Recalibration of DMSP SSMI/S for Weather and Climate Applications

Banghua Yan

NOAA/NESDIS/ORA & QSS Group Inc.

and

Fuzhong Weng
NOAA/NESDIS/ORA

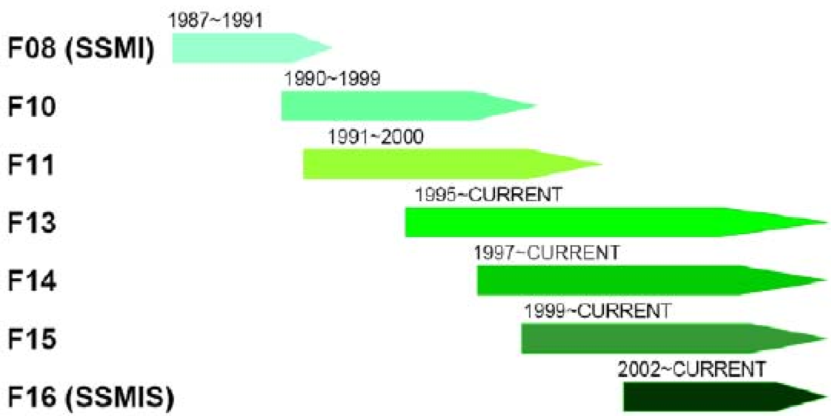
The 15th International TOVS Studies Conference, Maratea, Italy, October 3 – 10, 2006

SSMI/S Characteristics and Data History

Table 1 Special Sensor Microwave Imager (SSMI) Channel Characteristics

CHANNEL ABBREVIATION	CENTER FREQUENCY (GHz)	CENTER WAVELENGTH (cm)	BANDWIDTH (MHz)	POLARIZATION	INTEGRATION TIME (ms)
19V	19.35	1.549	240	Vertical	7.95
19H	19.35	1.549	240	Horizontal	7.95
22V	22.235	1.348	240	Vertical	7.95
37V	37.0	0.810	900	Vertical	7.95
37H	37.0	0.810	900	Horizontal	7.95
85V	85.5	0.351	1400	Vertical	3.89
85H	85.5	0.351	1400	Horizontal	3.89

TIME LINES OF SSMI/S MEASUREMENTS



- ► 19 years of continuous data (longest times series of satellite microwave imager)
- ► Highly overlapping measurements among sensors

Table 2 Special Sensor Microwave Imager/Sounder (SSMIS) Channel Characteristics

Channel	Center Freq.(GHz)	3-db Width (MHz)	Freq. Stab.(MHz)	Pol.	NEDT (K)	Sampling Interval(km)
1	50.3	380	10	V	0.34	37.5
2	52.8	389	10	H	0.32	37.5
3	53.596	380	10	H	0.33	37.5
4	54.4	383	10	H	0.33	37.5
5	55.5	391	10	H	0.34	37.5
6	57.29	330	10	RCP	0.41	37.5
7	59.4	239	10	RCP	0.40	37.5
8	150	1642(2)	200	H	0.89	12.5
9	183.31+/-6.6	1526(2)	200	H	0.97	12.5
10	183.31+/-3	1019(2)	200	H	0.67	12.5
11	183.31+/-1	513(2)	200	H	0.81	12.5
12	19.35	355	75	H	0.33	25
13	19.35	357	75	V	0.31	25
14	22.235	401	75	V	0.43	25
15	37	1616	75	H	0.25	25
16	37	1545	75	V	0.20	25
17	91.655	1418(2)	100	V	0.33	12.5
18	91.655	1411(2)	100	H	0.32	12.5
19	63.283248+/-0.285271	1.35(2)	0.08	RCP	2.7	75
20	60.792668+/-0.357892	1.35(2)	0.08	RCP	2.7	75
21	60.792668+/-0.357892+/-0.002	1.3(4)	0.08	RCP	1.9	75
22	60.792668+/-0.357892+/-0.0055	2.6(4)	0.12	RCP	1.3	75
23	60.792668+/-0.357892+/-0.016	7.35(4)	0.34	RCP	0.8	75
24	60.792668+/-0.357892+/-0.050	26.5(4)	0.84	RCP	0.9	37.5
Notes	(1) Sampling refers to along scan direction based on 833km spacecraft altitude. (2) NEDT for instrument temperature 0C and calibration target 260K with integration times of 8.4 msec for Channels 12-16; 12.6 msec for Channels 1-7, 24; and 25.2 msec for Channels 19-23 and 4.2 msec for Channels 8-11, 17-18. (3) Number of sub-bands is indicated by (n) next to individual 3-db width (4) RCP denotes right-hand circular polarization.					

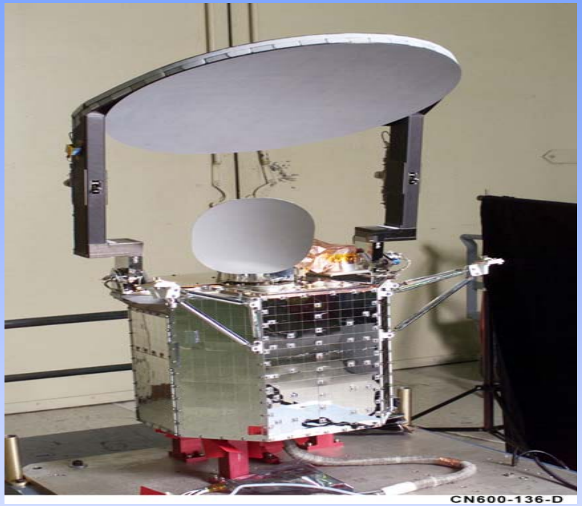
Major Impediments for MW Imager/Sounder

- Anomalous emission from unknown targets
- Warm load instability and solar and stray slight contamination
- Calibration uncertainty from instrument non-linearity
- Difficult to characterize the radio frequency interference in particular wavelengths
- Scan dependency due to intrusion of Glare Suppression System-B
- Pre-launch characterization, antenna patterns, brightness temperature standard, and well characterized target
- Difficult to correct for satellite orbit drift in trend analysis

(Weng et al, ASIC^3 2006)

SSMIS Antenna System and Antenna Emission

- Main-reflector conically scans the earth scene
- Sub-reflector views cold space to provide one of two-point calibration measurements
- Warm loads are directly viewed by feedhorn to provide other measurements in two-point calibration system
- The SSMIS main reflector emits radiation from its coating material
  - SiOx VDA (coated vapor-deposited aluminum)
  - SiOx and Al VDA Mixture
  - *Graphite Epoxy*



Theoretical SSMIS Reflector Surface Parameters

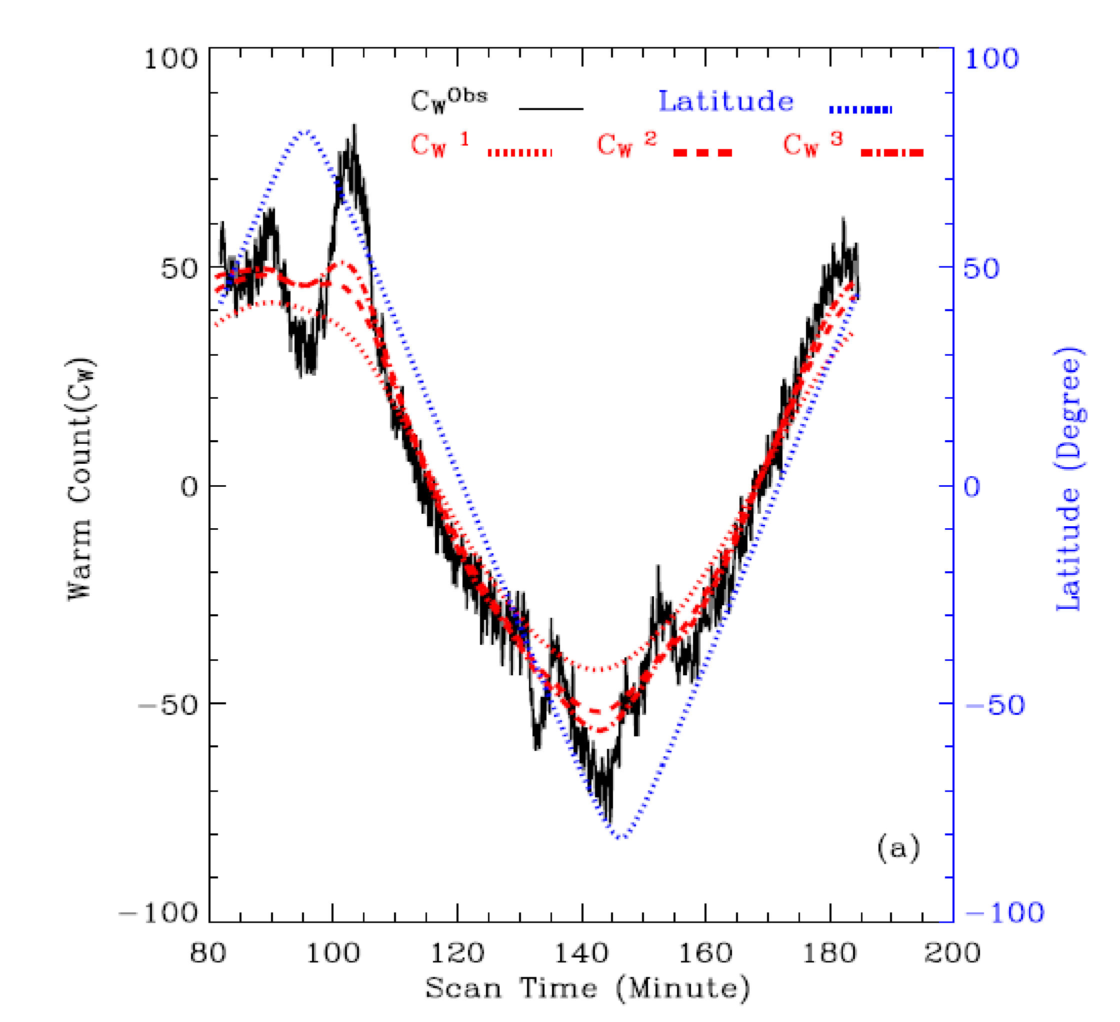
(NRL Multilayer Antenna Model)

	Emissivity (V-pol/20deg) [ϵ R]			
Freq. (GHz)	Al	GrEp	SiOx	SiOx/Al
19.35	0.00051	0.012	0.91	0.00051
37.0	0.00071	0.016	0.91	0.00071
60.0	0.00090	0.020	0.91	0.00090
91.65	0.00111	0.025	0.91	0.00111
183.0	0.00157	0.035	0.91	0.00157

$$T_A^{'} = T_A + \varepsilon_R (T_R - T_A)$$

FFT Analyses of Warm Counts (54.4 GHz)

- ► Warm load calibration is contaminated by solar and stray Lights
  - – Reflection Off of the Canister Top into Warm Load
  - – Direct Illumination of the Warm Load Tines
- ► CWF = FFT^{-1}(FFT(CW) * Filter(f_L))), where f_L is a cutoff frequency of the low pass filter, where T ≅102 minutes.



SSMIS Calibration Algorithms

1. Use the emissivity from NRL antenna model and the temperature measured from the thermister mounted on antenna arm as an approximation
2. Analyze the time series of warm load counts together with PRT and define the anomaly locations in terms of the FFT harmonics
3. Analyze the time series of cold space view count and define the anomaly locations in terms of the FFT harmonics and cosmic temperature plus antenna correction

$$T_A^{'} = T_A(1-\varepsilon_R) + \varepsilon_R T_R$$

$$T_A = \frac{T_A^{'} - \varepsilon_R T_R}{1-\varepsilon_R}$$

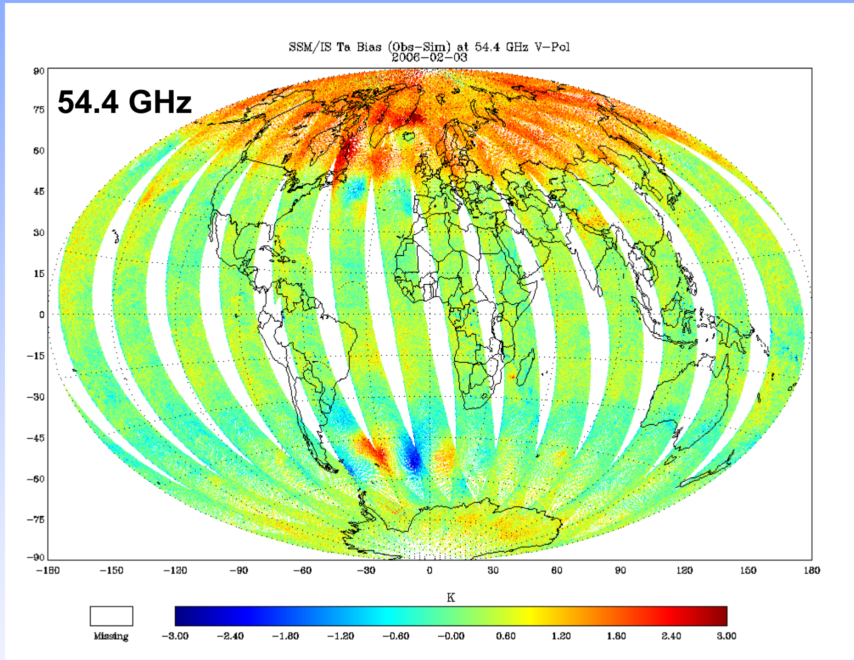
where T_A is the antenna temperature corresponding to the earth scene's radiance, *and* ε_R *and* T_R *is the reflector* emissivity and Temperature, respectively

$$T_A^{c} = T_A - \Delta T_A$$

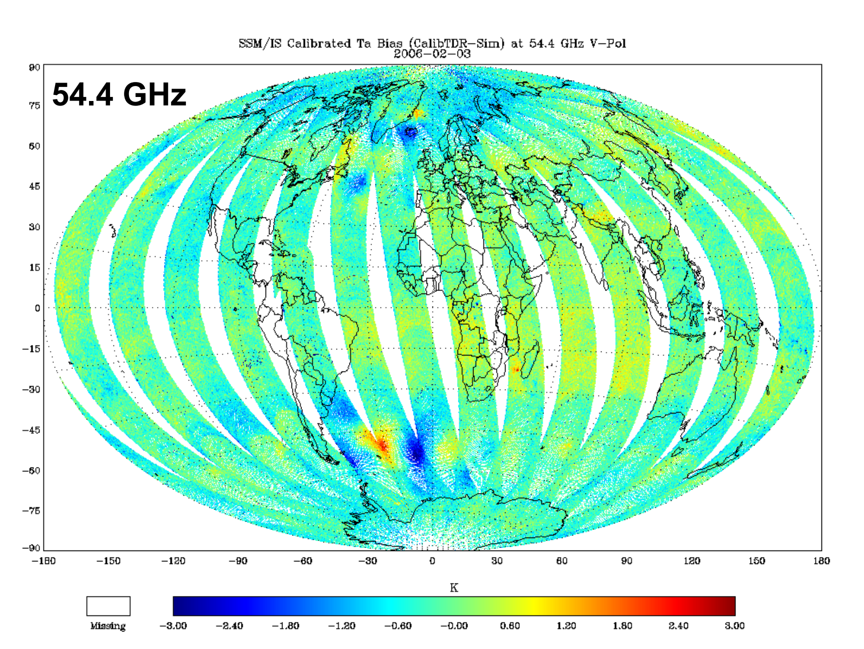
$$\Delta T_A = -\frac{T_A - T_C}{C_W - C_C}\Delta C_W - \frac{T_W - T_A}{C_W - C_C}\Delta C_C + \frac{C_A - C_C}{C_W - C_C}\Delta T_W$$

SSMIS Antenna Temperature Bias
February 3, 2006

(a) Before anomaly correction



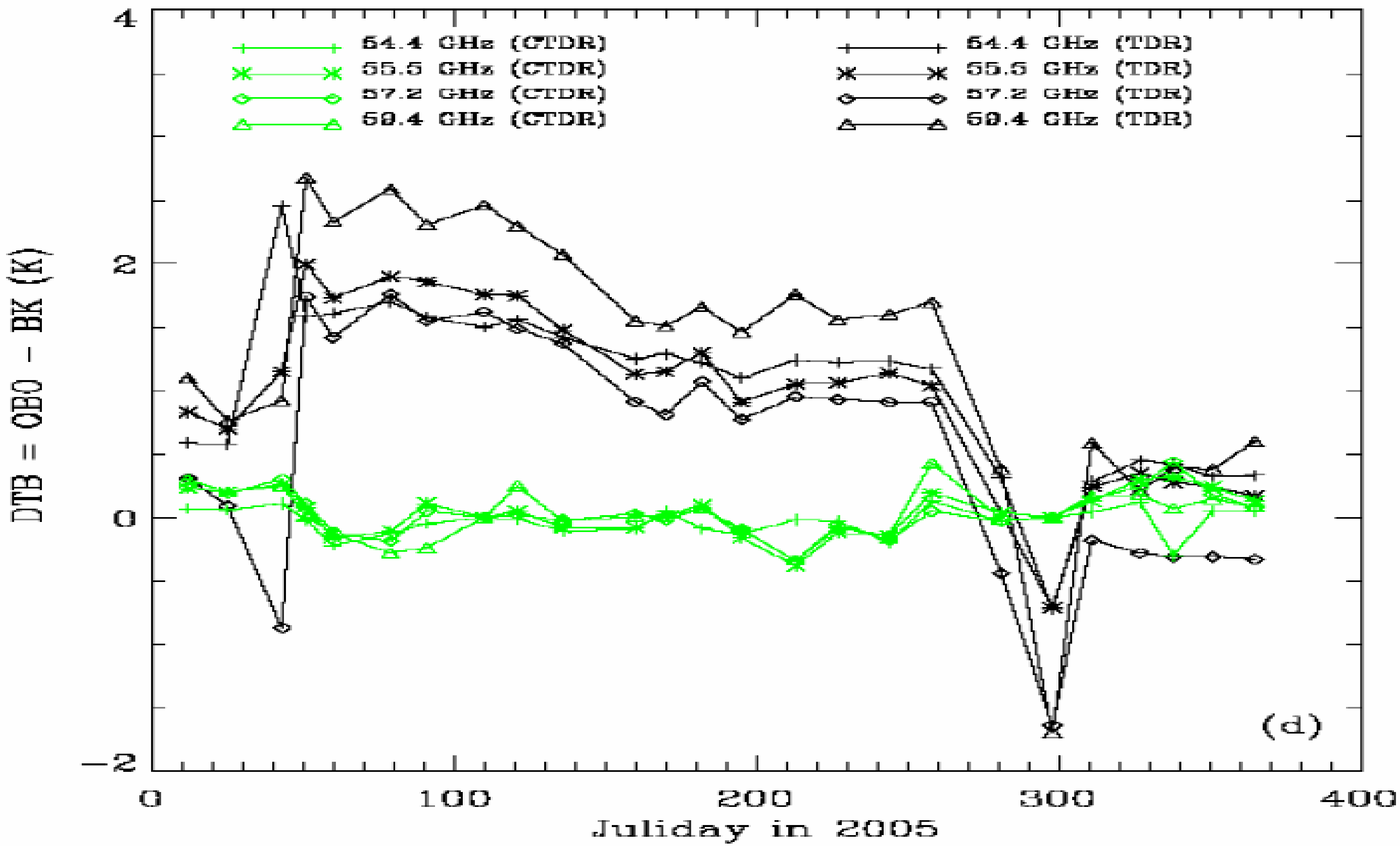
(b) After anomaly correction



Temperature biases from TDR and SDR space are related through the slope coeff. for spill-over correction, Tb = a*Ta + b

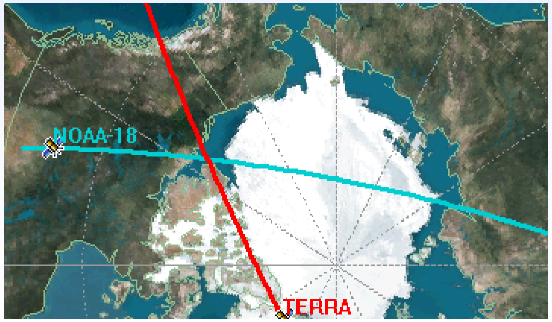
$$\Delta T_A = \Delta T_B / a$$

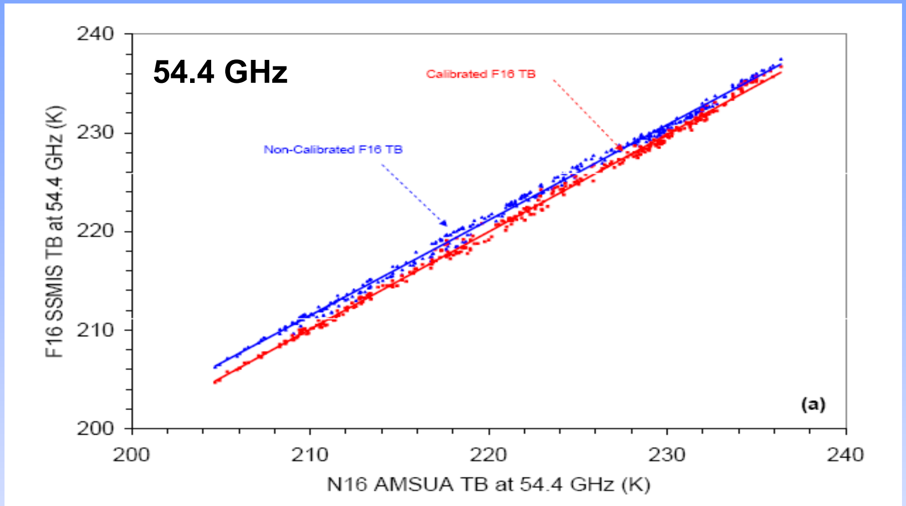
SSMIS Bias Trending

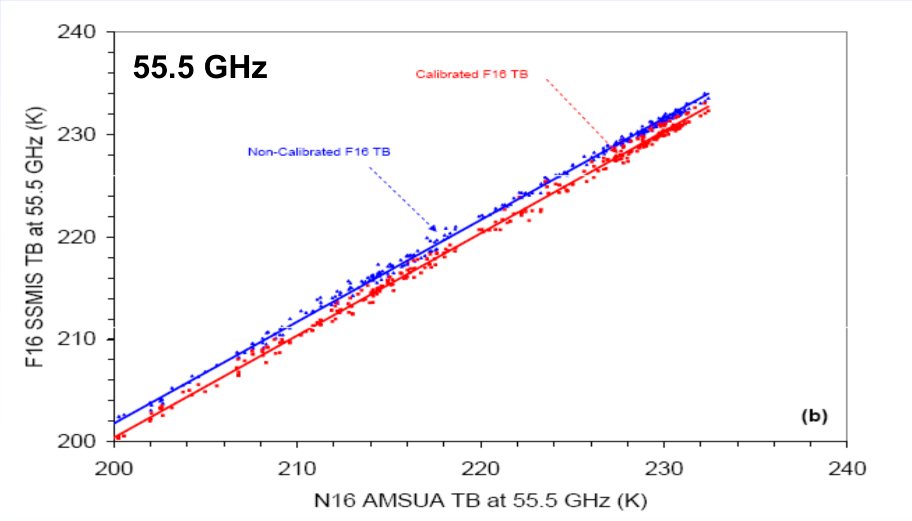


AMSU vs. SSMIS Matching through Simultaneous Conical Overpass

- SNO – every pair of POES satellites
- with different altitudes make orbital intersections within a few seconds regularly in the polar regions (predictable w/ SGP4)
- Precise coincidental pixel-by-pixel match-up data from radiometer pairs provide reliable long-term monitoring of instrument performance
- The SNO method (Cao et al., 2005) is used for on-orbit long-term monitoring of imagers and sounders (AVHRR, HIRS, AMSU) and for retrospective intersatellite calibration from 1980 to 2003 to support climate studies
- The method has been expanded for SSM/I with Simultaneous Conical Overpasses (SCO)







Non-Linear Algorithm

Non-linear calibration equation:

$$T_S = T_C + S(C_S - C_C) + \mu S^2 (C_S - C_C)(C_S - C_W) = T_{SL} + \mu Z,$$

where

$$T_{SL} = T_C + S(C_S - C_C), S = \frac{T_W - T_C}{C_W - C_C}, Z = S^2 (C_S - C_C)(C_S - C_W)$$

For SCO observations between two sensors (K,J):

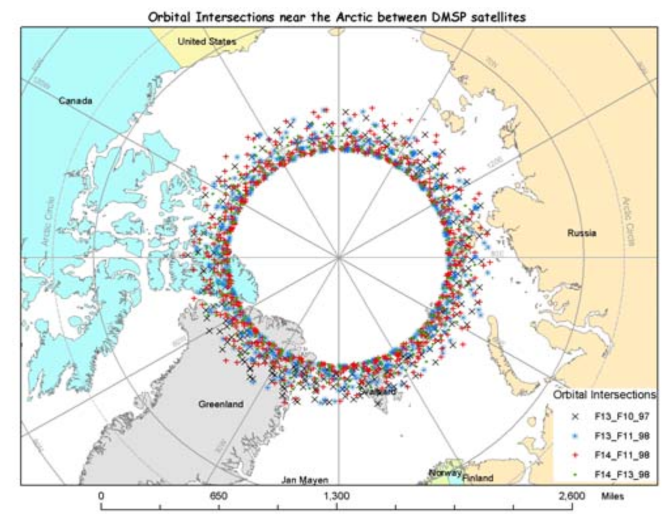
$$\Delta T_{SL,N} + (\mu_K Z_{K,N} - \mu_J Z_{J,N}) = 0$$

(in North Pole: **sea ice only**)

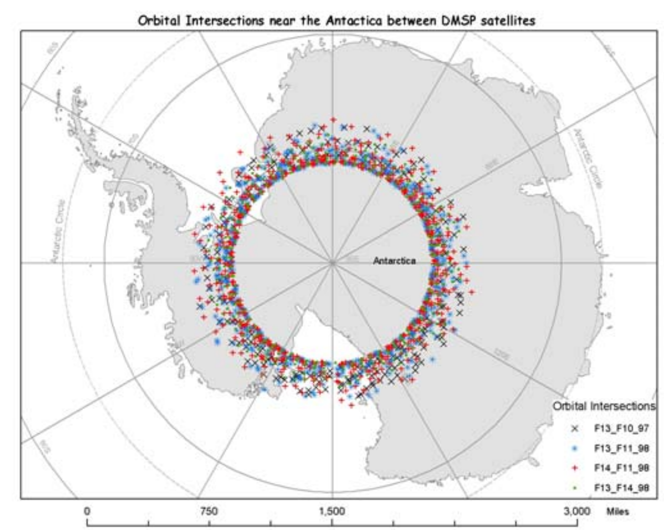
$$\Delta T_{SL,S} + (\mu_K Z_{K,S} - \mu_J Z_{J,S}) = 0$$

(in South Pole: **land** only)

SSMI/S SCO Distribution

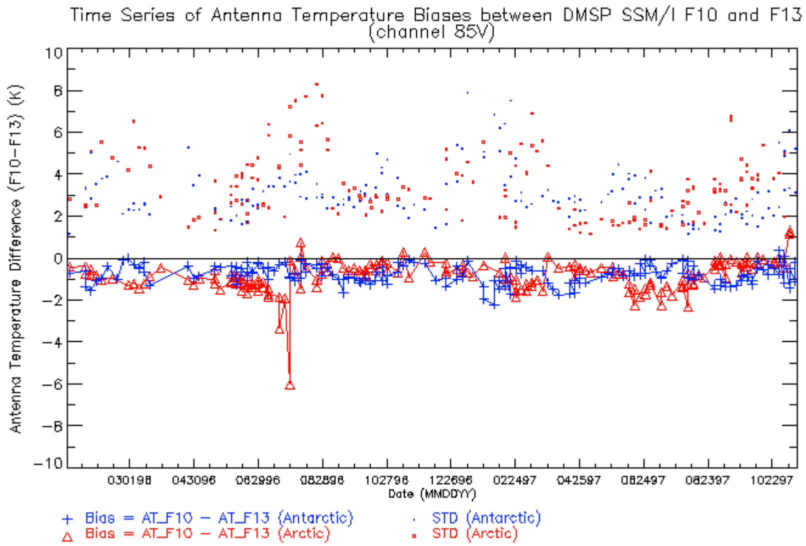


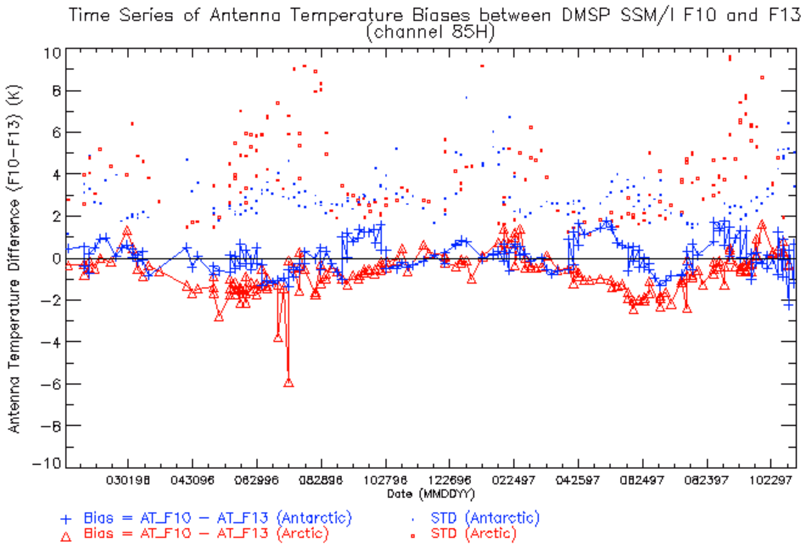
(a) Over North Pole

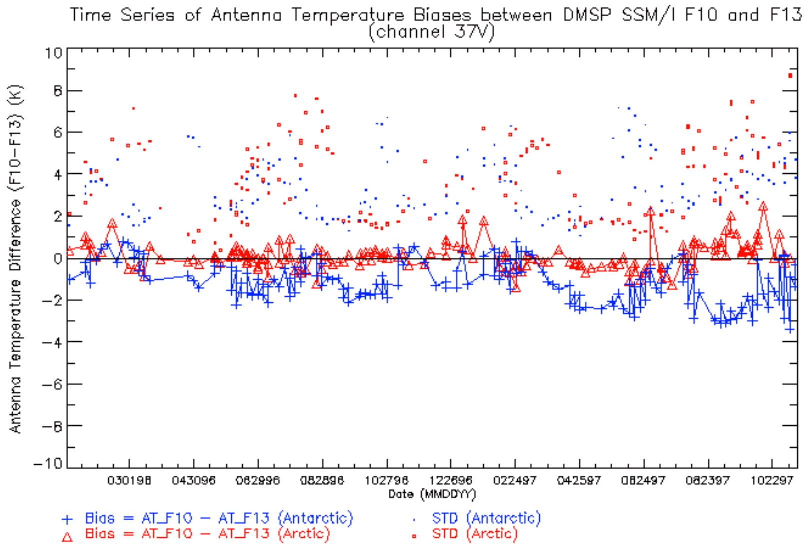


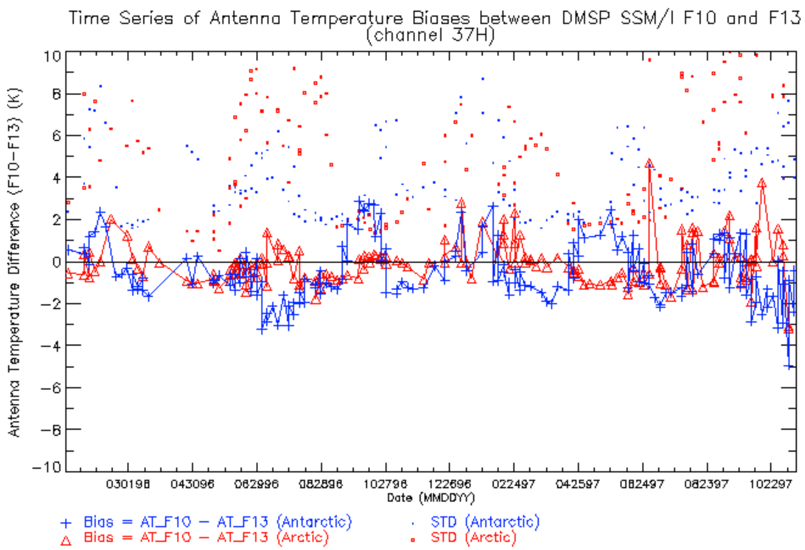
(b) Over South Pole

F-10 vs. F-13 SSM/I SCO Matching (37- 85 GHz Channels)



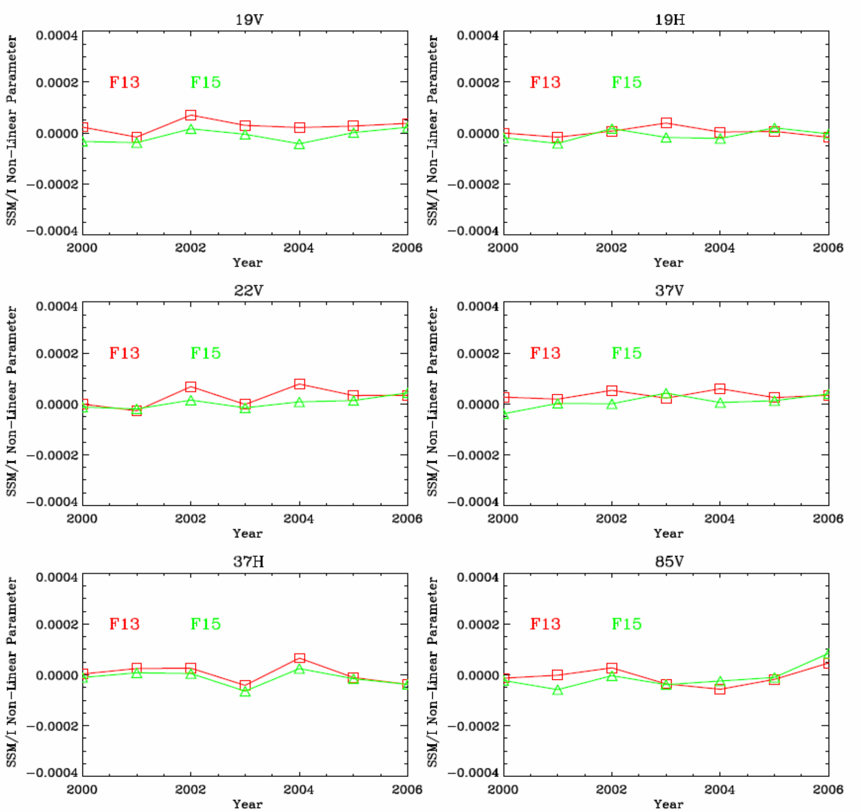


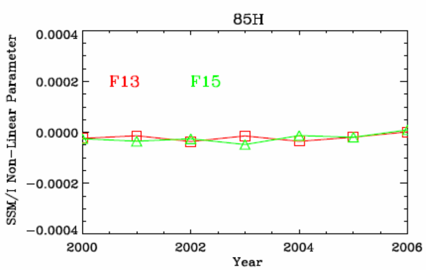




Preliminary Evaluation of Non-Linearity Term in F13 and F15

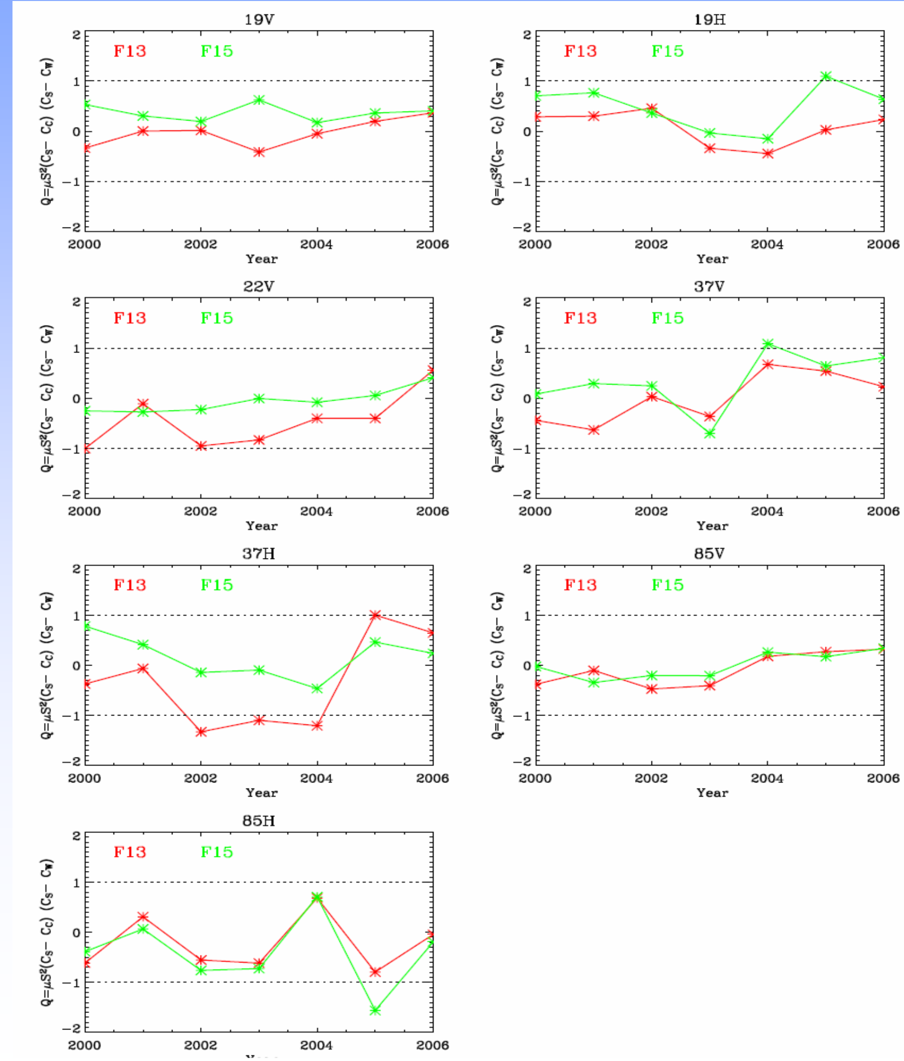
(a) Non-linearity parameter (μ)



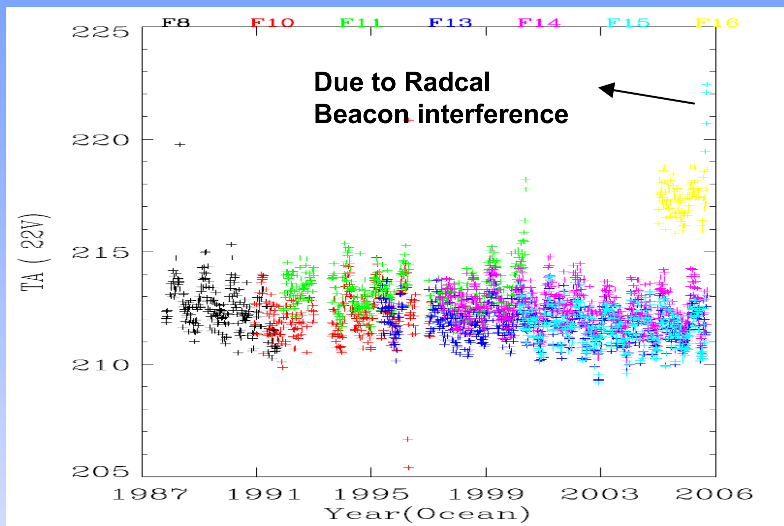


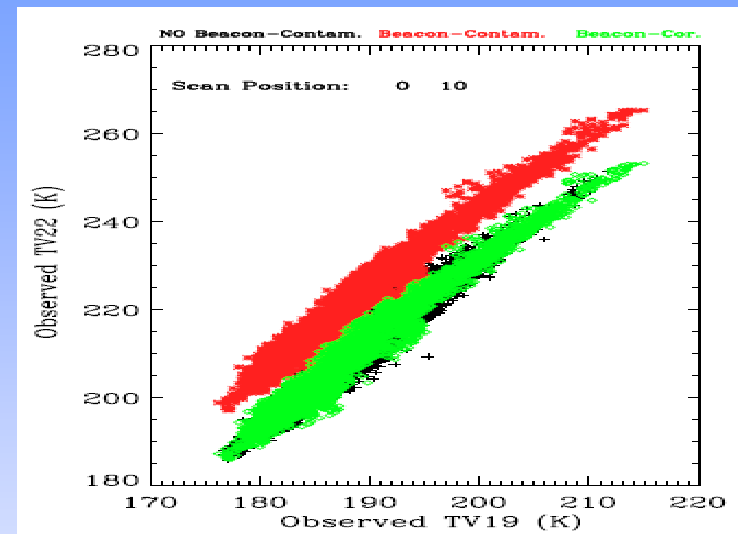
$$T_S = T_{SL} + \mu Z$$

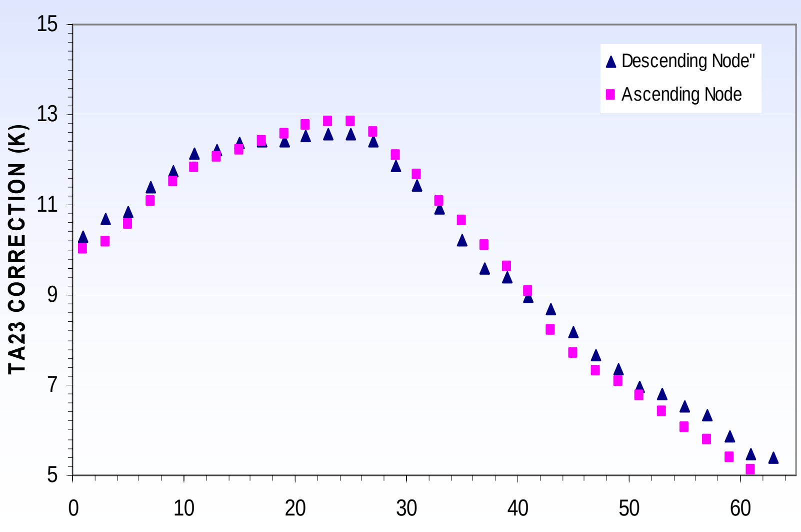
(b) Non-linearity term (Q = μZ)

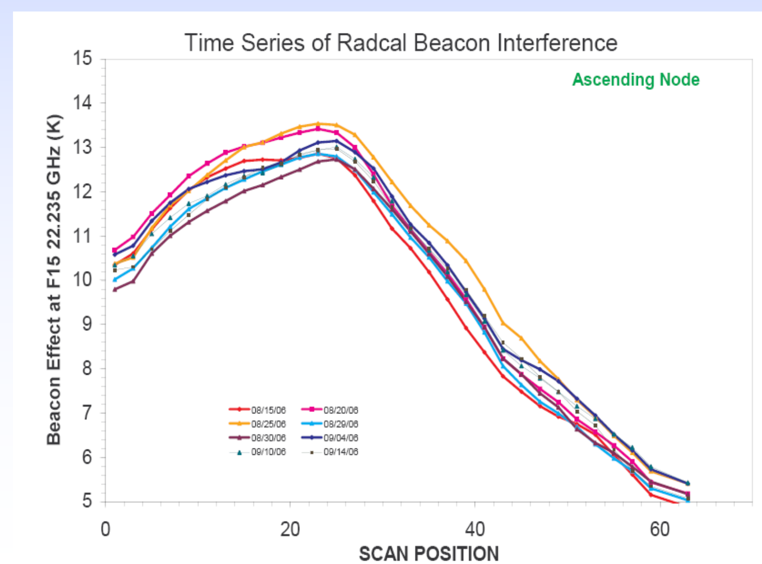


Rader Calibration Beacon Interference in F15 SSM/I 22.235 GHz



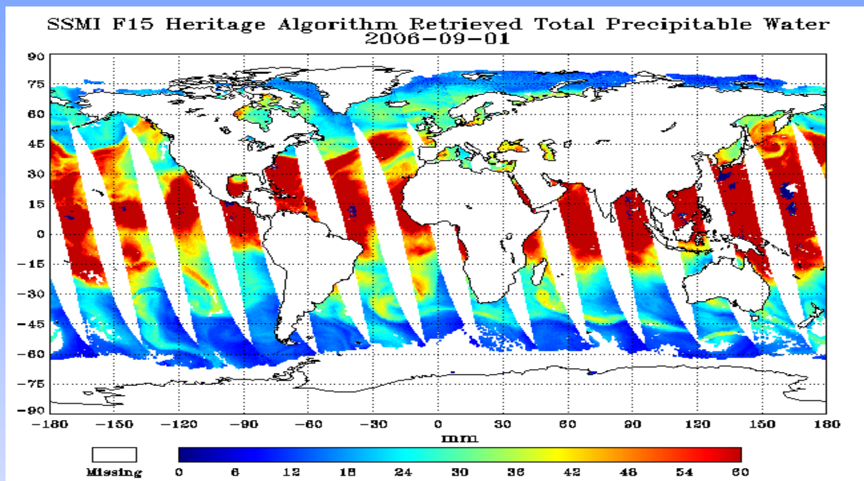




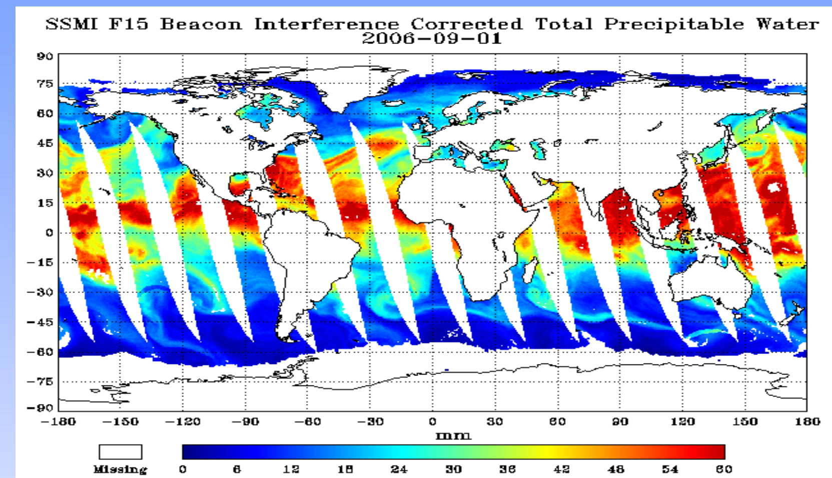


Total Precipitable Water (TPW) from F15 (& F13) SSM/I

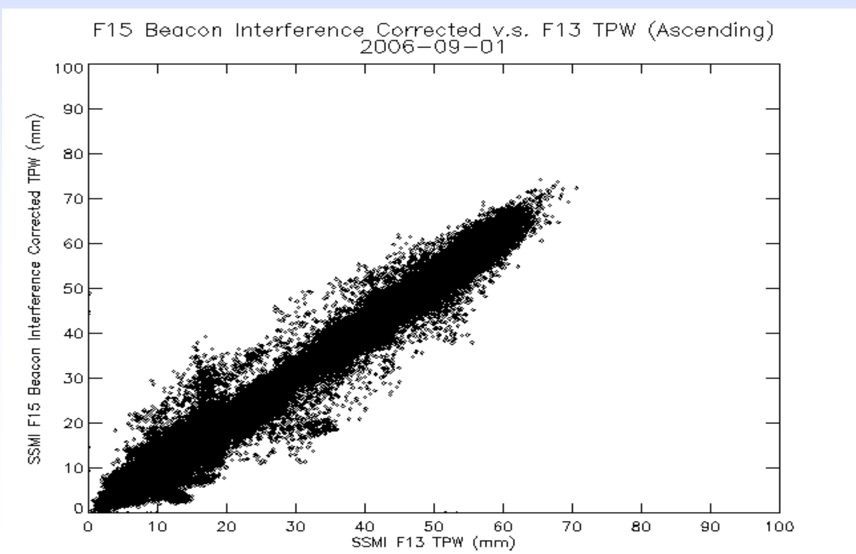
F15 TPW (beacon signal contaminated)



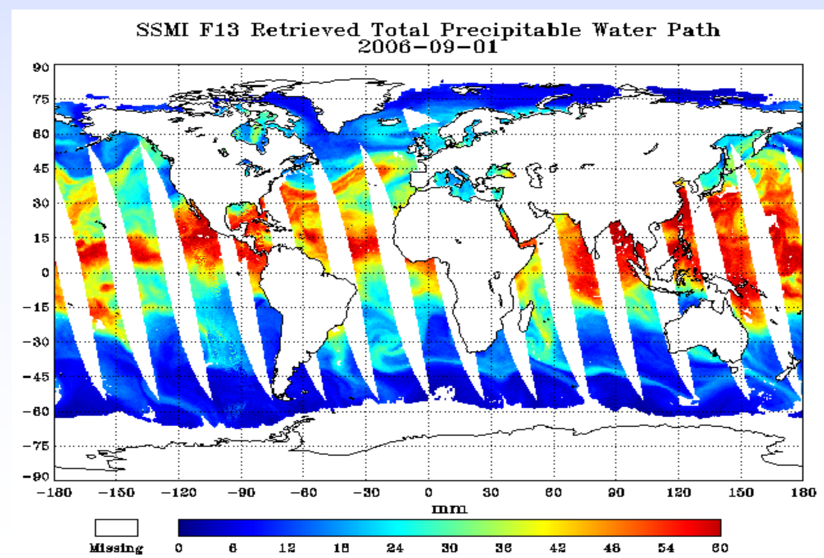
F15 TPW (beacon signal removed)



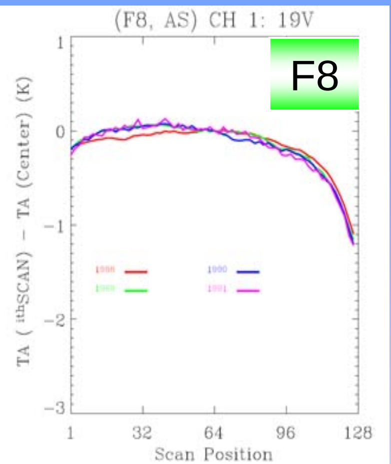
Comparison of F15 TPW (BC removed) with F13 TPW

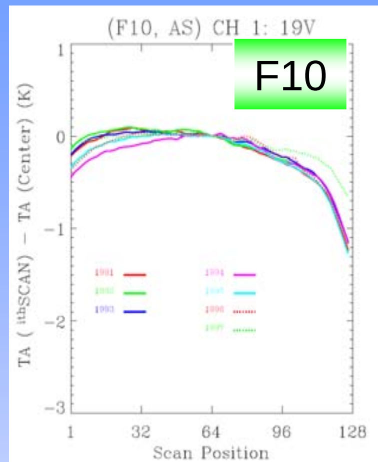


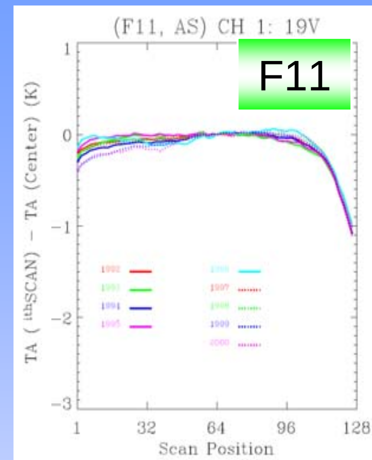
F13 TPW

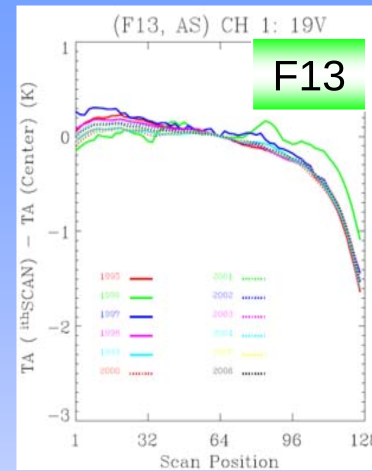


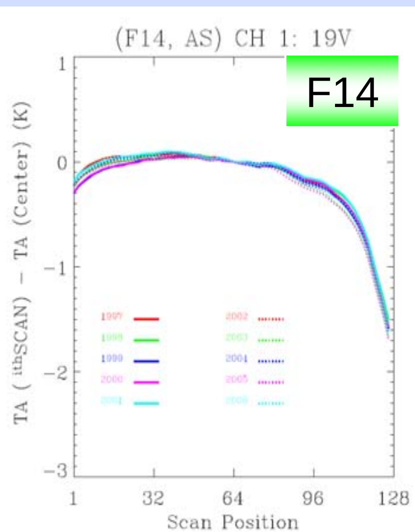
Scan Dependant Biases

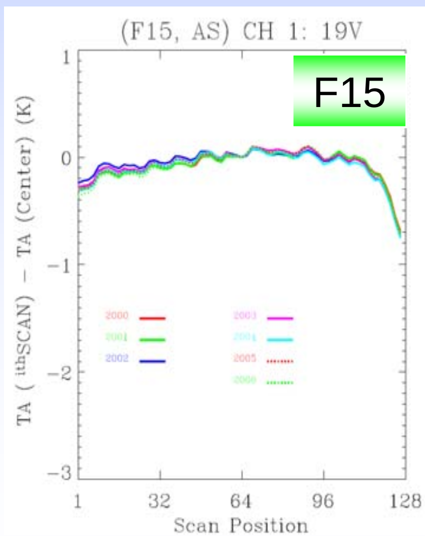


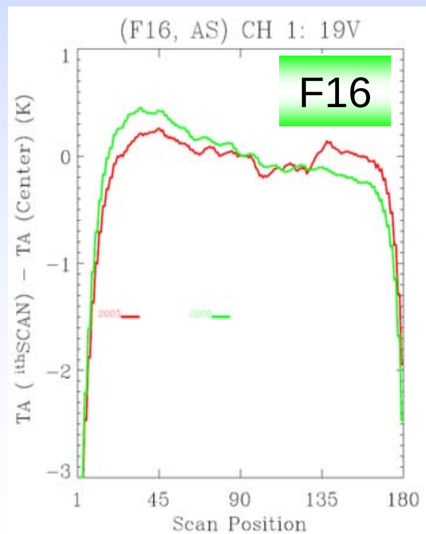












Conclusion:

Rapid fall-off 1~3 K at TA (TB) near end (sometimes at the beginning) of scan.

Summary

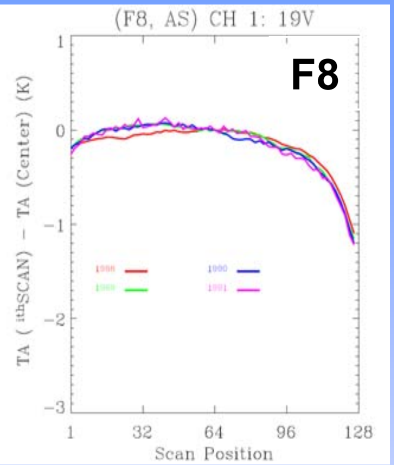
- *SSMIS Antenna emission and warm load anomaly*: the NESDIS/STAR beta-version of the SSMIS calibration algorithm has significantly eliminated most of SSMIS radiance anomalies.

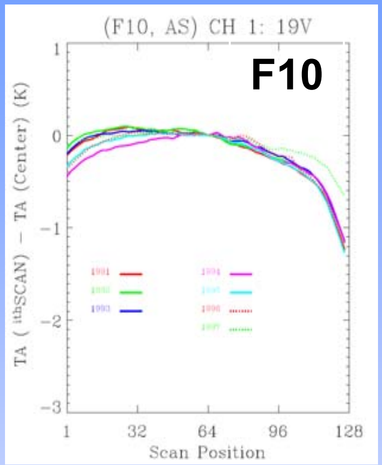
- *Nonlinearity* : a new algorithm to derive SSMI non-linear parameter has been developed. It is found that the nonlinearity of SSMI radiances is still important. However, more tests are needed.

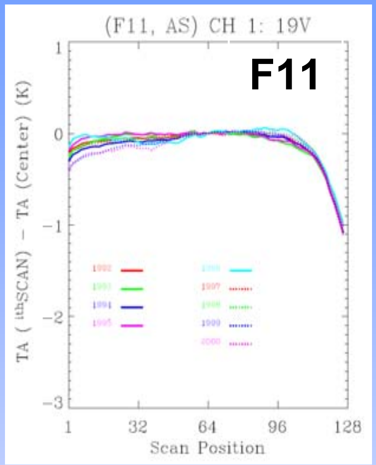
- *Radar calibration Beacon interference:* a beta version of the algorithm has been developed in NESDIS/STAR which can remove the Beacon signal from F15 22.235 GHz.

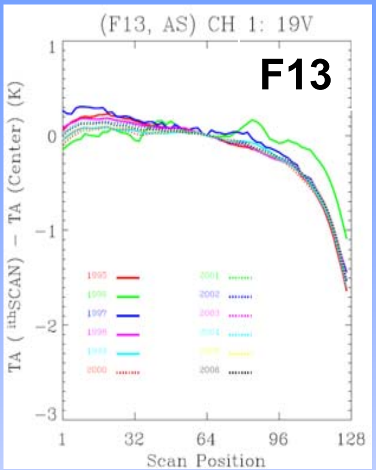
- *Scan dependency*: there is a rapid fall-off 1~3 K at TA (TB) near end (beginning) of scan primarily due to intrusion of Glare Suppression System - B.

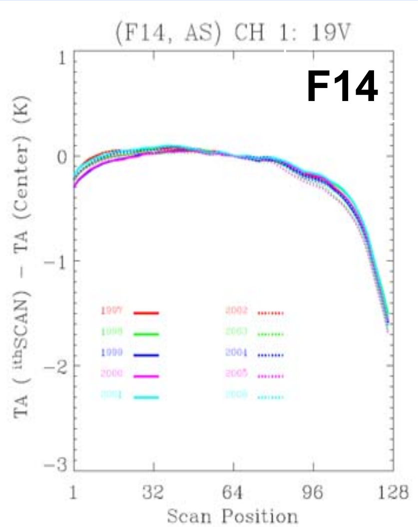
Scan Dependant Biases

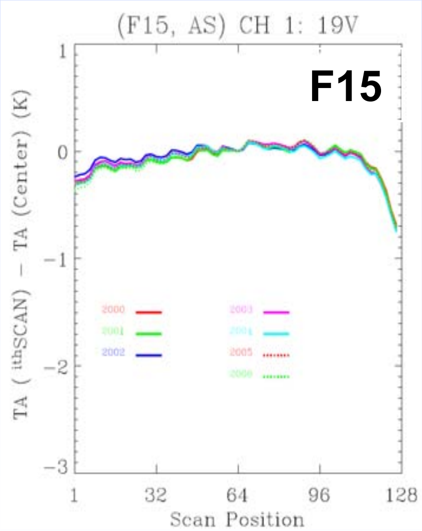


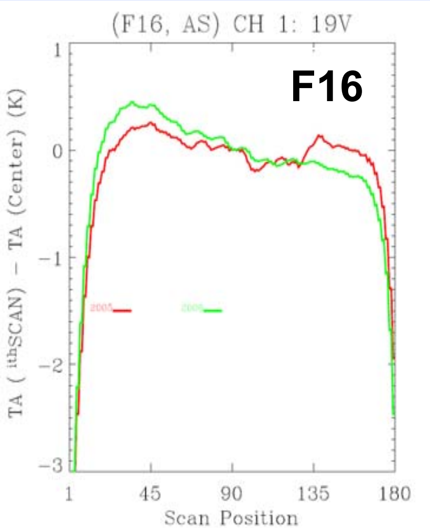








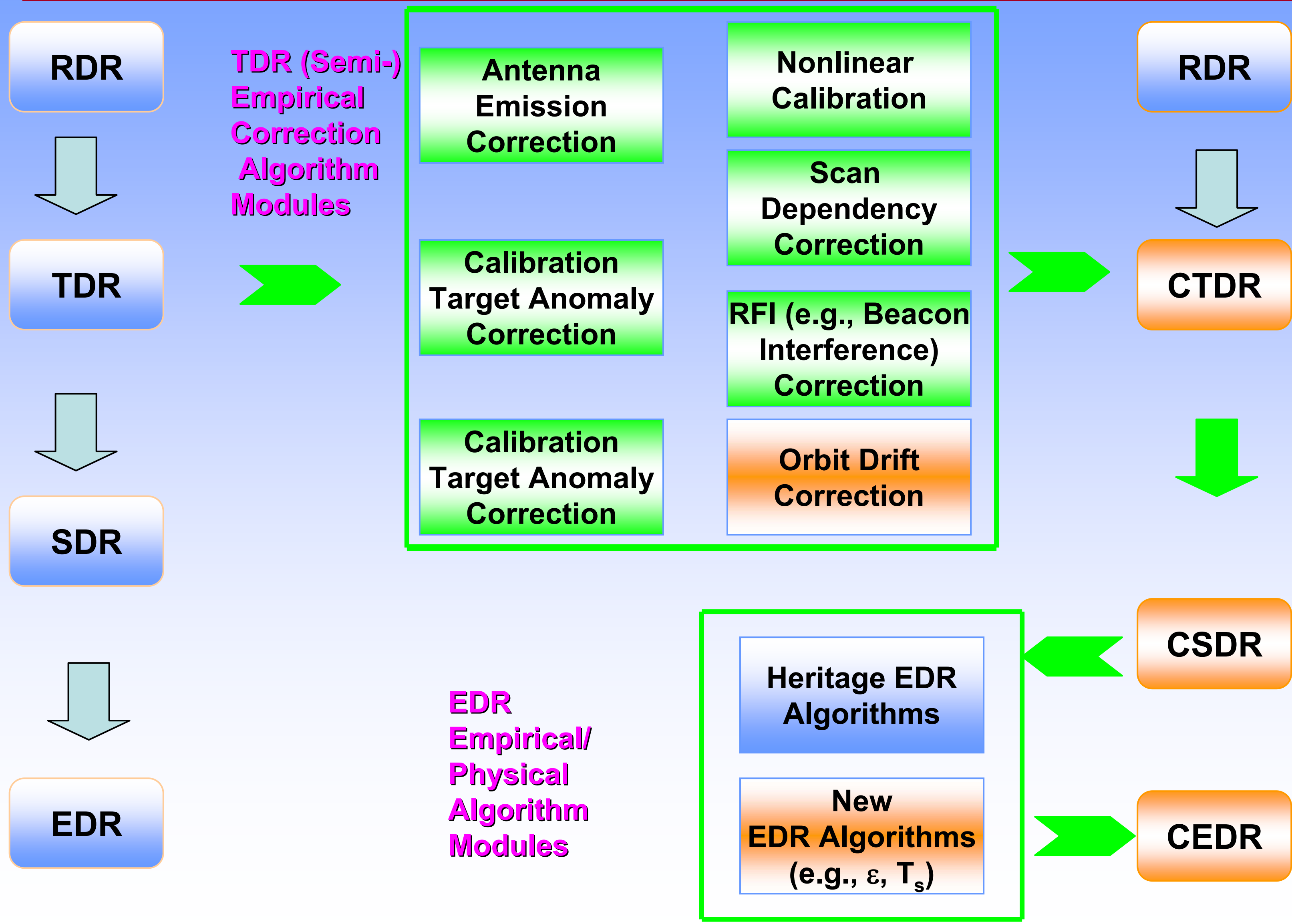




Conclusion:

Rapid fall-off 1~3 K at TA (TB) near end (sometimes at the beginning) of scan.

On-Going Plans: SSMI/S TDR/SDR/EDR Algorithm Flow

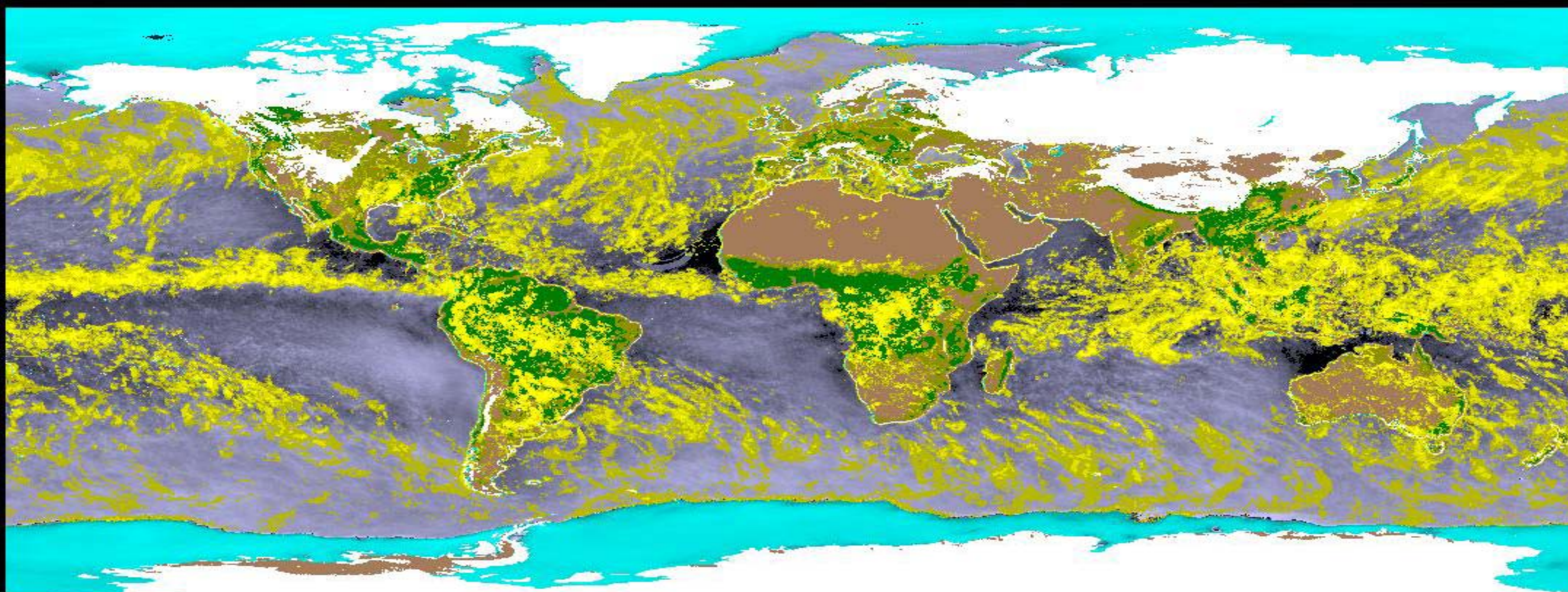


- **Backup**

The First SSM/I Monthly Products Generated from NOAA/NESDIS

SSM/I Monthly Composite Products

Cloud Liquid Water | Rain Rate | Snow Cover | Sea Ice | Vegetation/Moisture

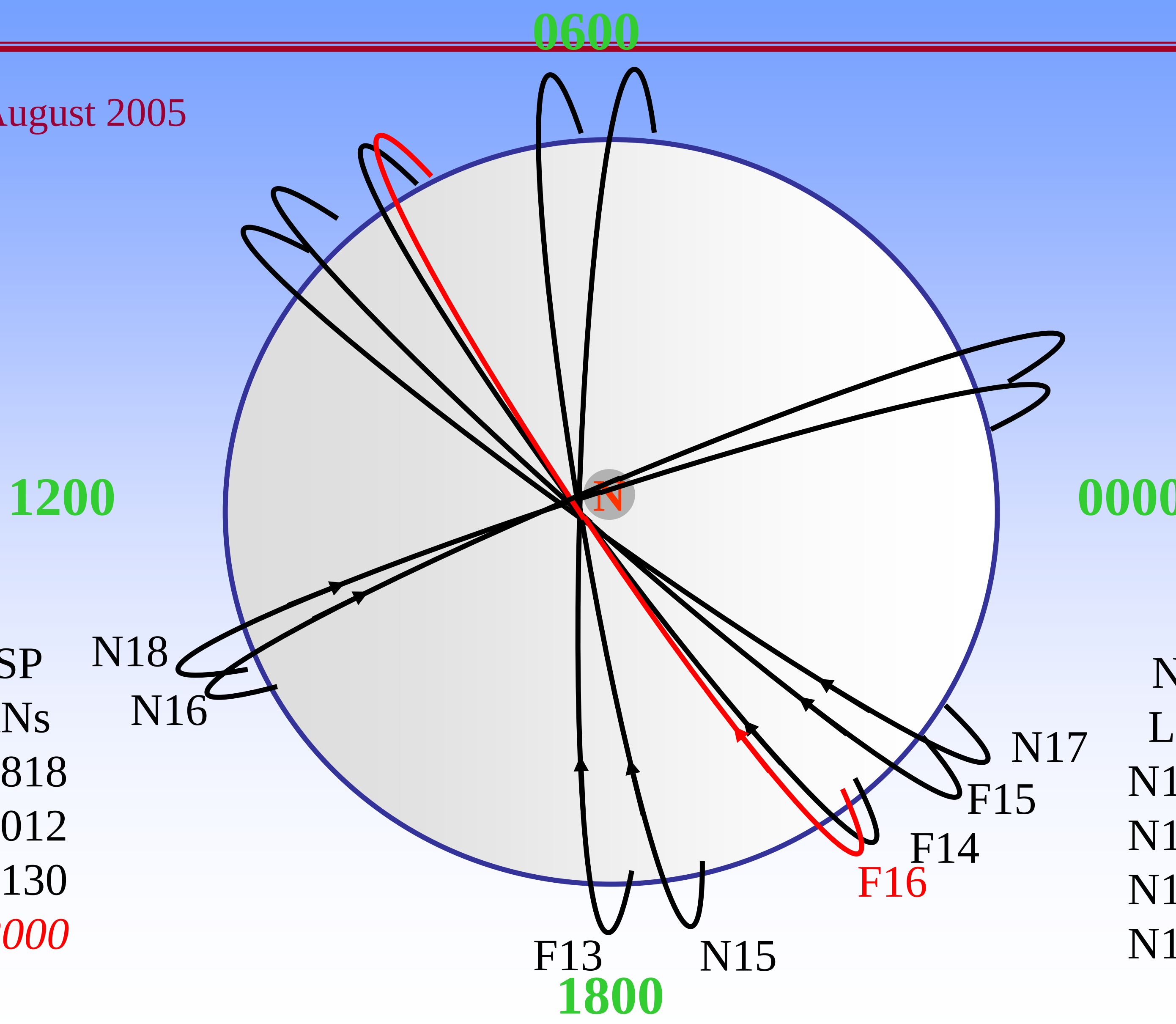


November 1987

Satellite Research Laboratory

DMSP and NOAA Constellation

- As of August 2005



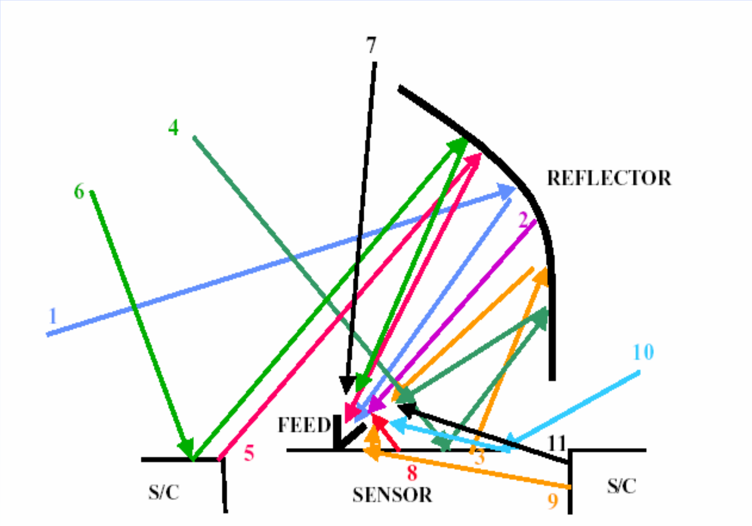
DMSP LTANs
F13 1818
F14 2012
F15 2130
F16 2000

NOAA LTANs
N15 1903
N16 1430
N17 2204
N18 1359

Microwave Instrument Calibration Components

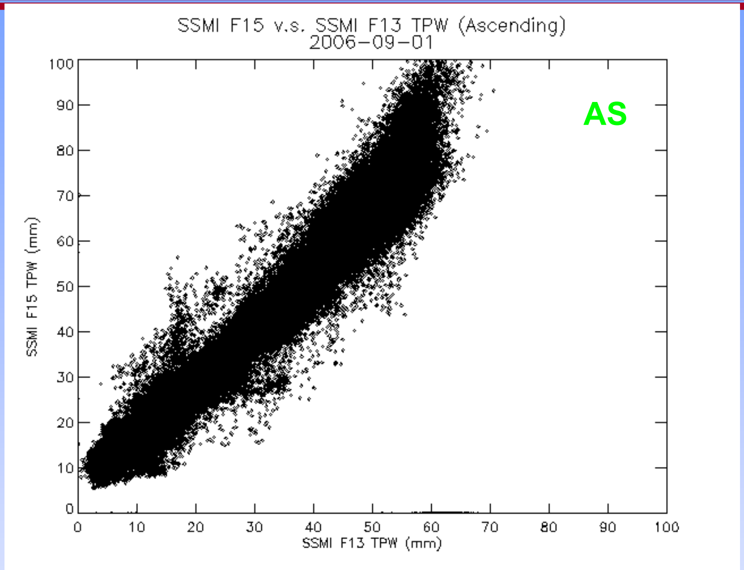
Energy sources entering feed for a reflector configuration

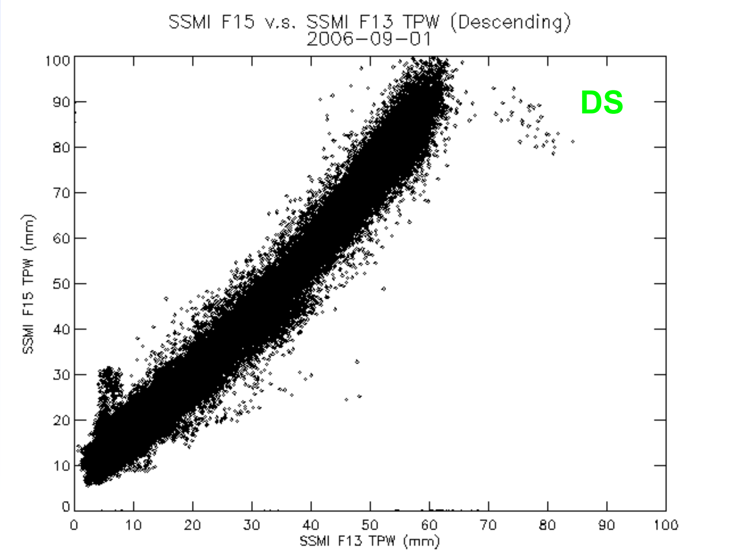
1. Earth scene Component,
2. Reflector emission
3. Sensor emission viewed through reflector,
4. Sensor reflection viewed through reflector,
5. Spacecraft emission viewed through reflector,
6. Spacecraft reflection viewed through reflector,
7. Spillover directly from space,
8. Spillover emission from sensor,
9. Spillover reflected off sensor from spacecraft,
10. Spillover reflected off sensor from space,
11. Spillover emission from spacecraft



Comparison of Total Precipitable Water (TPW) between F15 and F13

Before Beacon signal is removed





After Beacon signal is removed