Bias correction of AMSU-A channels in ERA-Interim and its comparison to STAR recalibrated time series

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Purposes

- To understand how and why ERA-Interim reanalysis trends differ from merged satellite trends
- To understand how recalibration/inter-calibration can help improving reanalysis trend in the future

Satellite Observations in the Analysis

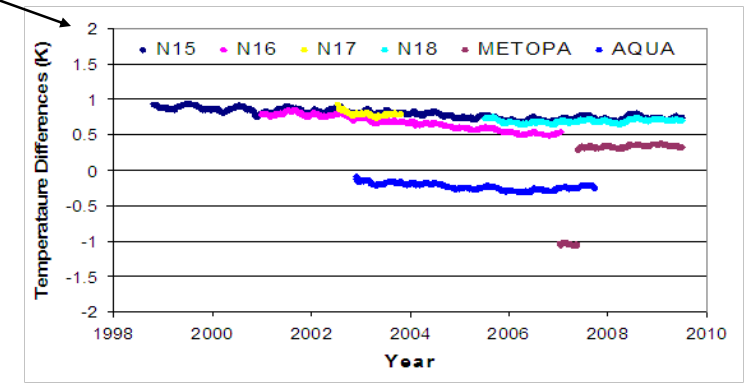
- Focus on AMSU-A channels 5, 6, 7, and 9
- Operational calibrated AMSU-A were assimilated in ERA-Interim
- Satellite periods:

Satellite Name	Start date	End date
NOAA-15	19980802	20090630
NOAA-16	20001026	20090603
NOAA-17	20020722	20031027
EOS-Aqua	20021205	20090630
NOAA-18	20050712	20090630

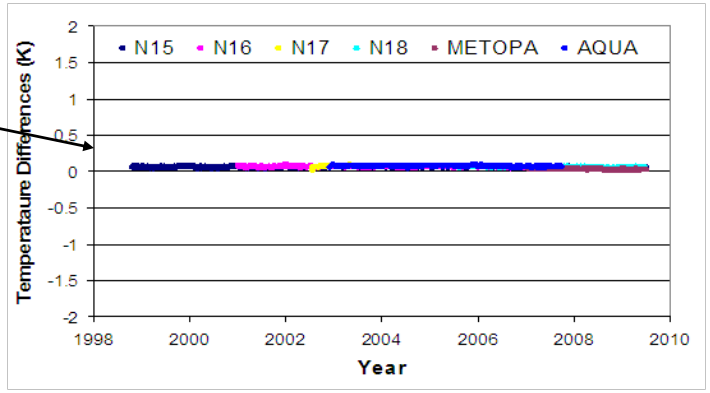
ERA-Interim Bias Correction Datasets

- ERA-Interim bias estimates: b
- NOAA operational calibrated AMSU-A level-1c data: y
- Departure between observations (y) and background after application of the bias correction: dy
- Background h(x): Reanalysis forecast field
- Balance equation: dy=y-h(x)-b
- dy can be ignored: b≅y-h(x)
- For global means, h(x) is identical to reanalysis, therefore, drift in b reflects trend differences between observation and reanalysis

ERA-Interim b time series for AMSU-A CH5, Ocean Mean



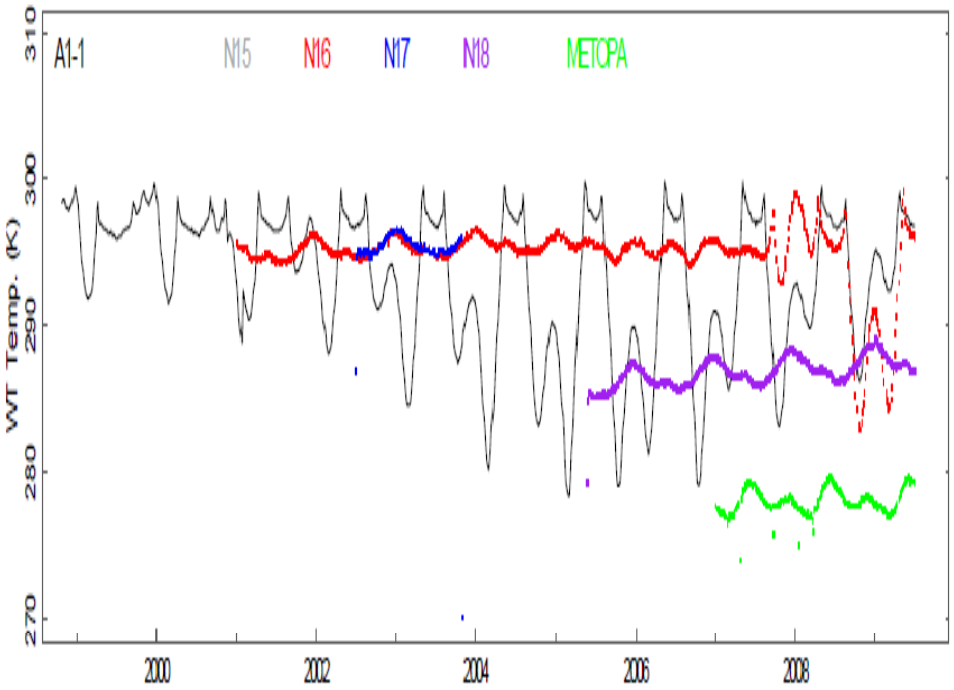
ERA-Interim dy time series for AMSU-A CH5, Ocean Mean



AMSU-A Warm Target Temperature Time Series

- NOAA-15 warm target temperature incurred sun heating related large variability up to 20 K throughout its life cycle
- NOAA-16 warm target temperature is relatively stable in the first 7 years; but incurred large variability when satellite drifted to certain position
- The warm target temperature of all other satellites are relatively stable

  and have smaller variability

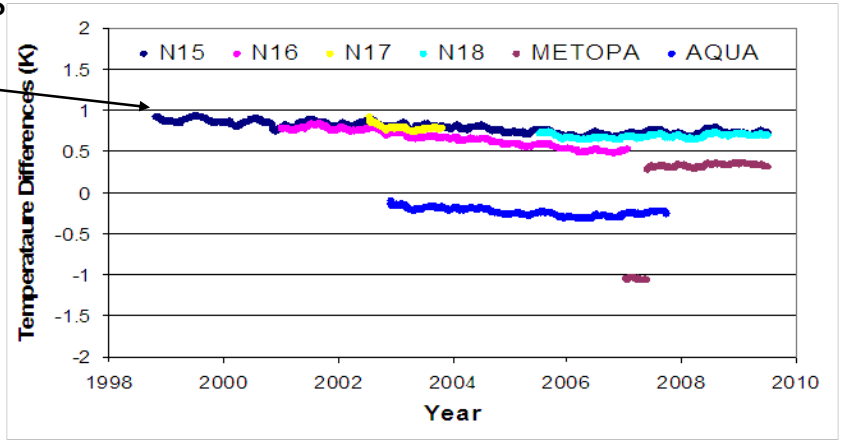


AMSU-A warm target temperature time series for different satellites

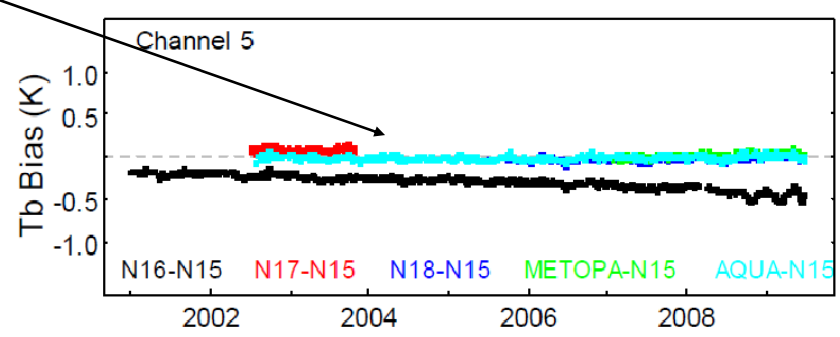
ERA-Interim Bias Estimates versus STAR Inter-Satellite Differences: CH5

- NOAA-15 bias estimate in ERA-Interim has a drift about 0.2 K/Dec
- NOAA-16 has a bias drift about 0.2 K/Dec relative to NOAA-15
- NOAA-17, NOAA-18 have bias estimates about the same as NOAA-15
- NOAA-15, 17, 18, METOP-A, AQUA agree with each other very well in inter-satellite difference time series
- METOP-A and AQUA have biases relative to NOAA-15 in ERA-I, but not in STAR analysis
- Antenna pattern correction problem

ERA-Interim Bias Estimates for CH5, Ocean Mean



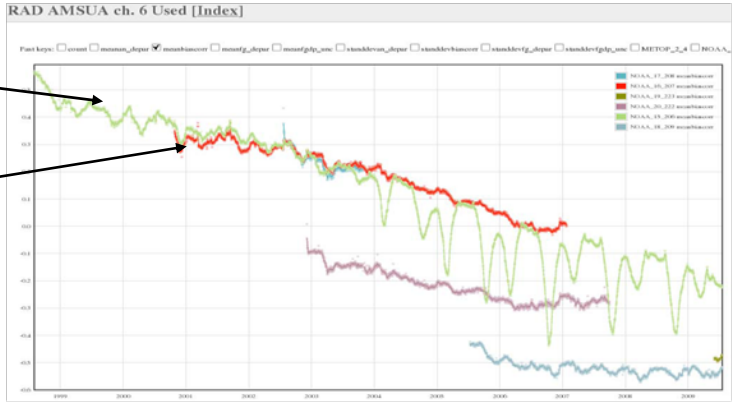
NOAA operational calibrated inter-satellite difference time series from analysis at STAR, Ocean Mean



ERA-Interim Bias Estimates versus STAR Inter-Satellite Differences: CH6

- NOAA-15 bias estimate has a drift about 0.8 K/Dec with warm target temperature variability
- NOAA-16 drifted similarly as NOAA-15, but no warm target temperature variability
- METOP-A, AQUA drifted away from NOAA-15
- All satellite pairs involving NOAA-15 show warm target temperature variability, suggesting strong calibration nonlinearity in NOAA-15 CH6
- A very different case from CH5
- ERA-Interim captured the warm target temperature variability

ERA-Interim Bias Estimates



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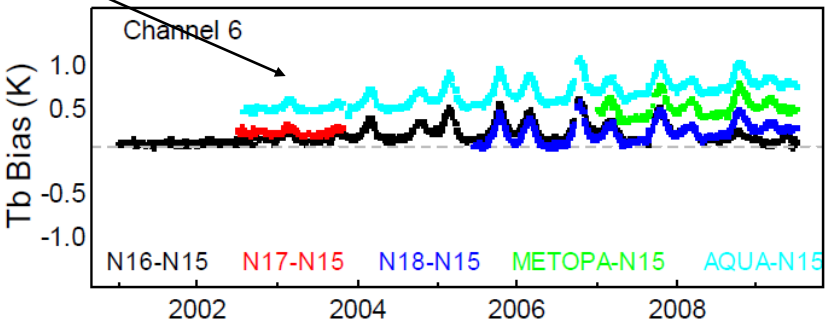
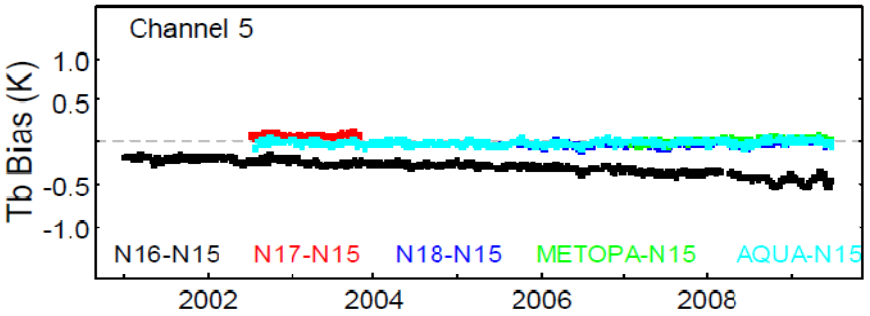


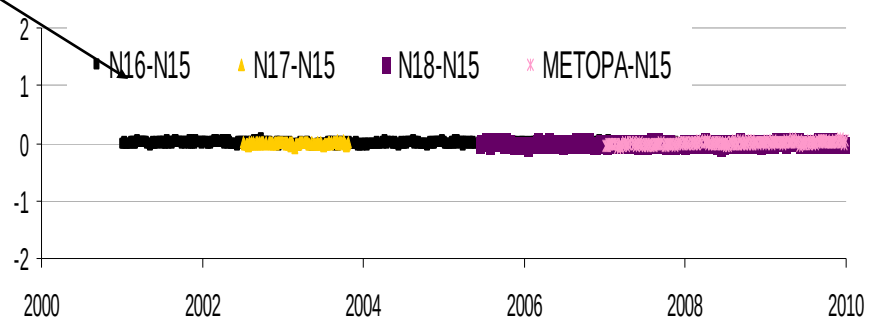
STAR Inter-Satellite Calibration: CH5

- NOAA-16 is believed to have a problem and thus recalibrated; bias drift is removed by introducing time-dependent calibration coefficients at Level-1c
- After SNO recalibration, inter-satellite differences close to zero
- Since all other satellites are close to each other before recalibration, recalibrated time series is expected to be close to NOAA-15 pre-launch calibrated data

NOAA operational calibrated inter-satellite difference time series from analysis at STAR, Ocean Mean:
No Inter-satellite calibration



Ocean mean inter-satellite difference time series after STAR SNO Inter-satellite calibration, CH5



Trend comparisons between ERA-Interim Reanalysis and STAR MSU/AMSU Analysis:CH5

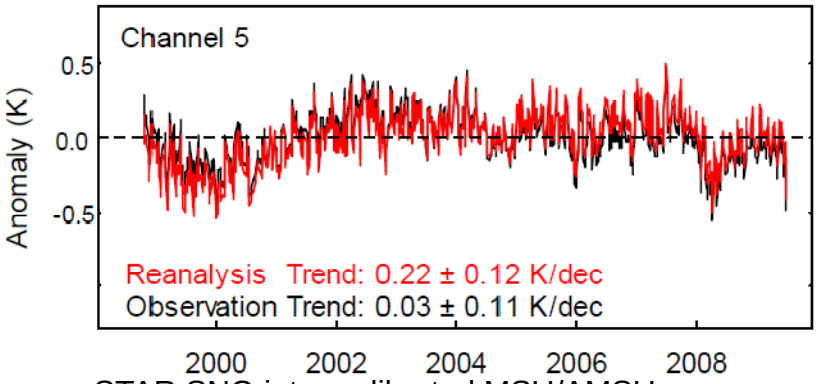
- Reanalysis and NOAA operational calibrated data have large trend differences due to drift in bias estimates in NOAA-15
- As expected, STAR SNO recalibrated trend is close to NOAA-15 trend of NOAA operational calibrated data, which is used in ERA-interim

$$R = R_L - \delta R + \mu Z \quad \Rightarrow \quad \frac{\partial T}{\partial t} = \frac{\partial T_L}{\partial t} + \mu \frac{\partial Z}{\partial t}$$

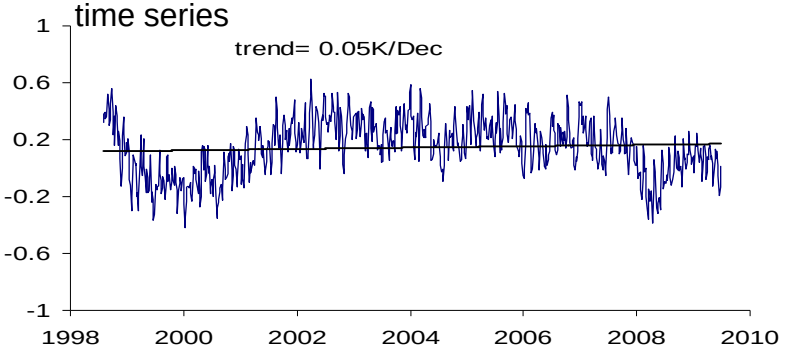
- Since R_L and Z depend only on raw counts observation (with fixed warm target calibration algorithm), the trends depend only on the value of μ
- For NOAA-15 CH5, the μ value for operational calibration and SNO calibration is similarly small $\cong$ 0.1-0.3. Therefore, the trend of NOAA-15 ch5 is close to SNO merged trend

NOAA-15 CH5 ocean mean time series and trend (black) as used in ERA-I and the ERA-I reanalysis mapped in the NOAA-15 observation samples (red);

h(x)=y-b



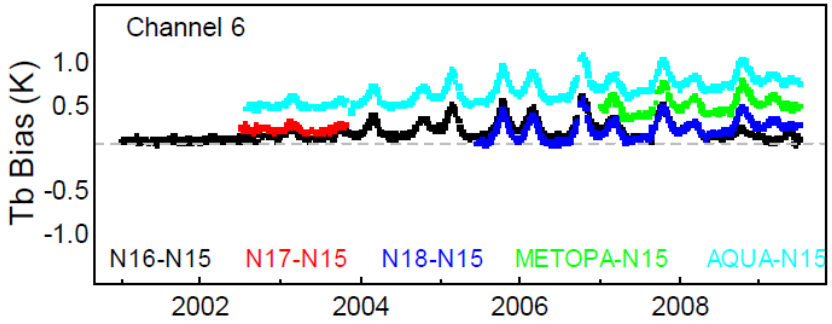
STAR SNO inter-calibrated MSU/AMSU ocean mean time series



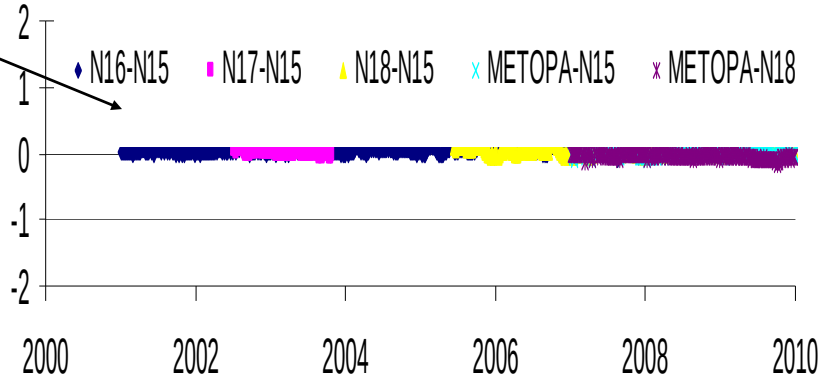
STAR Inter-Satellite Calibration: CH6

- NOAA-15 CH6 has strong calibration nonlinearity
- Time-dependent calibration coefficients for NOAA-15 are introduced at Level-1c
- After SNO recalibration, inter-satellite differences close to zero
- Recalibrated trend is expected to be different from NOAA-15

NOAA operational calibrated inter-satellite difference time series from analysis at STAR, Ocean Mean:
No Inter-satellite calibration



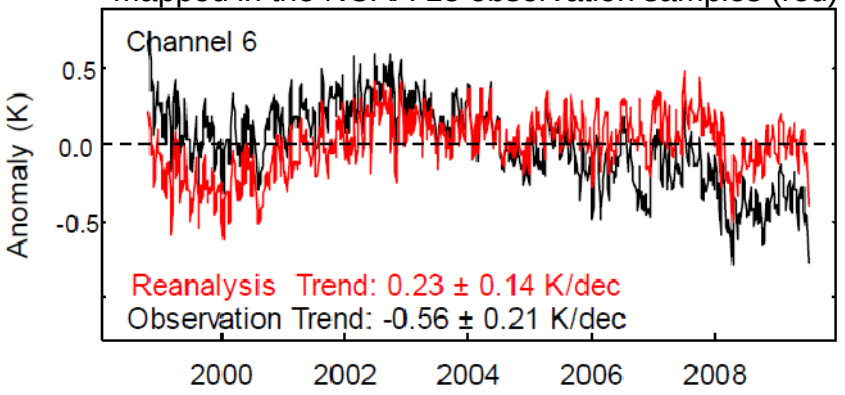
Ocean mean inter-satellite difference time series after STAR SNO Inter-satellite calibration, CH6



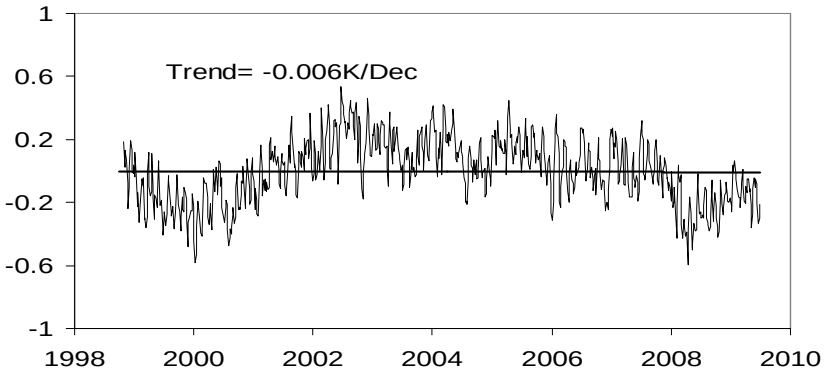
Trend comparisons between ERA-Interim Reanalysis and STAR MSU/AMSU Analysis:CH6

- Reanalysis and NOAA operational calibrated data have large trend differences up to 0.8 K/Dec due to drift in bias estimates in NOAA-15
- STAR SNO recalibrated CH6 trend is different from either reanalysis or NOAA operational calibrated data

NOAA-15 CH5 ocean mean time series and trend (black) as used in ERA-I and the ERA-I reanalysis mapped in the NOAA-15 observation samples (red)



STAR SNO inter-calibrated MSU/AMSU ocean mean time series, Ch6



Summary Trend Differences Between Different Analysis

Channels	5	6	7	9
NOAA operational calibrated NOAA-15	0.03±0.11	-0.56±0.12	0.03±0.16	-0.24±0.15
ERA-Interim Forecast	0.22±0.12	0.23±0.14	0.21±0.15	0.07±0.13
Recalibrated STAR MSU/AMSU CDR	0.05±0.11	-0.006±0.12	-0.03±0.16	-0.18±0.15

Conclusion and Discussion

- ERA-Interim reanalysis bias estimates can capture instrument calibration errors such as warm target temperature signals; similar to conclusions of Dee and Uppala's study on MSU
- ERA-Interim bias estimates of AMSU-A channels generally drift away from satellite observations
- Because of the drift, trends of the ERA-Interim reanalysis field differ from operational calibrated satellite trends from 0.2K/Dec to 0.8 K/Dec, depending on channels
- For the 'good' channel like AMSU CH5, most satellites (except NOAA-16) agree with each other in terms of trends, and they also agree with STAR recalibrated MSU/AMSU time series; however, ERA-Interim still show bias drift relative to the 'good' satellite observations

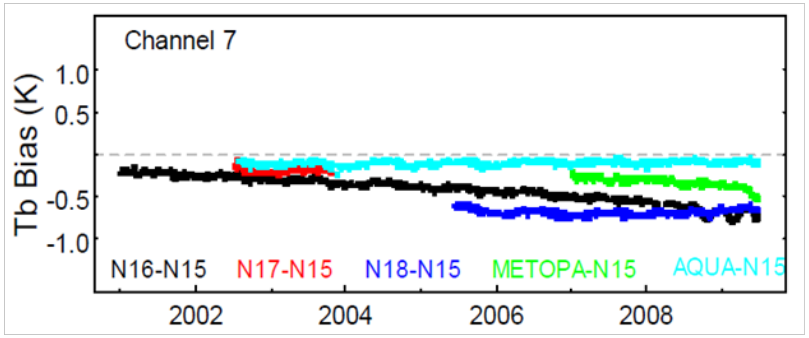
Conclusion and Discussion--Continue

- Part of these differences can be explained by the use of increasing numbers of aircraft observations, which are biased warm (Dee and Uppala, 2009)
- The ERA-Interim temperatures in the mid-troposphere are consistent with radiosondes (Dee and Uppala, 2009), not satellite data: Bad or good thing?
- The drifts occur likely because the reanalysis bias correction algorithm does not know the bias nature of the satellite data and thus does not know how to provide appropriate weightings to different satellite data
- Recalibrated satellite data may help reanalysis to reduce the bias correction uncertainty, since different satellite observations tend to agree with each other before being assimilated (inter-calibrated MSU cases in CFSRR and MERRA)
- Eventually, if RAOB or GPSRO data differ from inter-calibrated satellite data in terms of trends, how the reanalysis will choose?

Backup Slide: ERA-Interim Bias Estimates versus STAR Inter-Satellite Differences: CH7

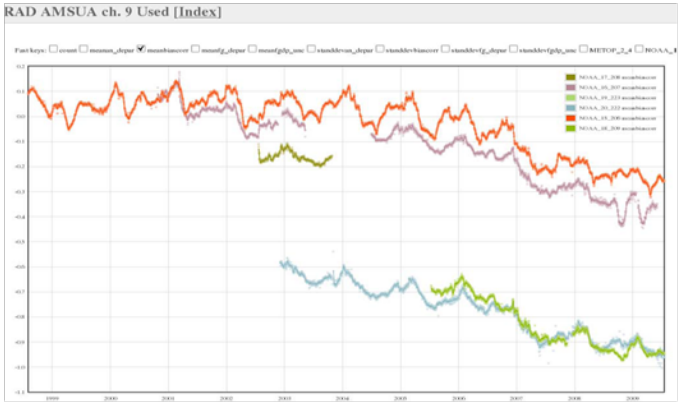
ERA-Interim Bias Estimates

Inter-satellite difference time series from analysis at STAR

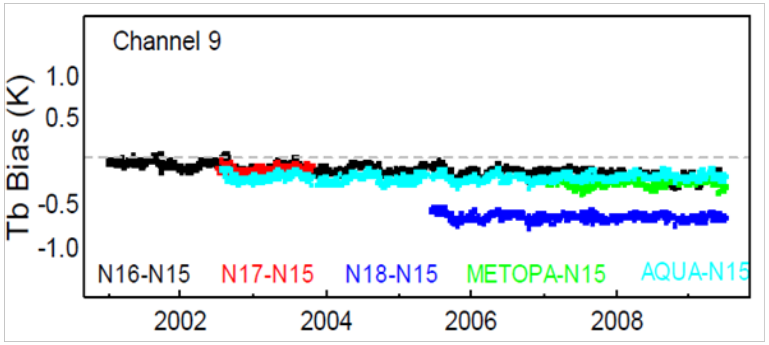


Backup Slide: ERA-Interim Bias Estimates versus STAR Inter-Satellite Differences: CH9

ERA-Interim Bias Estimates



Inter-satellite difference time series from analysis at STAR



Backup Slide: Trend comparisons between ERA-Interim Reanalysis and STAR Merged MSU/AMSU:CH9

NOAA-15 CH5 time series and trend (black) as used in ERA-I and the ERA-I reanalysis mapped in the NOAA-15 observation samples (red)