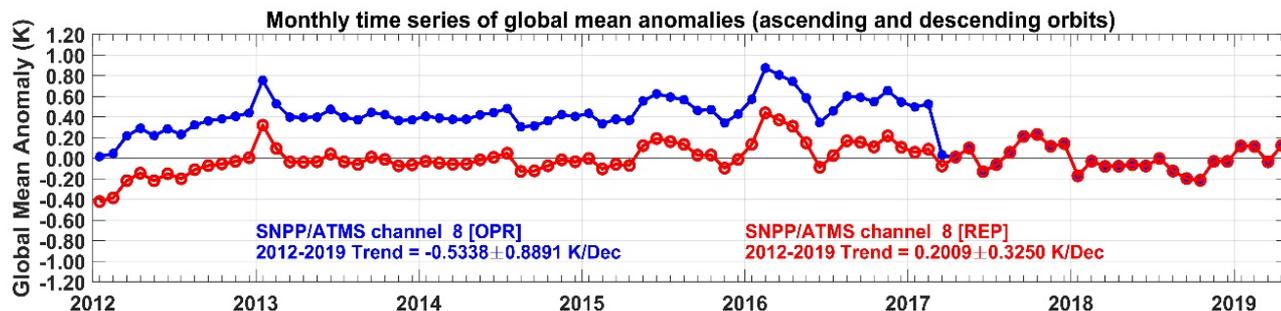
Reprocessed SNPP/ATMS SDRs

8

*Changes in operational calibration cause bias jumps

*Timing of bias jumps matches with known time when updates of calibration algorithms occurred

*Inconsistency in operational calibration can be revealed only when compared to a reference or a reprocessed dataset

Monthly time series of global mean anomalies (ascending and descending orbits)

SNPP/ATMS channel 8 [OPR]
2012-2019 Trend = -0.5338±0.8891 K/Dec

SNPP/ATMS channel 8 [REP]
2012-2019 Trend = 0.2009±0.3250 K/Dec

Monthly time series of global mean differences (ascending and descending orbits)

Difference (SNPP/ATMS channel 8 [OPR] - SNPP/ATMS channel 8 [REP])

Monthly global mean anomaly T_b time series for ATMS channel 8 from operational calibrated (blue, top) and reprocessed (red, top) sensor data records and their differences (green, bottom). The global means are calculated using limb-adjusted scan positions from 29 to 68 for both operational calibrated and reprocessed datasets. The limb-adjustment and data processing details can be found in Zou et al. (2018). The bias jump between the operational calibrated and reprocessed data found in March 2017 was caused by the calibration update for the operational calibration on 7 March 2017. After that date, the two datasets are identical since they use the same calibration algorithm.

New Analyses: Stable SNPP and JPSS Orbits Make A Difference
# (Zou et al. 2018, Science Advances)

- ➤ 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
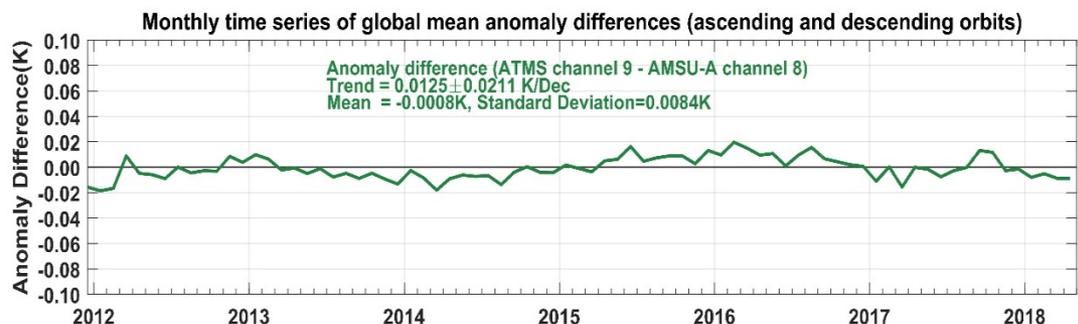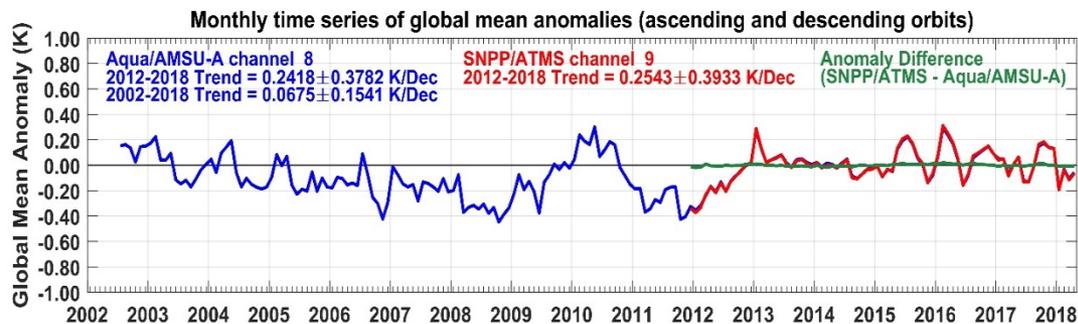
Monthly global mean anomaly time series of brightness temperatures for AMSU-A channel 8 onboard Aqua (blue, top panel) versus ATMS channel 9 onboard SNPP (red, top panel) and their difference time series (green, top and lower panels). The AMSU-A and ATMS data are respectively from June 2002 and December 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).
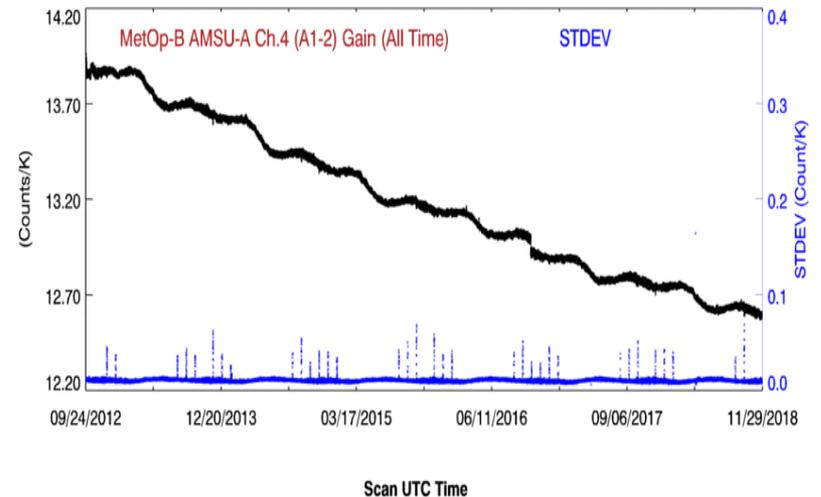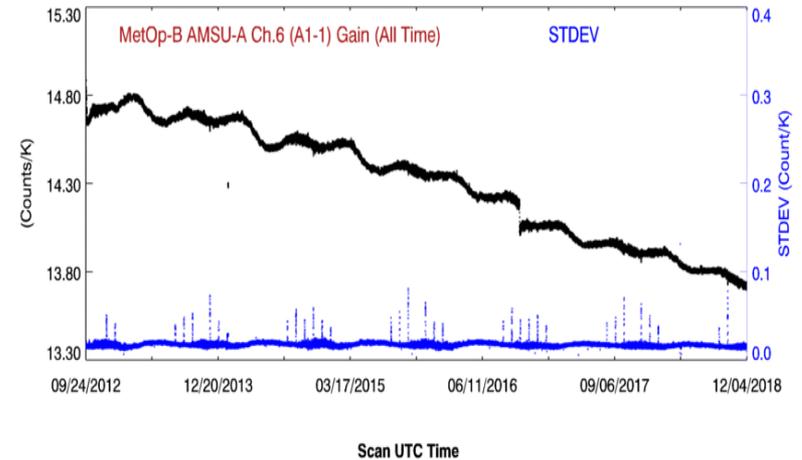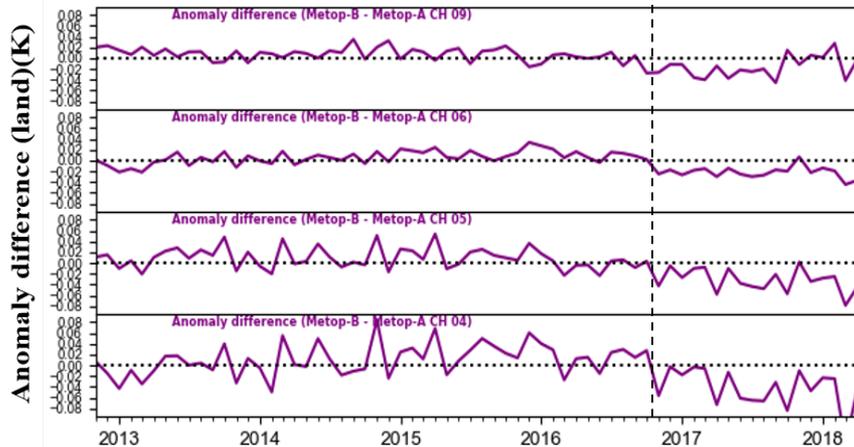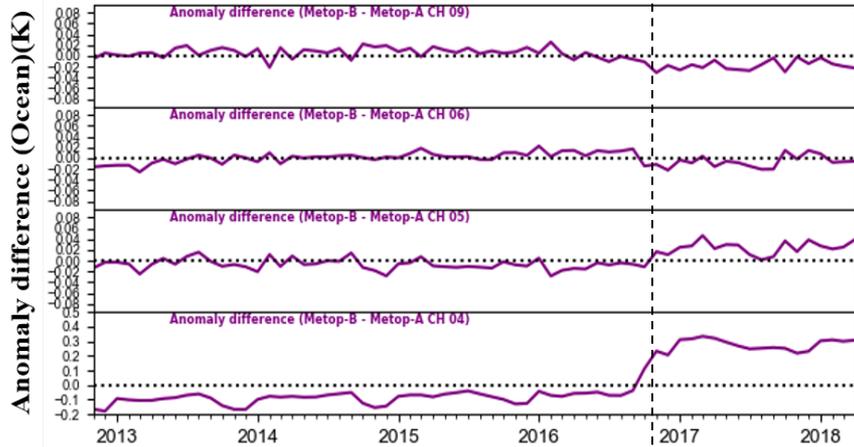
All analyzed channels
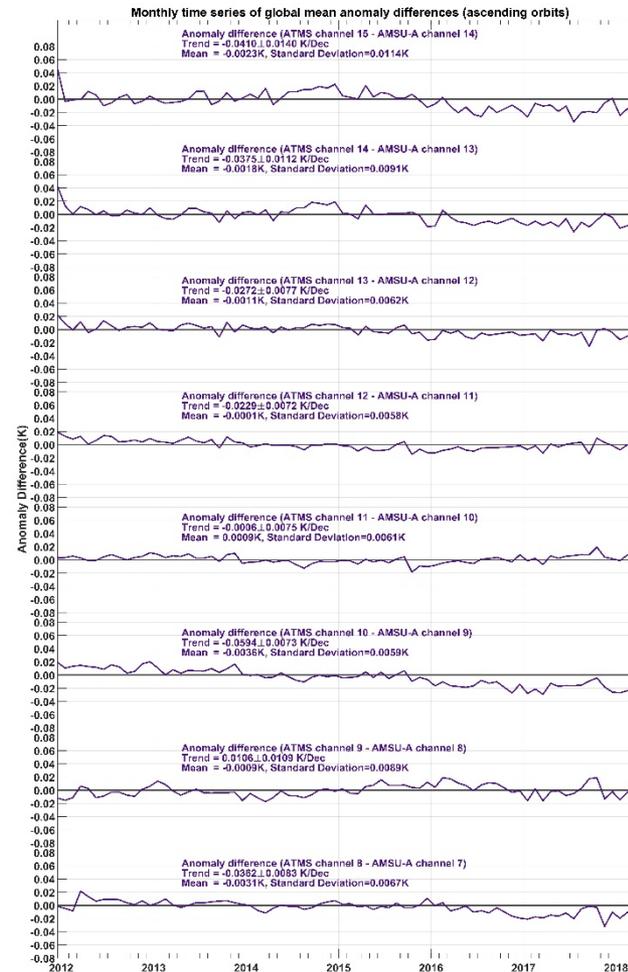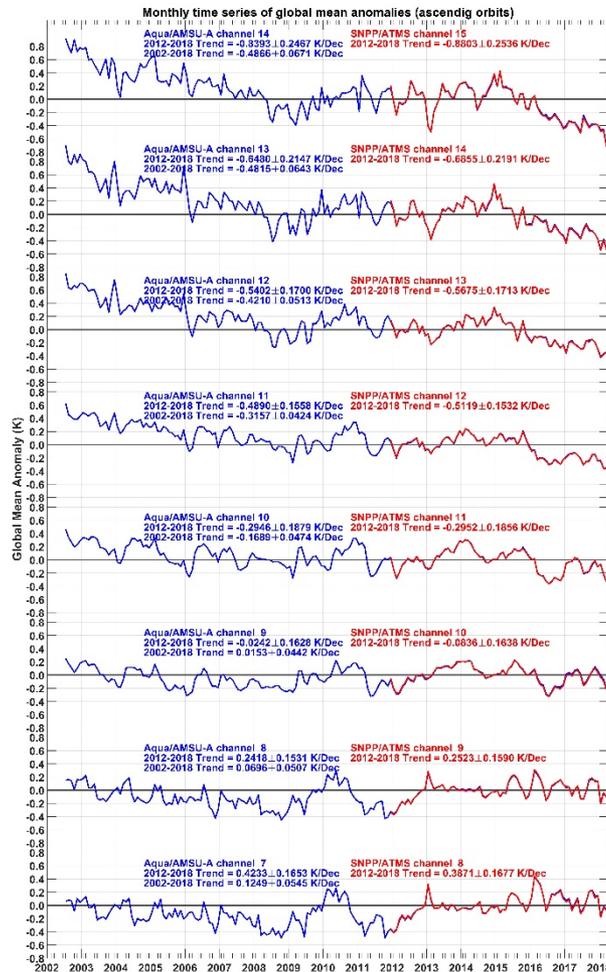
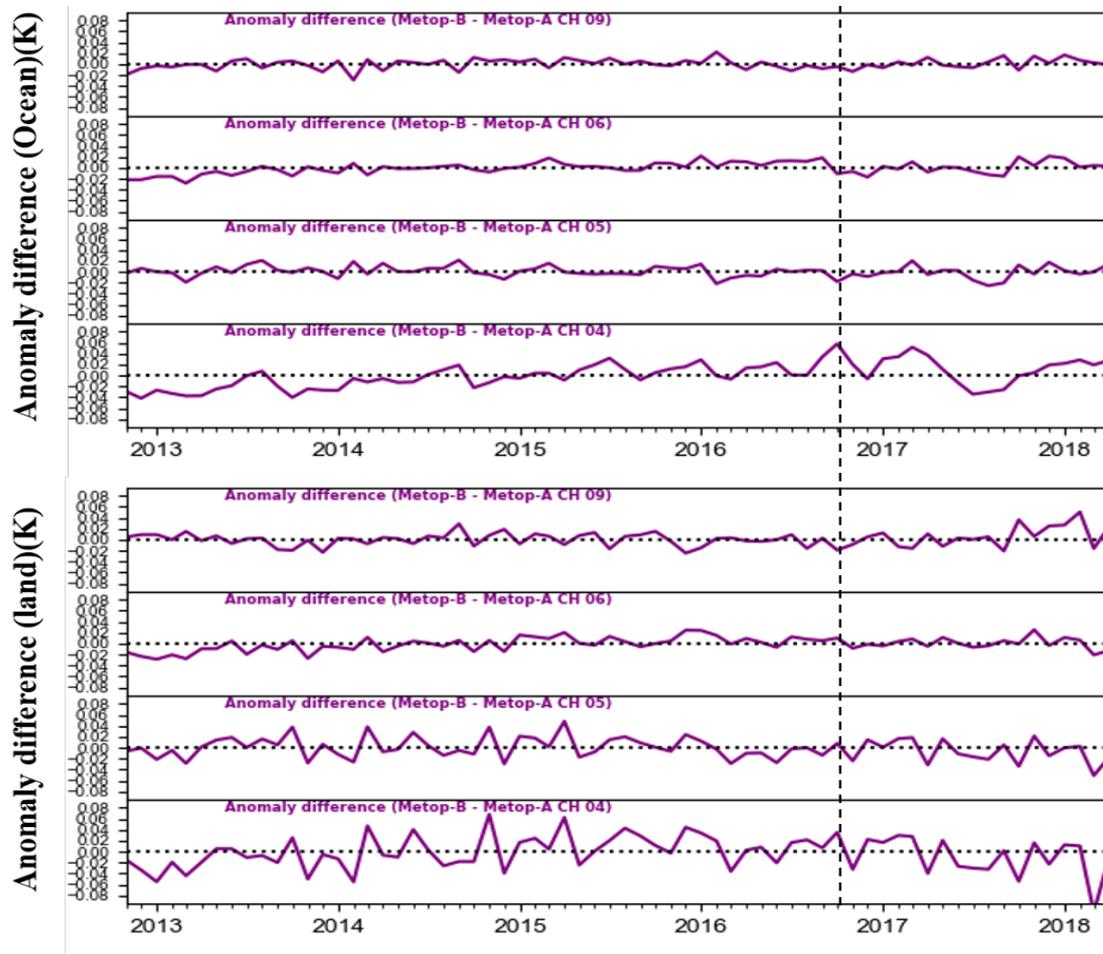Radiometric stability achieves 0.004K/Year for most channels

Analyses of Other Satellites

Jumps in MetOp-A and MetOp-B TB differences linked to gain jumps in MetOp-B

Extend Similar Analysis to Other Satellites

MetOp-A and MetOp-B TB differences After Recalibration

Perspective—Improved CDR Development

- ❑ SNPP/JPSS satellites could be merged together without conducting diurnal drift correction

- ❑ Adjusting satellites with orbital drifts to the references using their overlaps

- ❑ Developing CDRs from the stable satellites backward to the earlier satellites

- ❑ Improved accuracy in trend determination from CDRs are expected

Perspective—Determining Drifts in Measurements of Other Type of Instruments

- ❑ Radiosonde Measurements – Compare with GRUAN to understand if it drifts or not

- ❑ Compare with GPSRO data – trend in GPR RO and Aqua are in agreement within 0.04K/Dec for stratospheric channels (Khaykin et al. 2017)
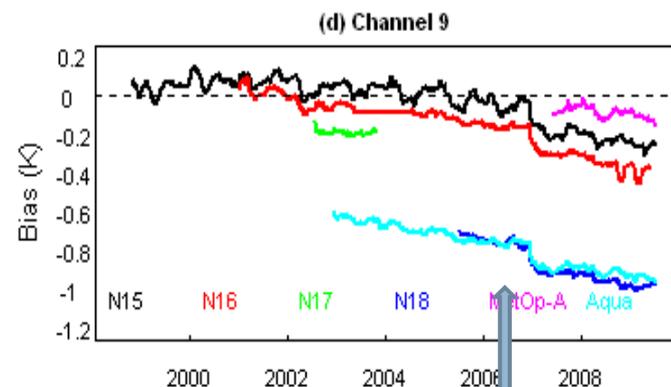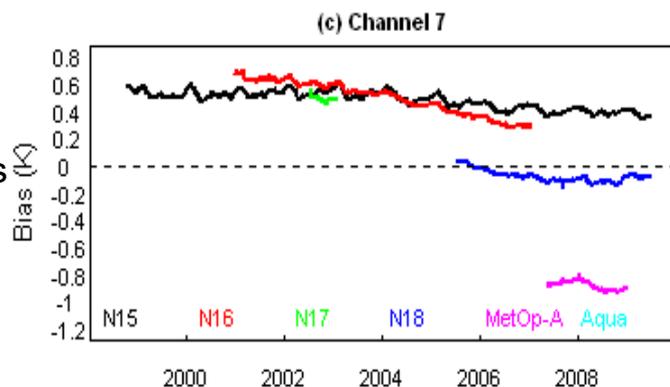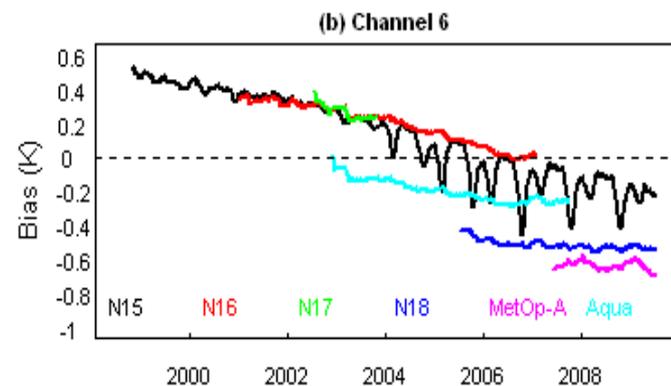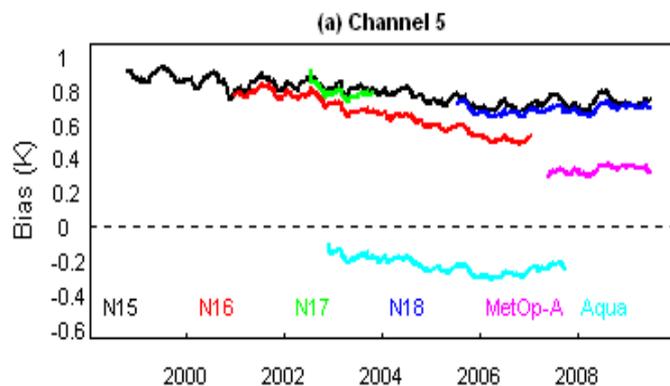
- ❑ Climate Reanalysis

Improving Bias Corrections in Climate Reanalyses?

➢ Temporal Bias correction patterns in climate reanalyses are inconsistent with Auqa stability found in our assessment

➢ How climate reanalysis bias correction can be improved with the new findings?

ERA-Interim bias corrections for different AMSU-A channels on different satellites

Note the Aqua bias drift

Summary

- Orbital and calibration drifts cause difficulty to find reference satellite

- Stable SNPP orbit and reprocessing allow measurement stability assessment for ATMS

- Radiometric stability of SNPP/ATMS and Aqua/MetOp-A/AMSU-A achieve 0.004K/Year for most analyzed channels

- SNPP/ATMS Aqua/MetOp-A/AMSU-A can be used as reference observations due to their high radiometric stability

- Improved CDRs with better accuracy are expected using these observations as references