Impact of Calibration Drift Removal on Tropospheric Warming Trends Observed from Satellite Microwave Sounders

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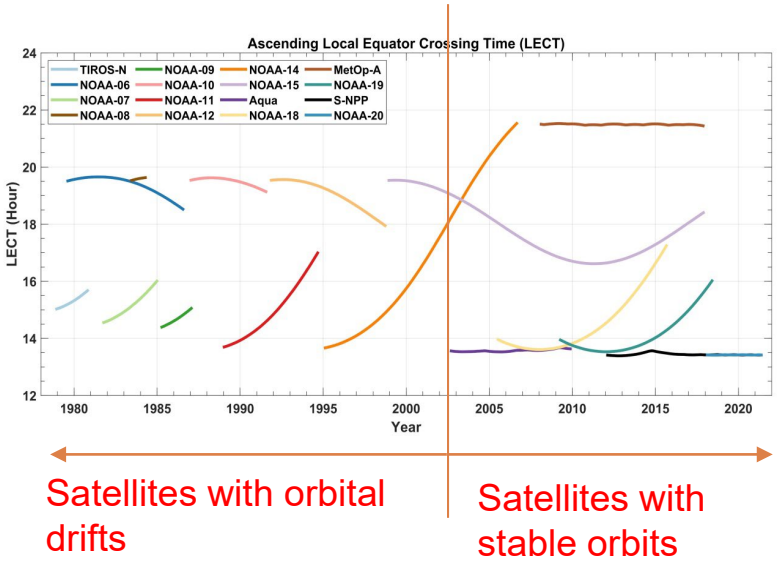
NOAA/STAR Mean Layer Temperature CDR from Satellite Microwave Sounder Observations

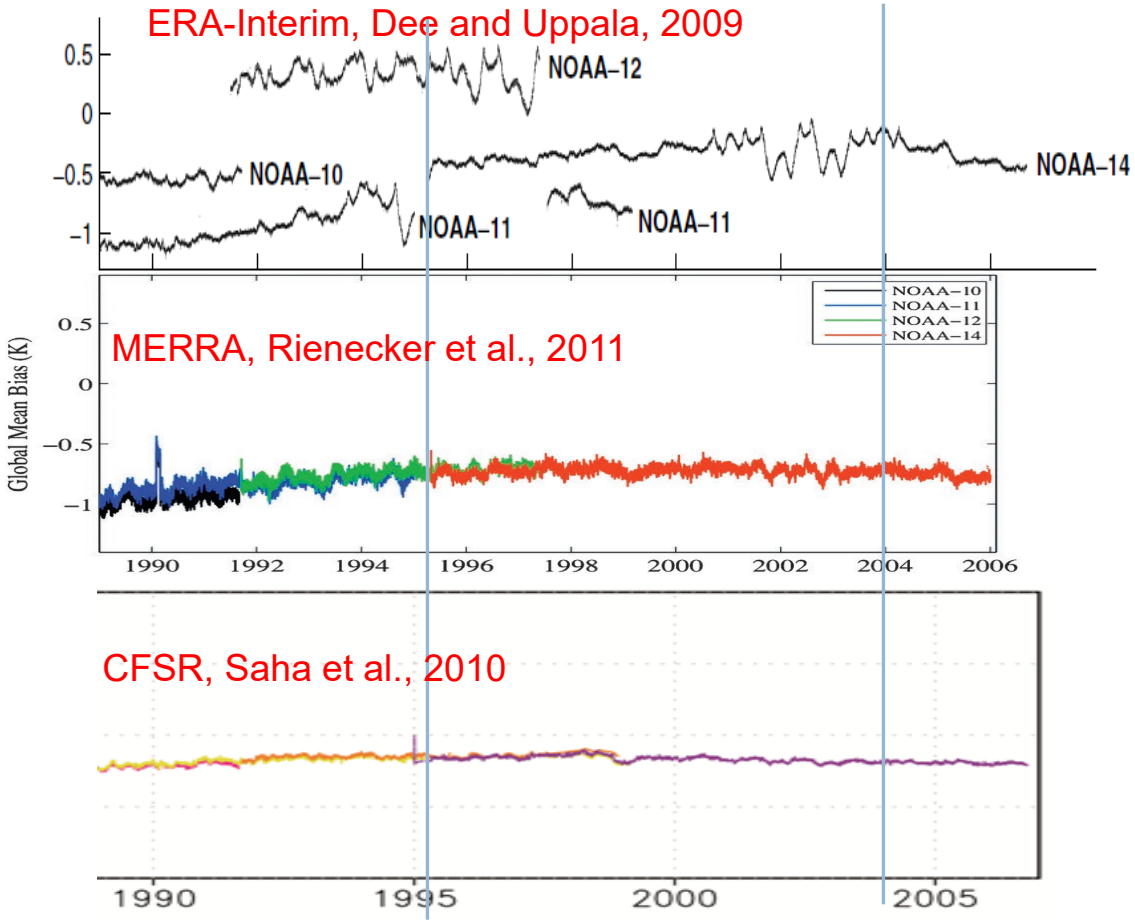
- NOAA/STAR has recently completed Version 5 (V5) of its mean layer temperature CDR
- STAR V5 CDR includes four mean layers of temperature: lower-troposphere (TLT), mid-troposphere (TMT), upper troposphere (TUT), and lower-stratosphere (TLS), which measure layer temperatures roughly peaking at 3 km, 5 km, 10 km, and 17 km, respectively, above the Earth's surface
- The CDR involves satellite microwave sounders on NOAA POSE series (MSU/AMSU-A), NASA EOS Aqua (AMSU-A), European MetOp (AMSU-A) series, and NOAA JPSS series (ATMS) from 1978 to present
- It removed biases due to diurnal drift, calibration drift, channel frequency differences, incident angle differences, and warm target temperature effects
- Climate trends in TLT and TMT largely differ from previous versions of STAR datasets and RSS dataset, mainly caused by calibration drift removal
- This talk discusses calibration drifts and their removals in CDRs

Ascending Local Equator Crossing Time (LECT) of POES, MetOp-A, Aqua, and JPSS satellites



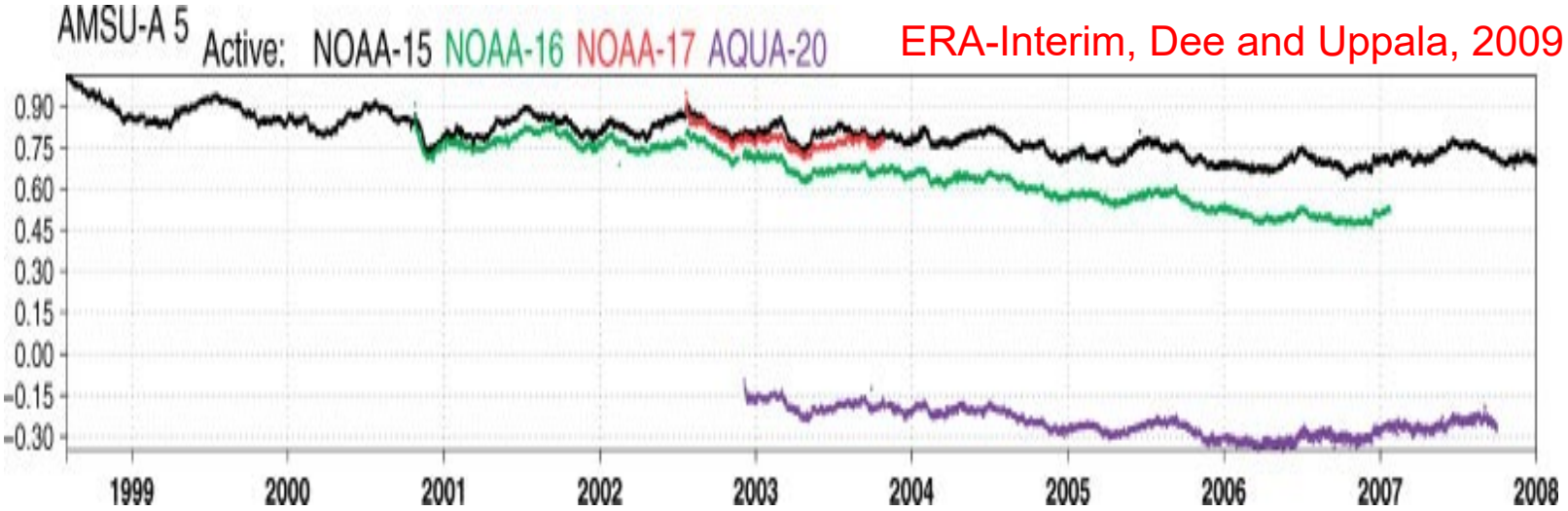
Bias Drift in MSU Ch2 Onboard NOAA-10 to NOAA-14 in Climate Reanalyses

- NOAA-10 (1987-1992):
  - Flat in ERA-I
  - Warming drift in MERRA and CFSR
- NOAA-11 (1989-1995):
  - Warming drift in all ERA-I, MERRA, and CFSR
- NOAA-12 (1992-1999):
  - Flat in ERA-I
  - Warming drift in MERRA and CFSR
- NOAA-14 (1995-2004):
  - Warming drift in ERA-I
  - Flat in MERRA
  - Cooling drift in CFSR



Global mean bias correction time series in climate reanalyses

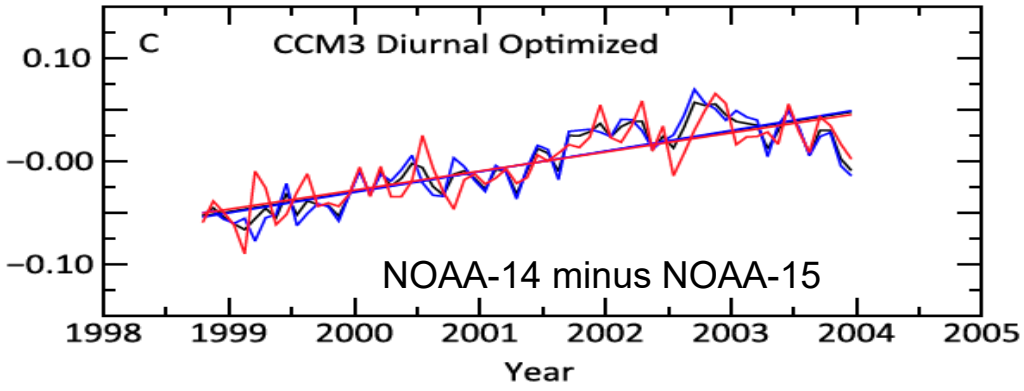
Bias Drift in NOAA-15 AMSU-A Ch5 in ERA-Interim



- NOAA-15:
  - ➢ Cooling drift in ERA-I

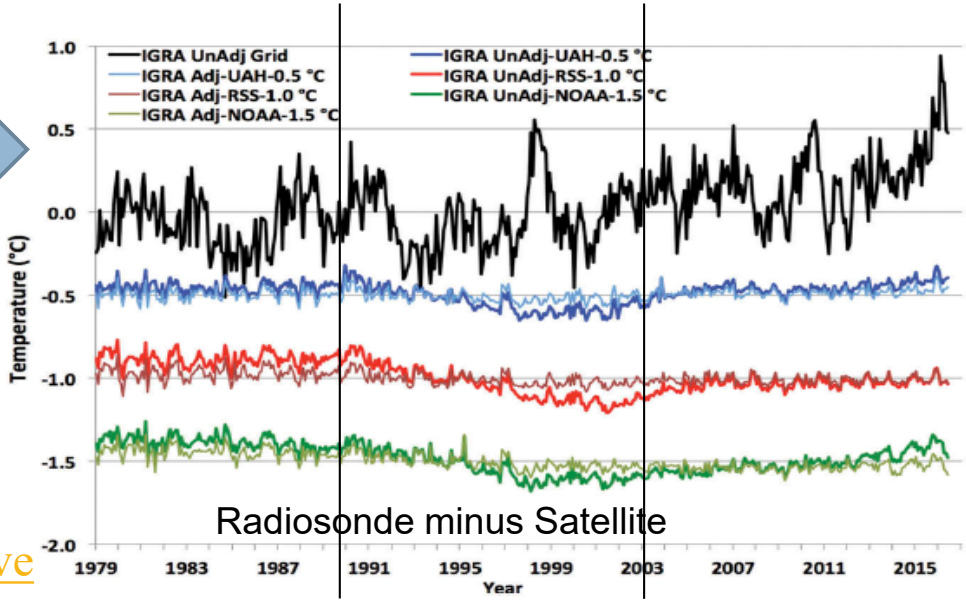
Bias Drift in NOAA-11 to NOAA-15 Continued

Drifts between NOAA-14 MSU Ch2 and NOAA-15 AMSU-A Ch5 (Mears et al. 2016)



Black: IGRA radiosonde anomaly time series (unadjusted, near-global)

Thick Blue: Unadjusted IGRA- UAH
Thick Red: Unadjusted IGRA - RSS
Thick Green: Unadjusted IGRA – STAR (Christy et al. 2017).



IGRA: Integrated Global Radiosonde Archive

How Bias Drifts Were Handled in Previous Datasets?

- UAH (University of Alabama at Huntsville) Version 6 (Spencer and Christy, 2017)

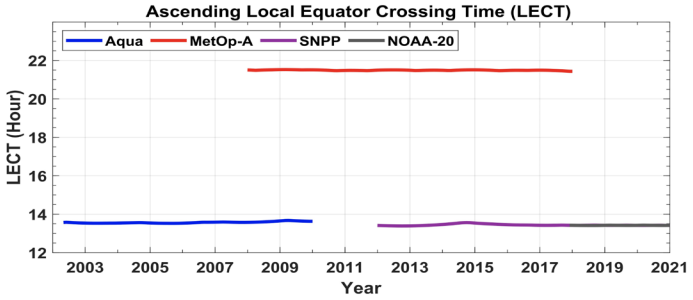
→ "we apply a trend adjustment of NOAA-11 relative to NOAA-10 and NOAA-12, and another trend adjustment of NOAA-14 relative to NOAA-12 and NOAA-15. These force an average match between the middle satellite's trends to the bounding satellites' trends during their mutual overlap periods." (Quote from Spencer and Christy 2017)

→ No adjustment for NOAA-10, NOAA-12, and NOAA-15

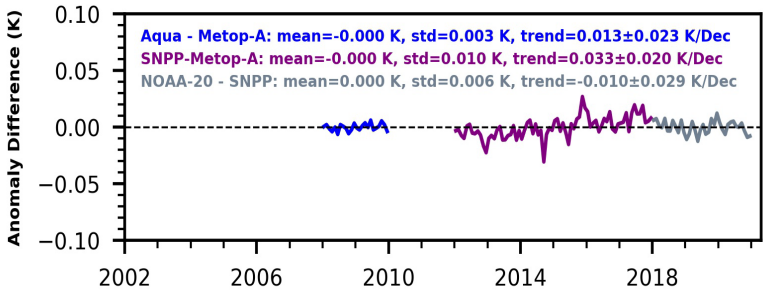
- RSS Version 4.0 (Mears and Wentz, 2016): NO adjustment
- NOAA/STAR Version 4.1 (Zou and Wang 2011): NO adjustment

Satellites in Stable Orbits Used as Reference Time Series

Satellite microwave sounders in stable orbits (Aqua, MetOp-A, SNPP, NOAA-20)

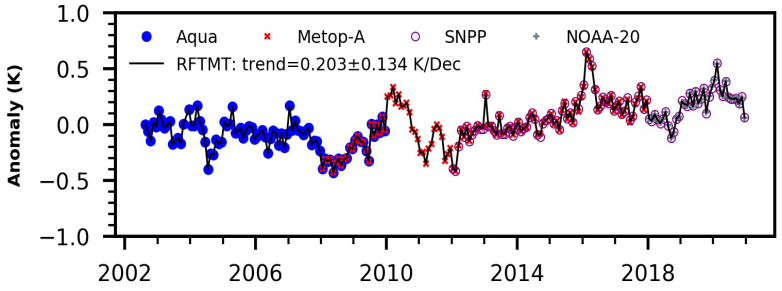


Inter-satellite difference trends are small (less than 0.004 K/year), suggesting high radiometric stability



AMSU-A Ch5
ATMS Ch6

Averaged anomaly time series has an accuracy of 0.01K/decade in trend detection, better than the required 0.02K/decade given in GCOS (2016) document



- When two independent satellite observations agree with each other in time series, both are believed correct
- When two satellite observations disagree with each other in time series, both or either one could be wrong

Recalibration to Remove Bias Drifts

- Use simultaneous nadir overpasses (SNOs) to solve for level-1 calibration coefficients (Zou et al. 2023)

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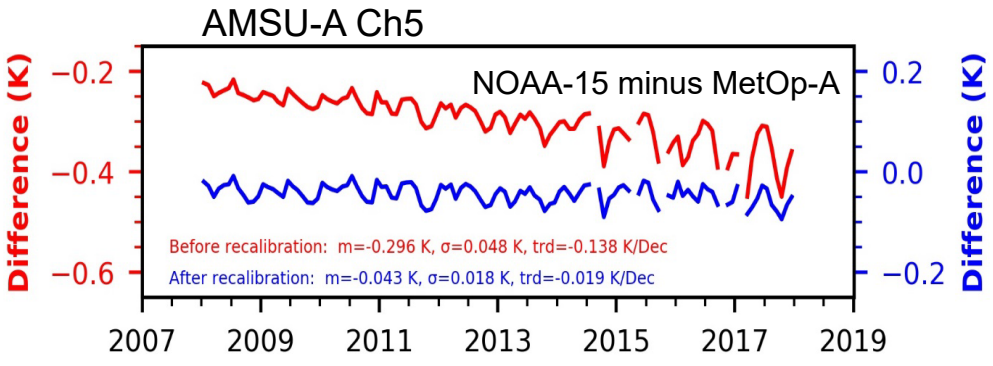
- Calibration coefficients were allowed to change with time due to instrument degradation

- Possible instrument degradation may include

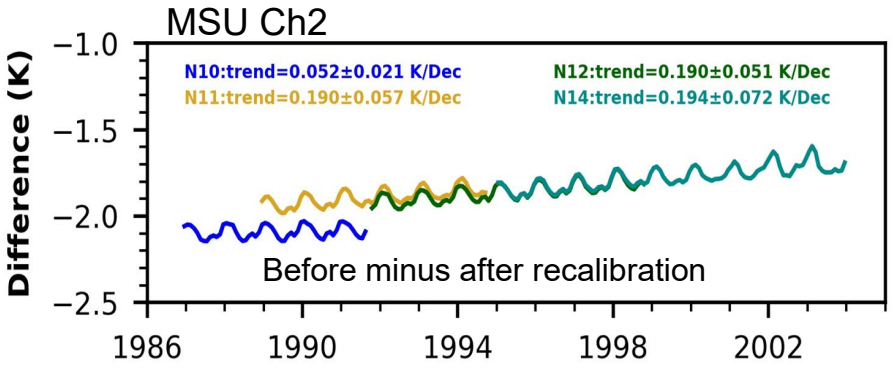
➢ Calibration nonlinearity changes caused by detector or amplifier degradation

➢ Time-varying side-lobe effect caused by degradation in reflector mirror or antenna surface materials

➢ Degradation in blackbody emissivity



Cooling drift in AMSU-A Ch2 was removed by recalibration

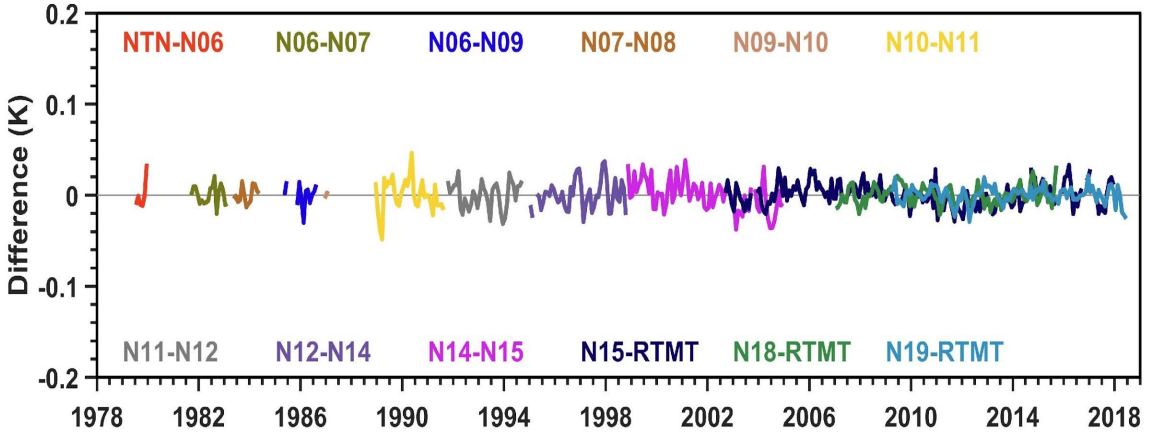


Warming drifts in MSU Ch2 before recalibration in NOAA-11 to NOAA-14 were removed by recalibration

Consistent Satellite Time Series

- All adjustments, including diurnal drift, calibration drift, channel frequency differences, incident angle differences, and warm target temperature effects, have contributed to the consistency of multiple satellite time series

Global mean inter-satellite difference time series after all adjustments

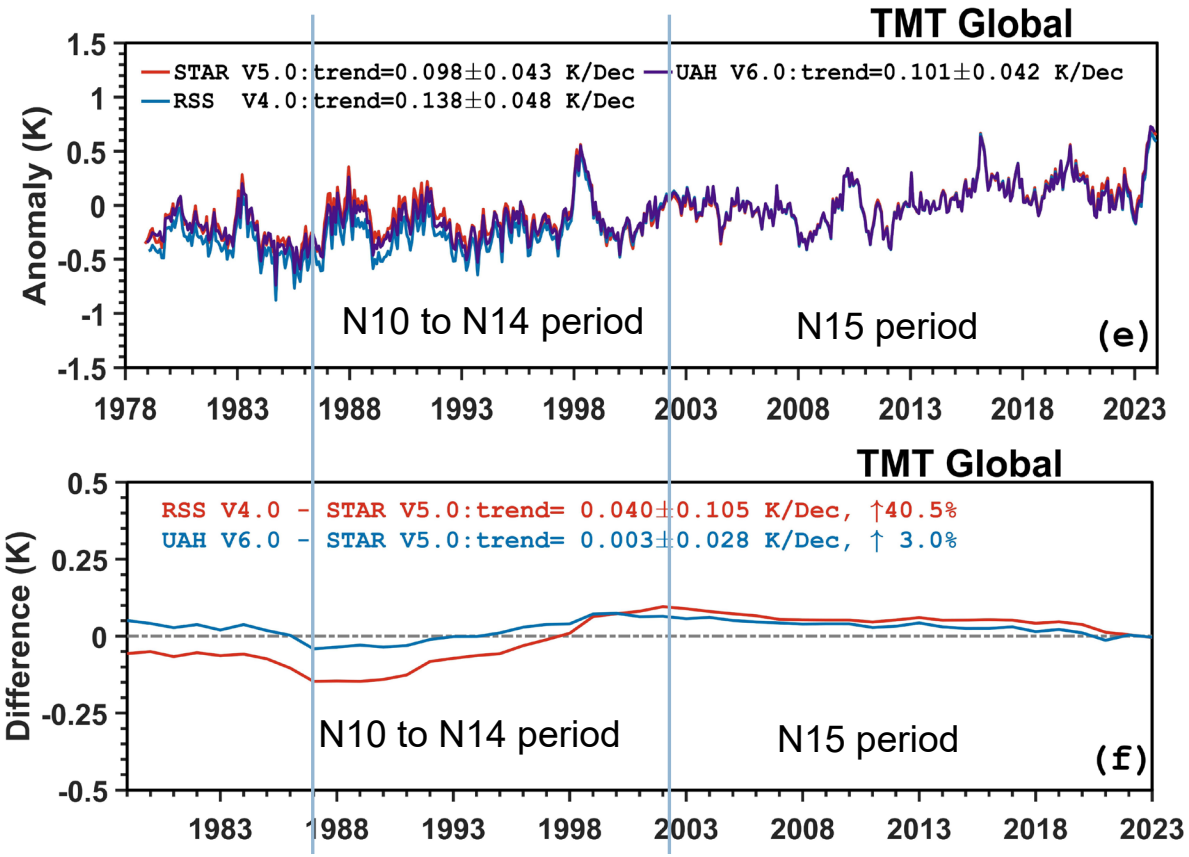


Impact of Calibration Drift Removal: TMT

- Removal of spurious cooling drift in NOAA-15 caused trends in STAR V5 TMT warmer than the RSS and UAH time series during 2002-present

- Removal of spurious warming drift in NOAA-10 to NOAA-14 caused STAR V5 TMT warming trends much smaller than RSS during 1987-2002

- Warming trend in STAR V5 during the entire data period was also much reduced by cascading removal of the warming drift in NOAA-11 to NOAA-14 compared to RSS V4

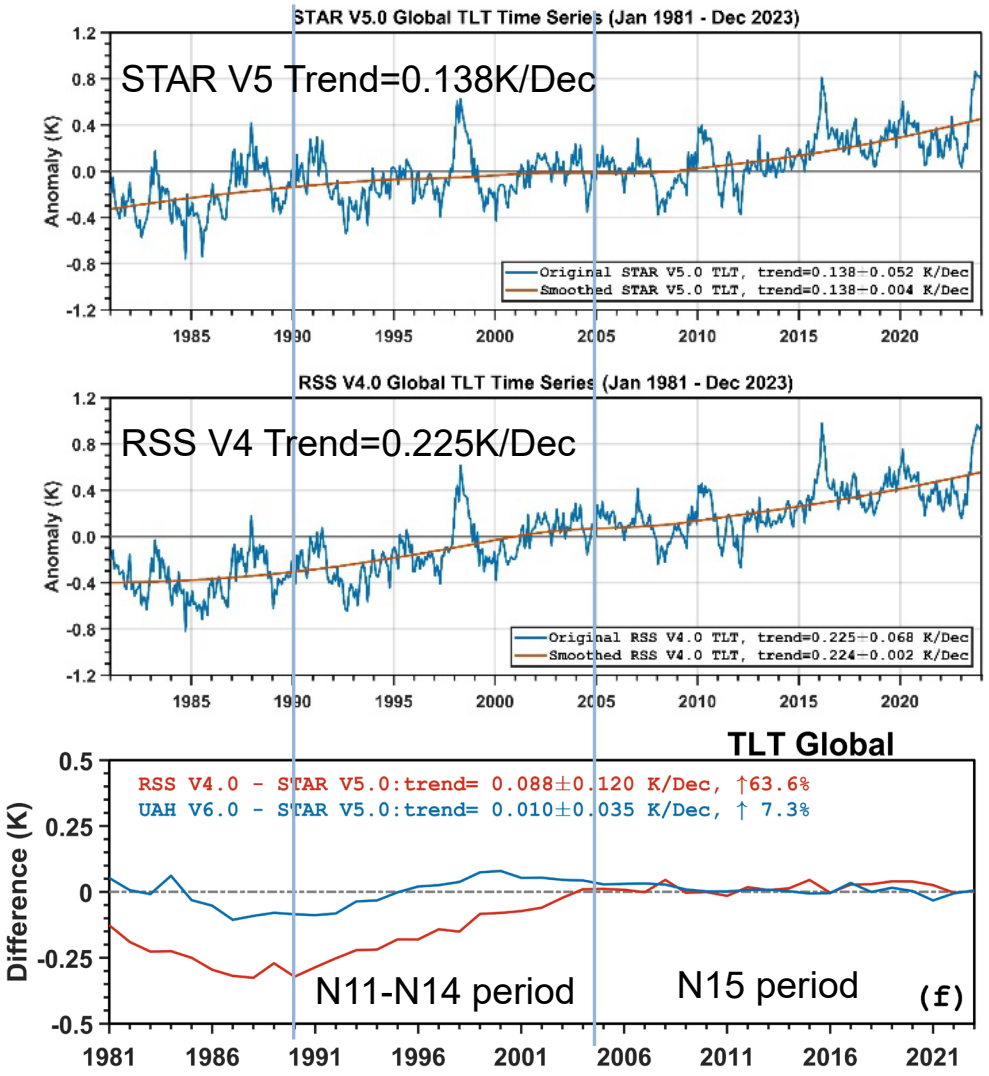


Upper panel: TMT global monthly anomaly time series for STAR V5, RSS V4, and UAH V6
Lower panel: Annual mean differences for RSS minus STAR (red) and UAH minus STAR (Blue)

Impact of Calibration Drift Removal: TLT

- Removal of spurious warming drift in NOAA-11, NOAA-12, and NOAA-14 caused STAR V5 TLT warming trends much smaller than RSS V4 during 1989-2004

- Warming trend during the entire data period was also much reduced by cascading removal of the warming drift in NOAA-11 to NOAA-14 compared to RSS V4



Blue curve: Global TLT time series for STAR (upper panel) and RSS (lower panel)

Orange curve: smoothed TLT time series using the locally weighted regression method (LOESS)

Annual mean difference time series
Red: RSS V4 minus STAR V5
Blue: UAH V6 minus STAR V5

Global Warming Projection

- In the context of sustainable development, IPCC has suggested to limit the global warming below the benchmark of 1.5 ^{0}C or 2.0 ^{0}C above the pre-industrial level (1850-1900 average)

- It is widely accepted that the current temperature is about 1.2 ^{0}C above the pre-industrial level, which leaves 0.3 ^{0}C for the global temperature to reach the 1.5 ^{0}C benchmark

- It will take 22 years to reach the 1.5 ^{0}C benchmark if the STAR 0.14 ^{0}C/decade TLT trend is used for global warming projection

- If 0.05 ^{0}C/Decade^2 acceleration rate is considered, it will take 16 years for the global temperature to reach the 1.5 ^{0}C benchmark

- It will take 13 years to reach the 1.5 ^{0}C benchmark if the RSS 0.22 ^{0}C/decade TLT trend is used for global warming projection

- Given the temperature variability, when the mean trend line reaches 1.5 ^{0}C benchmark, the instant annual mean temperature could be above 2.0 ^{0}C (the 2023 global temperature has already been above the 1.5 ^{0}C benchmark)

Conclusions

- Removal of spurious cooling drift in NOAA-15 AMSU-A channel 5 resulted in the warming trend in STAR V5 TMT larger than the RSS and UAH data versions after 2002

- Removal of spurious warming trends in NOAA-11 to NOAA-14 resulted in much smaller warming trend in STAR V5 TMT and TLT than the RSS dataset during 1990-2002

- The smaller warming trends during the NOAA-11 to NOAA-14 period (1990-2002) in STAR V5 TMT and TLT caused large trend differences between the earlier half and the latest half periods of the entire observation period from 1979 to present. This resulted statistically significant accelerated warming trends in STAR V5 TMT and TLT

- Calibration drift removal resulted in overall smaller warming trends in STAR V5 TMT and TLT than the RSS dataset during the entire observation period from 1979 to present

- The STAR V5 TMT and TLT trends during the entire observation period from 1979 to present are close to the UAH data version partly because the later has adjusted trends in NOAA-11 and NOAA-14. But differences still exist in different subperiods between the two data versions

References

Zou, C.-Z., M. Goldberg, and X. Hao (2018), New generation of U.S. satellite microwave sounder achieves high radiometric stability performance for reliable climate change detection, Science Advances, 4(10), eaau0049, doi: 10.1126/sciadv.aau0049.

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URL address for data products:
https://www.star.nesdis.noaa.gov/smcd/emb/mscat/products.php