



SSM/I Version-7 Calibration

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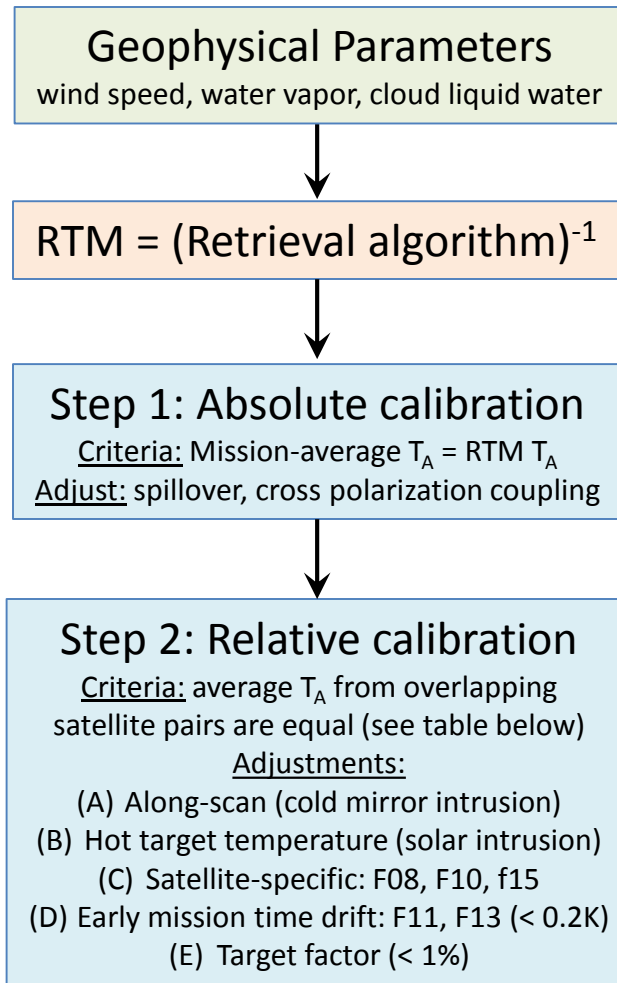


Outline

- Overview of Calibration Procedure
- Major Differences: V6 to V7
- Absolute Calibration
- Relative Calibration
- Calibration Metrics
- Documentation



Overview of Calibration Procedure



- In situ observations come from: buoys, radiosondes, and GPS measurements
- Relative calibration errors depend on a number of parameters, for example: scan position, solar angles, position in orbit
- Adjustments are derived one at a time, once all adjustments are found, the process is repeated
- Inter-satellite sensor error crosstalk
 - Varying the calibration procedure (e.g., using different pairs to derive same adjustments) indicates that the aliasing of calibration errors from one sensor to another is not a problem for most types of errors
 - On the second iteration, errors in reference satellite are mostly removed
- Orthogonality of calibration adjustments
 - Relative calibration adjustments are designed to be as orthogonal as possible
 - Order of finding adjustments does not matter as long as two complete iterations of all five adjustments are done

Primary	Short	Primary	Problem	Problem	Primary	Primary	Short	Primary	Primary	Primary
F08	F08	F10	F10	F10	F11	F11	F11	F13	F13	F14
F10	F11	F11	F13	F14	F13	F14	F15	F14	F15	F15



Major Differences Between Version-6 and Version-7

	Version 6	Version 7
Calibration Time Period	1987-2006	1987-2011
Absolute Calibration	Average unadjusted T_A for all SSM/I	RTM is absolute reference
Absolute Inter-Satellite Biases	Removed by fixed T_A offsets	Removed by APC adjustments
Relative Inter-Satellite Biases	Removed by zonal T_A offsets	Hot target temperature adjusted
PM versus AM T_A Differences	Lump into EIA adjustment	Hot target temperature adjusted
F08 SSM/I Closure Problem	Not realized	Non-linearity correction
Handling of F10 SSM/I	Zonal, seasonal, time varying T_A offsets	Non-linearity correction
Pointing Geometry	Adjustments made to EIA	No EIA adjustment required

Wentz, 2010: The Version-6 Calibration of SSM/I. RSS Technical Report 102210.

http://www.remss.com/papers/tech_reports/Wentz_SSMI_Version6_Calibration.pdf

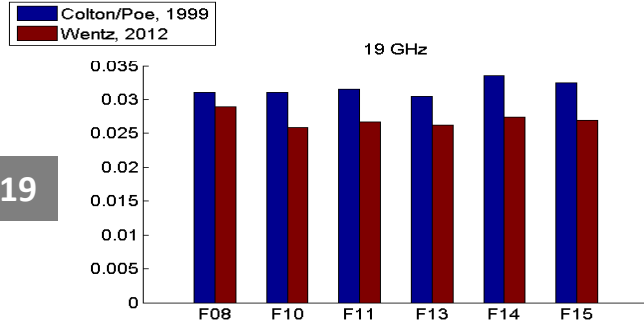
Wentz, 2013: SSM/I Version-7 Calibration Report. RSS Technical Report 011012.

http://www.remss.com/papers/tech_reports/2012_Wentz_011012_Version-7_SSMI_Calibration.pdf

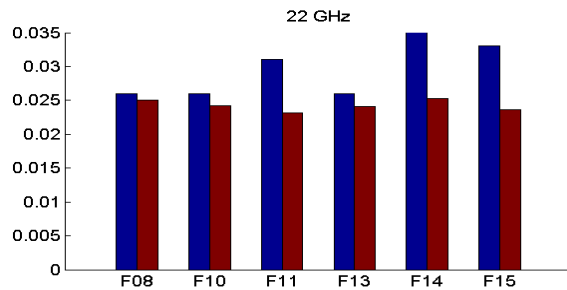


Antenna Spillover

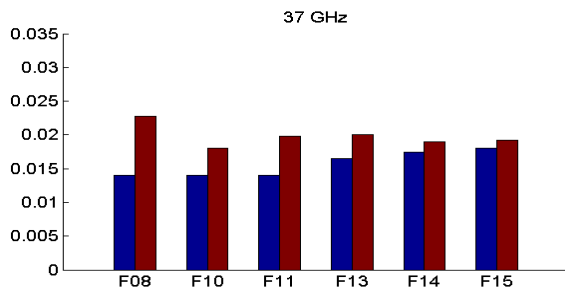
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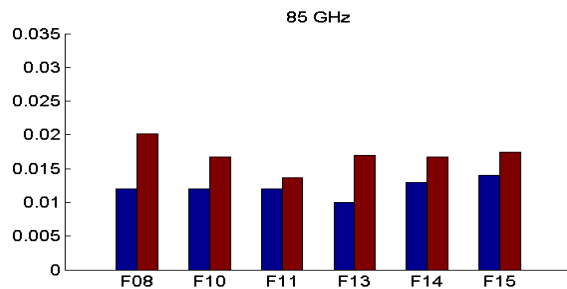
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37



85



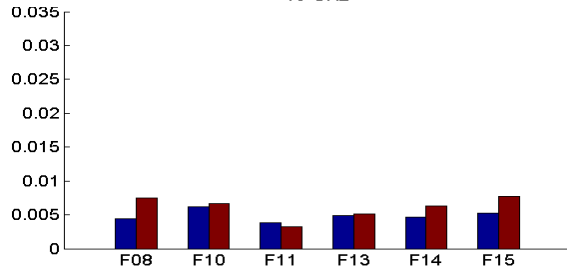
- Shown: spillover for each SSM/I (fraction of received power coming from cold space)
- Figures compare Wentz (red) with Colton and Poe (blue), which are derived from pre-launch antenna range measurements
- Assumption: spillover and cross-polarization coupling is same for both polarizations
 - Supported by pre-launch antenna patterns and observations over heavily forested areas
 - Since 22 GHz doesn't have h-pol, WindSat vapor provides the other constraint
- Typical differences are about 0.005, which corresponds to about 1 K for a 200 K earth scene
- Wentz is lower than C&P for 19 and 22 GHz, and higher for 37 and 85 GHz
- Noted: errors in spillover and in hot target temperature have nearly the same effect on calculation of T_B
- 1 K reduction in hot target temperature results in spillover 0.004 higher



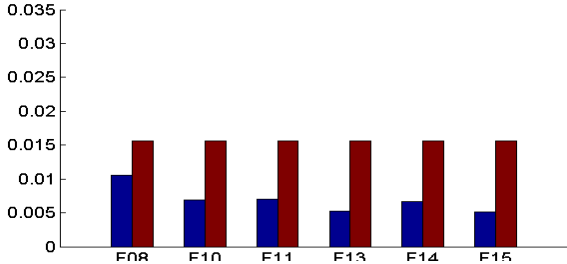
Cross Polarization Coupling

Colton/Poe, 1999
Wentz, 2012

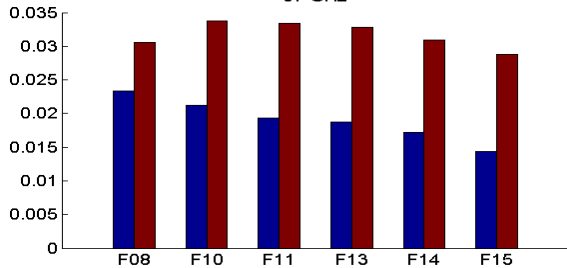
19 GHz



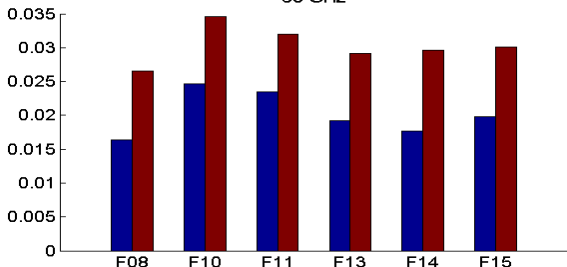
22 GHz



37 GHz



85 GHz



- Shown: cross polarization coupling for each SSM/I (fractional power coming from orthogonal polarization) for Wentz (red) and Colton and Poe (blue)
- Wentz agrees with C&P at 19 GHz
- Wentz is higher than C&P for 22, 37, and 85 GHz
- Differences are equivalent to about 0.5 K in TB
- When this analysis is applied to WindSat, AMSR-E, and SSMIS: cross-pol coupling is in good agreement (0.2 K) with the ground-based measurements

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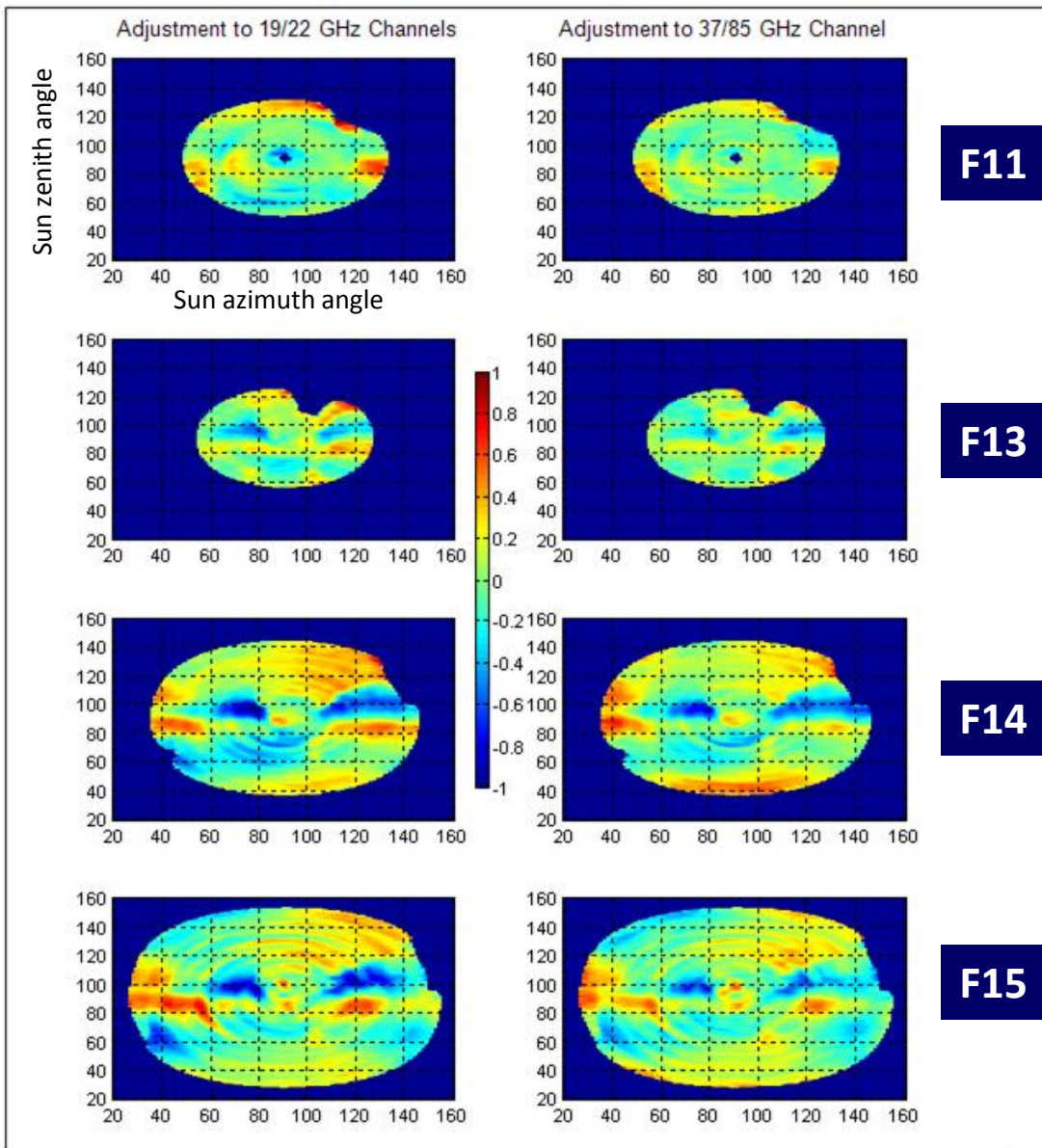
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Hot Target Adjustments

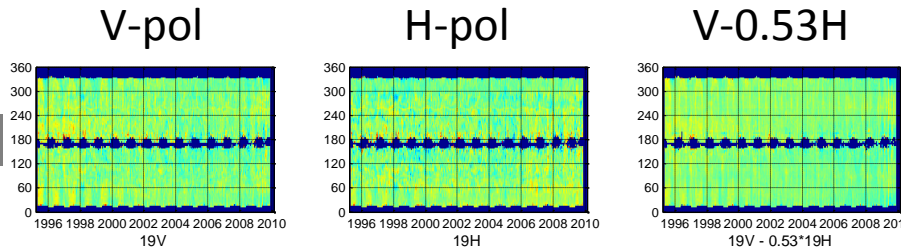


- Shown: hot target adjustments for F11-F15 as a function of sun angles
- Note similarity across satellites
- A linear combination of T_A differences (V-0.53H) is used because it is very insensitive to variations in atmospheric moisture
- SSM/I has 3 thermistors from which to infer hot target temperature
- Hot target errors are caused by solar intrusions at certain points in the orbit; thermal gradients are produced that are not captured by thermistors
- Assumption: error in hot target temperature is a function of solar azimuth and polar angle and is polarization independent
 - X-axis along s/c velocity vector
 - Z-axis points up away from nadir
- F08: too little overlapping data to derive correction
- F10: other time-dependent error sources not related to hot target error
- Since 22 GHz does not have h-pol, the 19 GHz adjustment is used
- Since 85 GHz has atmospheric noise (even with linear combo), 37 GHz used

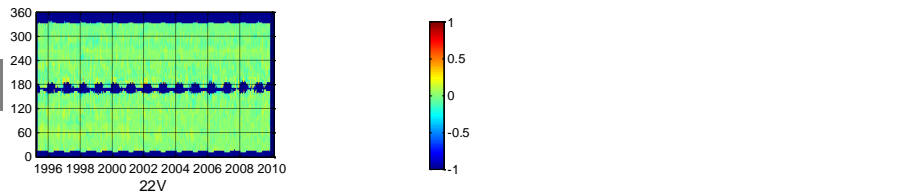


Closure Analysis

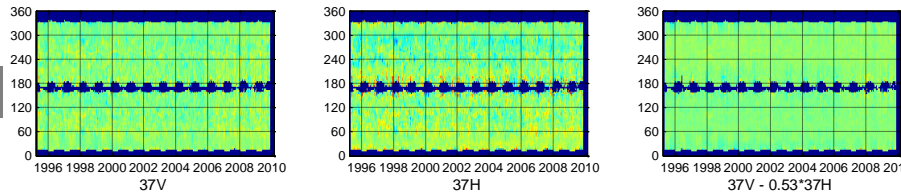
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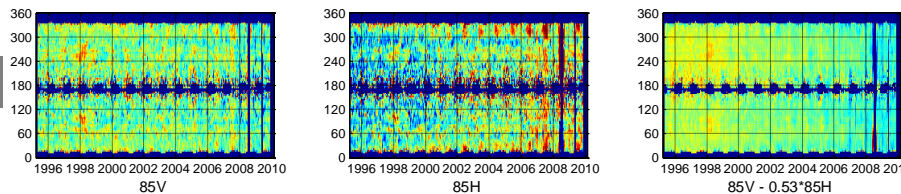
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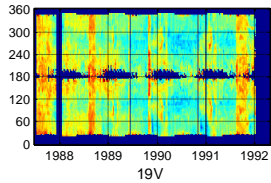
F13 closure residual vs s/c orbit position and time
Orbit position goes from 0°(SP), 180°(NP), 360°(SP)

- Closure analysis: T_A minus RTM T_A using retrievals from self
- Figure shows closure analysis for F13
- F13 observations are consistent with the RTM at the 0.1-0.2 K level over the full range of ocean latitudes and over full mission
- Larger differences for 85 GHz, including the 85H anomaly in 2008
- F10, F11, F14 show similar good closure
- F08 closure shows abrupt changes
- F15 closure shows residual RADCAL
- Why should there be any differences?
 - Three retrieved parameters (wind, vapor, cloud)
 - Seven T_A s (19-85, v-h)
 - Differences should be very small, so this is a very sensitive indicator of previously undetected problems
- Closure analysis does not require another satellite, collocated observations, or model data
- Closure analysis requires careful interpretation because retrieval mixes frequencies

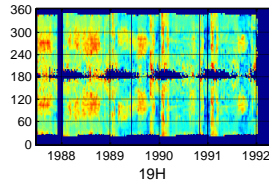


Non-linearity Correction

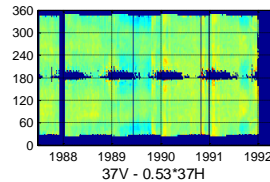
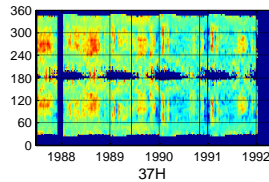
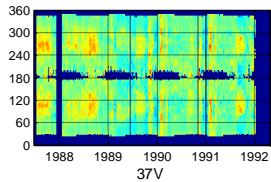
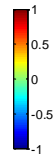
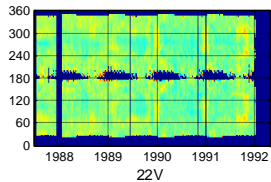
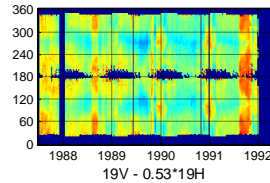
V-pol



H-pol

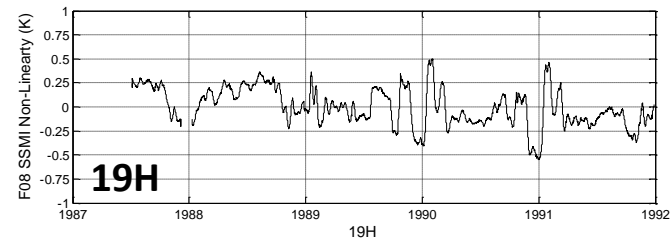
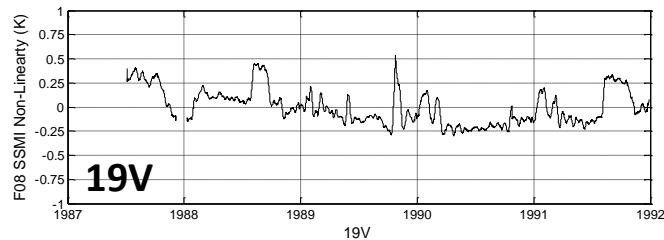


V-0.53H

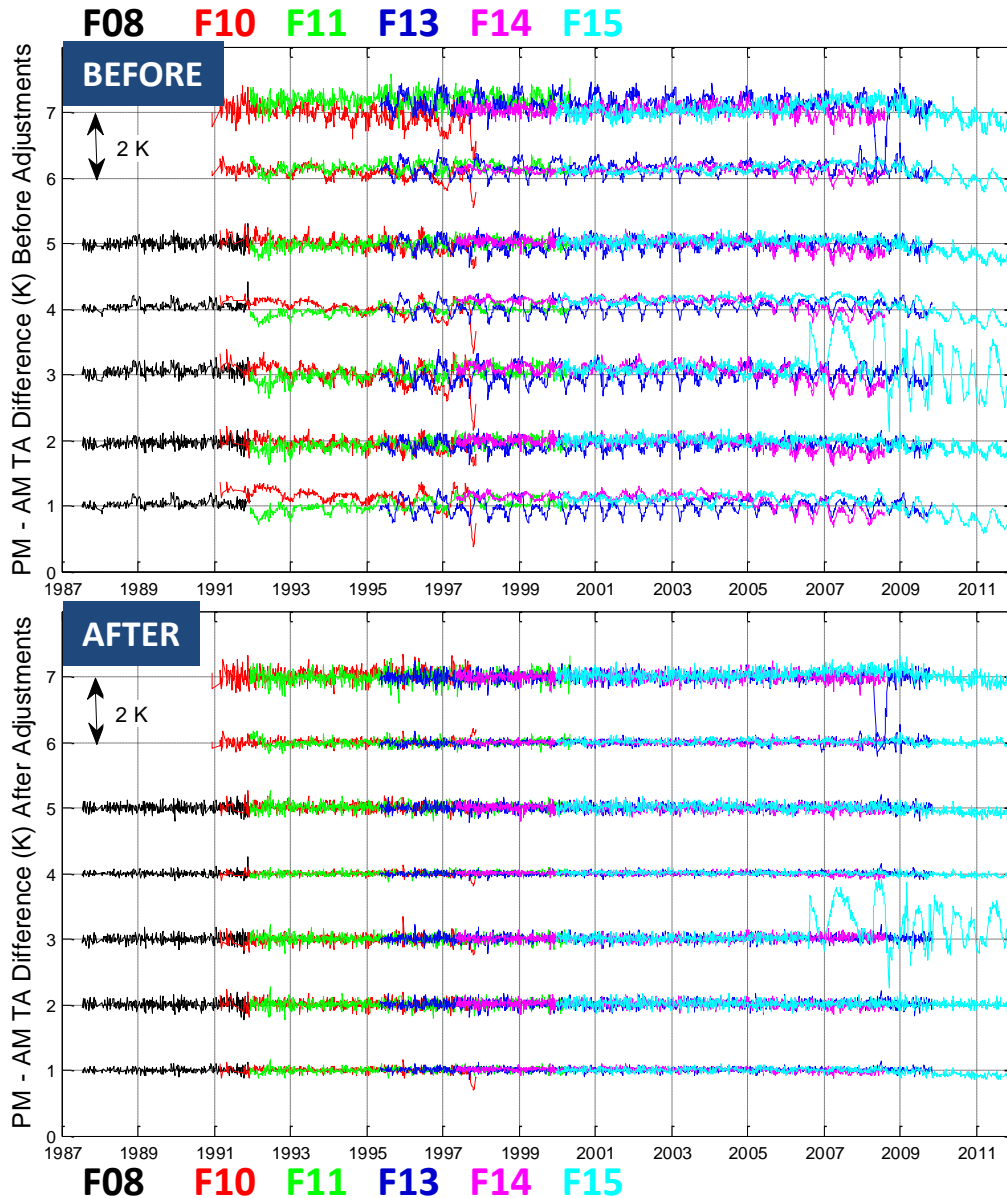


F08 closure residual vs s/c orbit position and time
(85 GHz channel not shown, failed on F08)

- Figure shows closure analysis for F08
- Notice that closure residual exhibits abrupt changes (vertical bars in 19 GHz)
- Cause of abrupt changes:
 - Hard to believe cold or hot target could change this abruptly
 - Could be intermittent RFI
 - Non-linearity with receivers
- 19 GHz channels are primary cause of problem
- Weaker features seen in 37 GHz are due to errors in cloud retrievals produced by the 19 GHz errors
- Usual treatment of non-linearity: correction has no effect when T_A equals cold or hot target temperature
- Non-linearity is function of time, shown by time series below



PM-AM differences

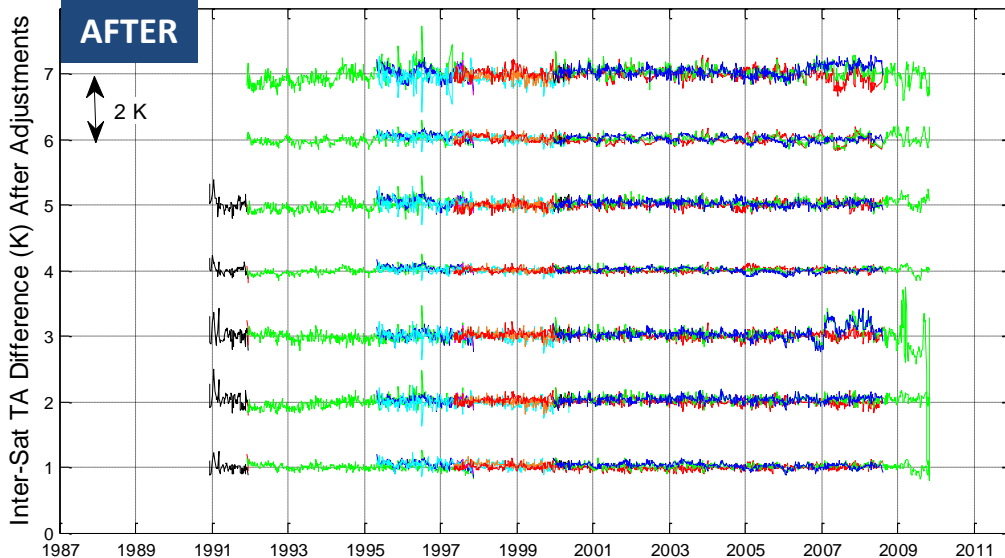
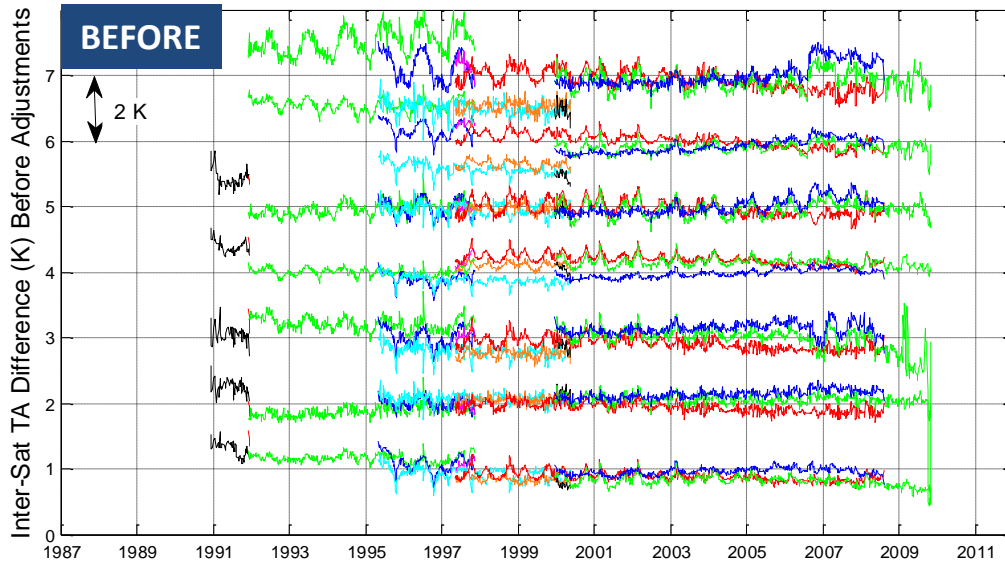


- Shown: PM-AM T_A differences for each satellite before and after calibration adjustments
- Diurnal adjustments are applied to both, based on diurnal model
- Cloud liquid water
 - SSM/I: diurnal amplitude is 0.008 mm, peaking around 3 AM
 - Compares well with TMI analysis: 0.009 mm, peaking around 4 AM
 - Global average diurnal amplitude depends on time of year, peaks in December
- Vapor diurnal amplitude about 5 times smaller than cloud (in terms of T_A)
- Dependence of T_A on SST is weak, and small when globally averaged
- Wind diurnal features small when globally averaged
- Residual error in hot target temperature is small < 0.15 K, and lumped with hot target adjustments
- F15 has some residual RADCAL
- F13 anomaly in 85H in 2008



Inter-satellite differences

08-10, 08-11, 10-11, 10-13, 10-14, 11-13, 11-14, 11-15, 13-14, 13-15, 14-15



08-10, 08-11, 10-11, 10-13, 10-14, 11-13, 11-14, 11-15, 13-14, 13-15, 14-15

- Shown: T_A differences between pairs of satellites
- Before calibration, differences are on the order of 1-2 K
- After calibration, the RMS difference over all overlaps is 0.1 K, except for 85H, which has an RMS difference of 0.2 K
- After calibration, the inter-satellite retrieval differences averaged over overlap periods are:
 - Wind speed: 0.01 m/s
 - Water vapor: 0.1 mm
- Accounting for diurnal variation, inter-satellite cloud differences are 0.0002 mm
- Mission average T_A minus RTM T_A differences are typically 0.05 K



Documentation

- Wentz, F. J., 2013: SSM/I Version-7 Calibration Report, RSS Technical Report 011012, 46 pp.

Available online:

http://www.remss.com/papers/tech_reports/2012_Wentz_011012_Version-7_SSMI_Calibration.pdf

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