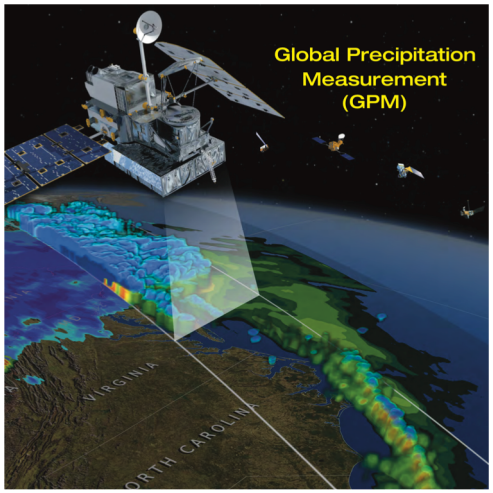
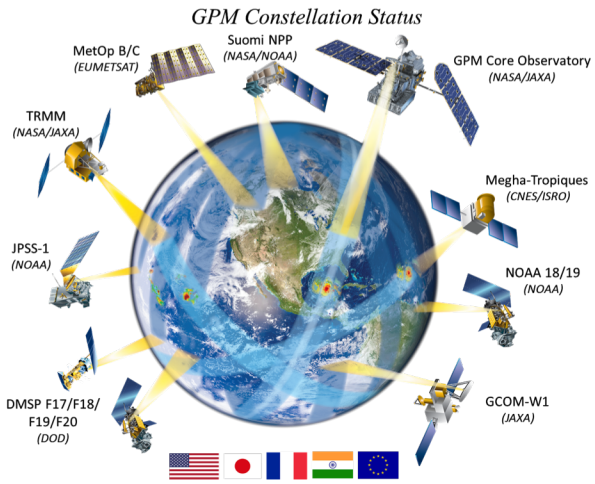
# XCAL Update

PMM XCAL Team

Wesley Berg, Faisal Alquaeid, Steve Bilanow, Ruiyao Chen, Joyce Chou, Saswati Datta, David Draper, Hamideh Ebrahimi, Spencer Farrar, Yimin Ji, Linwood Jones, Rachael Kroodsma, Darren McKague, Erich Stocker, Tom Wilheit et al.



# XCAL Activities

The **XCAL team** is a working group within the Precipitation Measurement Missions (i.e. TRMM/GPM) science team responsible for the **Level 1C intercalibrated brightness temperature files** used as input to the operational precipitation retrieval algorithm for available constellation microwave radiometers.

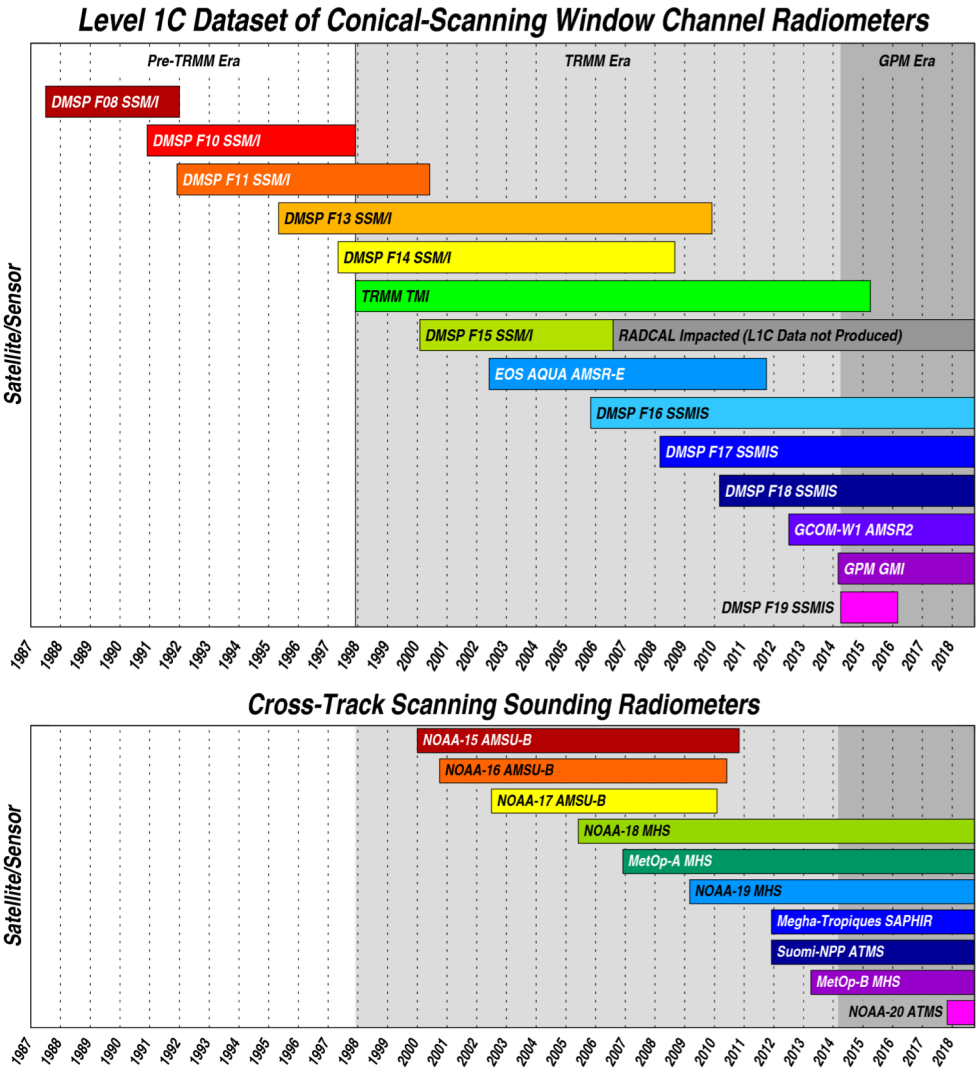
**Activities:** Following launch of the GPM core satellite in Feb 2014 (Complete, In Progress)

- Assess and update calibration for calibration reference sensor: GPM GMI V05
- Intercalibrate the GPM constellation radiometers
- Update the TRMM TMI Calibration (V8) and intercalibrate to GMI V05
- Intercalibrate the TRMM constellation radiometers
- Extend radiometer constellation back to SSM/I on board DMSP F08 in July of 1987
- Incorporate new (i.e. NOAA-20 ATMS, MetOp-C MHS) and additional sensors (i.e. WindSat)
- Ongoing (quantify uncertainties, improve techniques, RFI, documentation, etc.)

# TRMM/GPM Radiometer Constellation

## Research and Operational Sensors with Different Capabilities and Calibrations

| Satellite (Sensor) | Imager/ Sounder | 6-7 GHz | 10 GHz | 19 GHz | 23 GHz | 31-37 GHz | 85-92 GHz | 150-166 GHz | 183 GHz |
|---|---|---|---|---|---|---|---|---|---|
| **GPM GMI (Calibration Reference)** | **Imager** | | **10.65vh** | **18.7v/h** | **23.8v** | **36.64v/h** | **89.0v/h** | **166v/h** | **183.31±3, 7** |
| TRMM TMI | Imager | | 10.65v/h | 19.35v/h | 21.3v | 37.0v/h | 85.5v/h | | |
| EOS AQUA AMSR-E | Imager | 6.925v/h | 10.65v/h | 18.7v/h | 23.8v/h | 36.5v/h | 89.0v/h (A)<br>89.0v/h (B) | | |
| GCOM-W1 AMSR-2 | Imager | 6.925v/h<br>7.3v/h | 10.65v/h | 18.7v/h | 23.8v/h | 36.5v/h | 89.0v/h (A)<br>89.0v/h (B) | | |
| DMSP F08, F10, F11, F13, F14 and F15 SSM/I (6) | Imager | | | 19.35v/h | 22.235v | 37.0v/h | 85.5v/h | | |
| DMSP F16, F17, F18, F19 SSMIS (4) | Imager | | | 19.35v/h | 22.235v | 37.0v/h | 91.655v/h | 150h | 183.31±1, 3, 6.6 |
| NOAA 15, 16 and 17 AMSU-B (3) | Water Vapor Sounder | | | | | | 89qv | 150qv | 183.31±1, 3, 7qv |
| METOP A/B, NOAA 18/19 MHS (4) | Water Vapor Sounder | | | | | | 89qv | 157qv | 183.31±1, 3qh<br>190.31qv |
| Suomi NPP and NOAA-20 ATMS | Water Vapor Sounding | | | | 23.8qv | 31.4qv | 88.2 qv | 165.5qh | 183.31±1.0, 1.8, 3.0, 4.5, 7.0qh |
| Megha-Tropiques SAPHIR | Water Vapor Sounder | | | | | | | | 183.31±0.2, 1.1, 2.8, 4.2, 6.8, 11qh |




**Major Additions/Changes to Level 1C data**

- Going forward
  - Updated NPP Calibration
  - Added NOAA-20 Level 1C
- Going backward
  - Updated SSM/I corrections and intercalibration
  - Extended Level 1C data back to F08 in July of 1987

**Intercalibrated Level 1C data record**

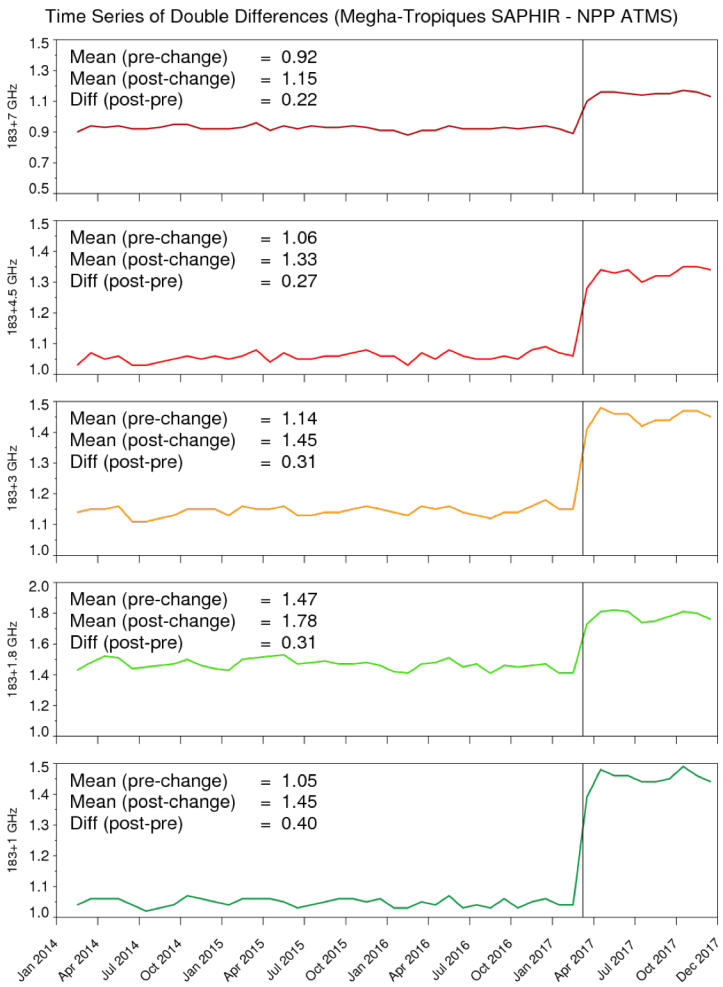
- Comprehensive
  - 31+ years
  - 14 conical-scanning window-channel imagers
  - 10 cross-track scanning water-vapor sounders
  - Most comprehensive microwave dataset available
- High quality
  - GMI V05 used as calibration reference standard
  - 20+ year TMI/GMI reference dataset
  - Focus on developing best possible corrections.
  - Used for many applications beyond precipitation

# NPP ATMS Calibration Change

## March 7, 2017

| Channel | Wilheit | Berg | Kroodsma | Mean | Stdev |
|---|---|---|---|---|---|
| 1) 23 GHz | -0.46 | -0.56 | -0.67 | **-0.56** | 0.11 |
| 2) 31 GHz | -0.26 | -0.35 | -0.34 | **-0.32** | 0.05 |
| 16) 88 GHz | -0.58 | -0.52 | -0.74 | **-0.61** | 0.11 |
| 17) 165 GHz | -0.29 | -0.19 | -0.01 | **-0.16** | 0.14 |
| 18) 183+/-7.0 GHz | -0.29 | -0.24 | -0.15 | **-0.23** | 0.07 |
| 19) 183+/-4.5 GHz | -0.34 | -0.31 | -0.21 | **-0.29** | 0.07 |
| 20) 183+/-3.0 GHz | -0.39 | -0.32 | -0.28 | **-0.33** | 0.06 |
| 21) 183+/-1.8 GHz | -0.36 | -0.32 | -0.33 | **-0.34** | 0.02 |
| 22) 183+/-1.0 GHz | -0.45 | -0.40 | -0.40 | **-0.42** | 0.03 |

Change in the NPP ATMS calibration on March 7, 2017 as determined using various intercalibration techniques. For all of the window and water vapor sounding channels analyzed, the mean Tb decreased by a few tenths to a just over half a Kelvin

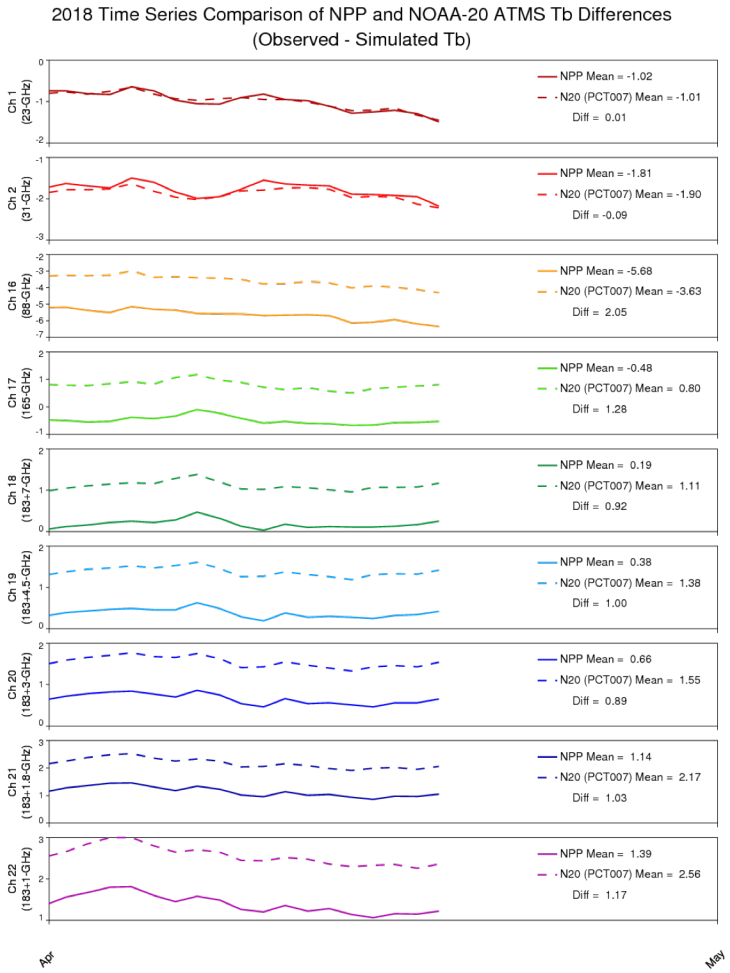


# N0AA20 – NPP ATMS Tb Differences

## (January 24 – July 31, 2018)

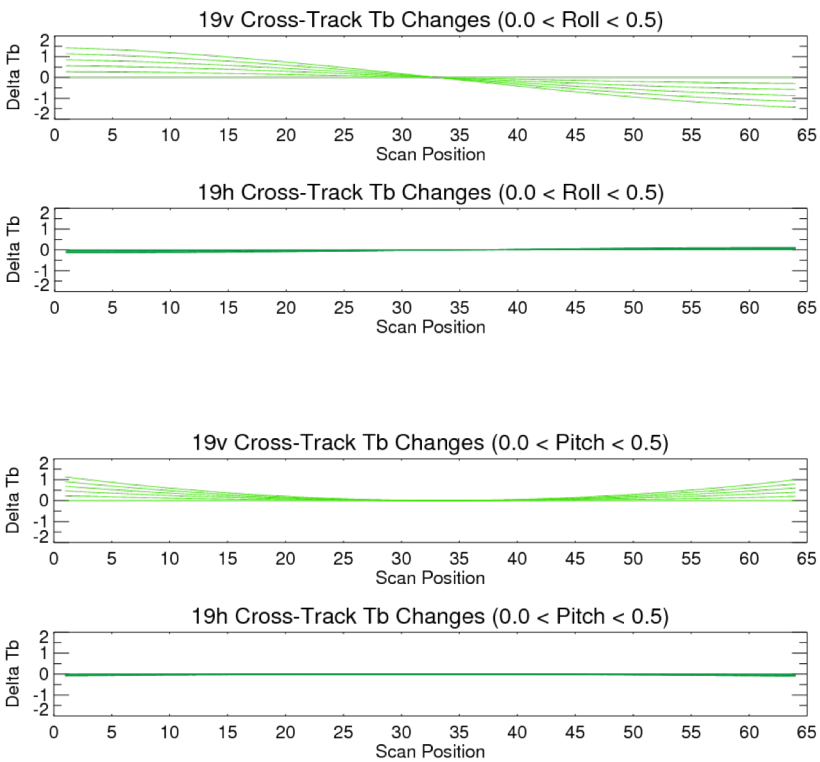
| Channel | Kroodsma (45 < EIA < 55) | Berg (45 < EIA < 55) | Kroodsma (All EIA) | Berg (All EIA) | Wilheit (All EIA) | Mean (All EIA) | Stdev (All EIA) |
|---|---|---|---|---|---|---|---|
| 1) 23 GHz | -0.10 | -0.19 | -0.24 | -0.16 | -0.26 | **-0.22** | 0.05 |
| 2) 31 GHz | -0.18 | -0.28 | -0.32 | -0.29 | -0.36 | **-0.32** | 0.04 |
| 16) 88 GHz | 2.32 | 2.26 | 1.58 | 1.73 | 1.68 | **1.66** | 0.08 |
| 17) 165 GHz | 1.13 | 0.82 | 1.17 | 0.80 | 0.97 | **0.98** | 0.19 |
| 18) 183+/-7.0 GHz | 0.95 | 0.76 | 1.06 | 0.90 | 0.96 | **0.97** | 0.08 |
| 19) 183+/-4.5 GHz | 0.95 | 0.75 | 1.04 | 0.82 | 0.89 | **0.92** | 0.11 |
| 20) 183+/-3.0 GHz | 0.95 | 0.66 | 1.09 | 0.79 | 0.98 | **0.95** | 0.15 |
| 21) 183+/-1.8 GHz | 0.94 | 0.75 | 1.07 | 0.88 | 1.04 | **1.00** | 0.10 |
| 22) 183+/-1.0 GHz | 1.05 | 0.83 | 1.14 | 1.01 | 1.16 | **1.10** | 0.08 |

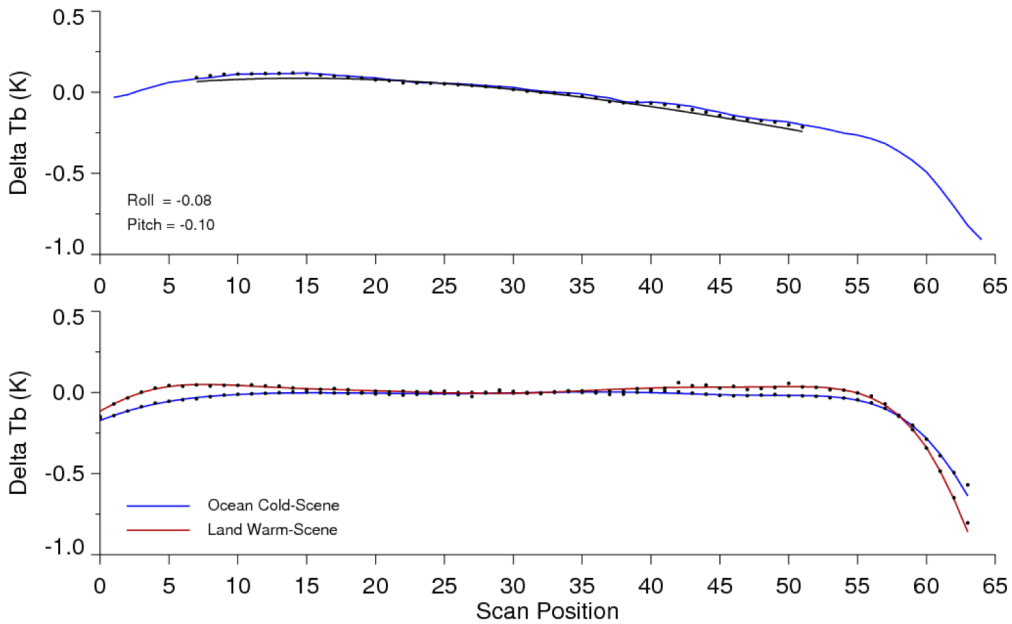
Mean ATMS SDR Tb differences between NOAA20 and NPP for window and water vapor channels based on six months of validated NOAA-20 SDR data.



# Updates to SSM/I Calibration Corrections

## Cross-Track Biases

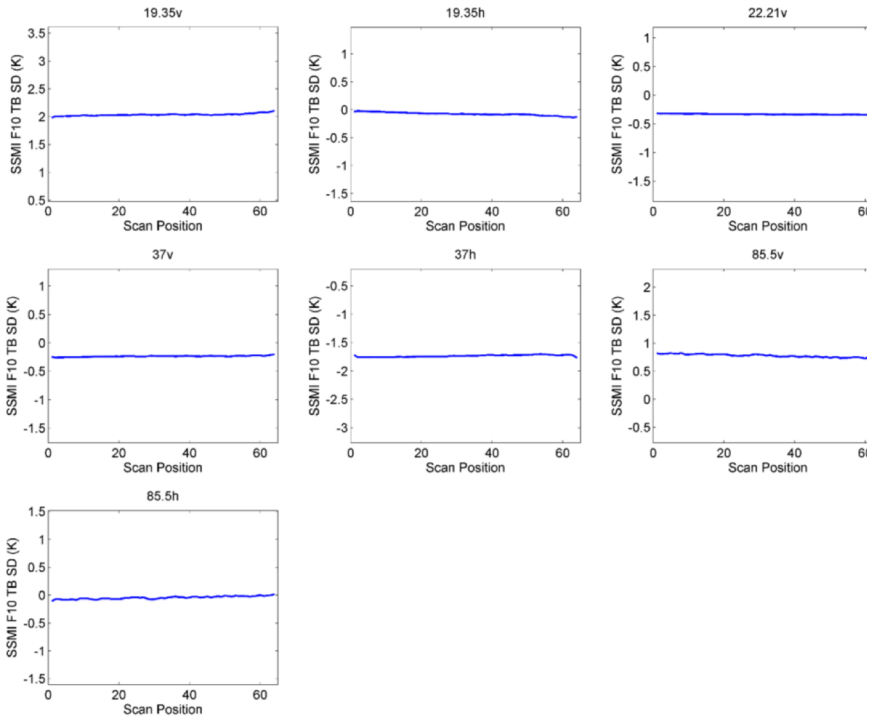


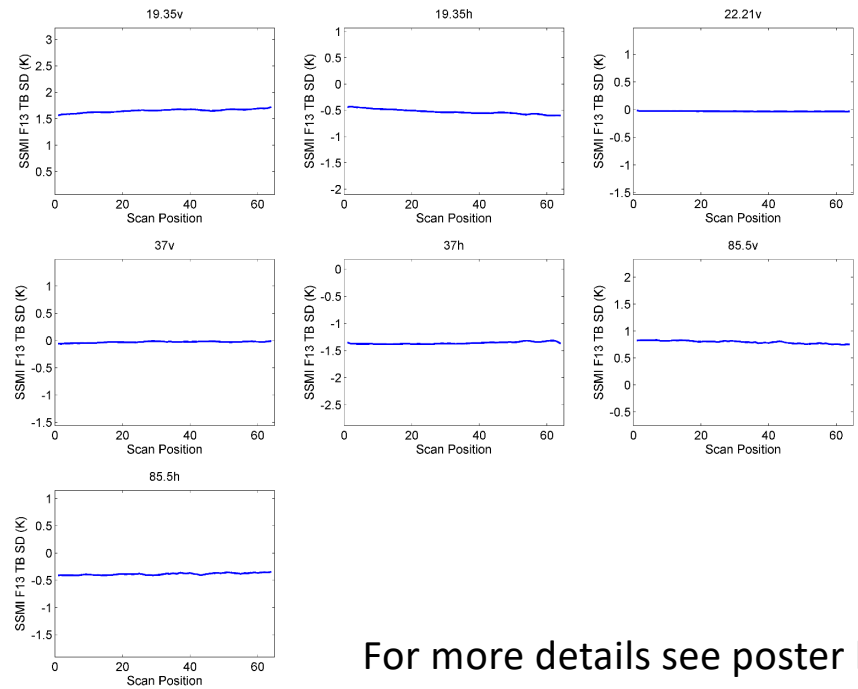
# Verification of Cross-Track Bias Correction

## Based on SSM/I Warm-Cal Analysis

**DMSP F10**



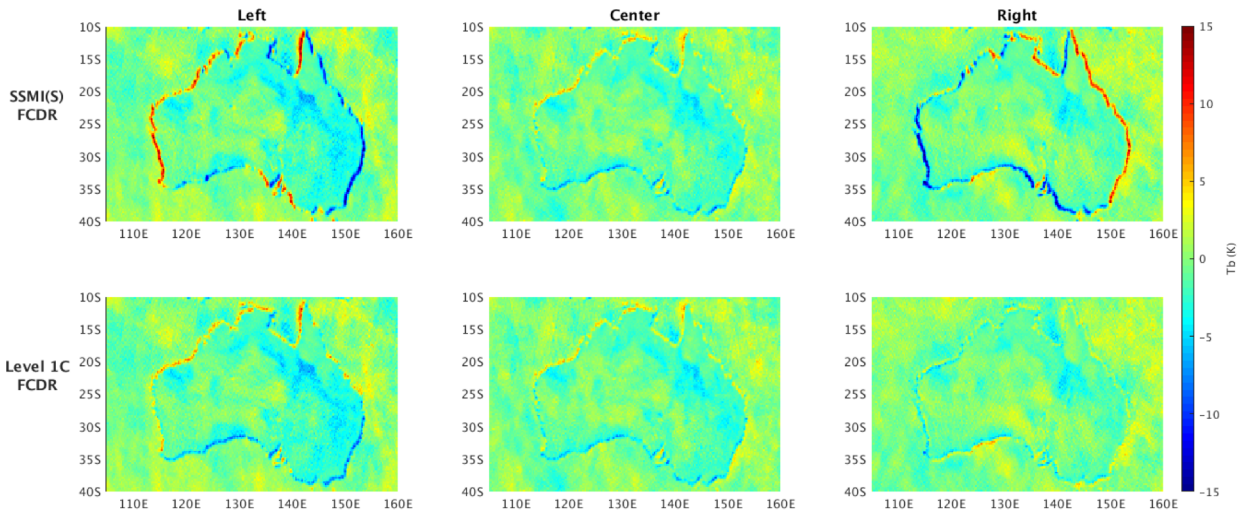

**DMSP F13**



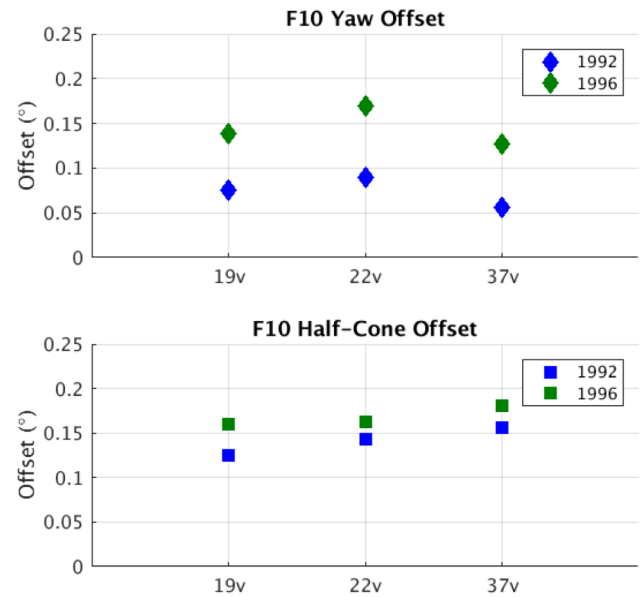

For more details see poster by Darren McKague

# Updates to SSM/I Calibration Corrections

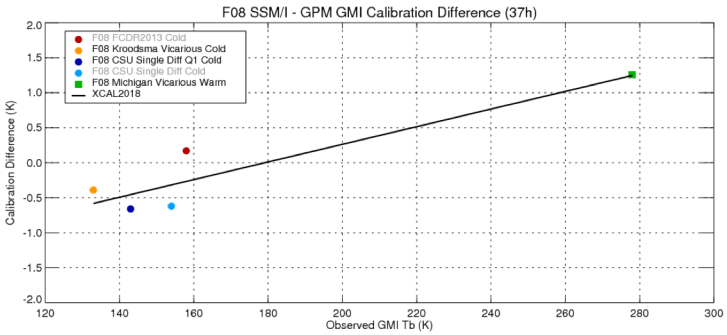
## Cross-Track Biases



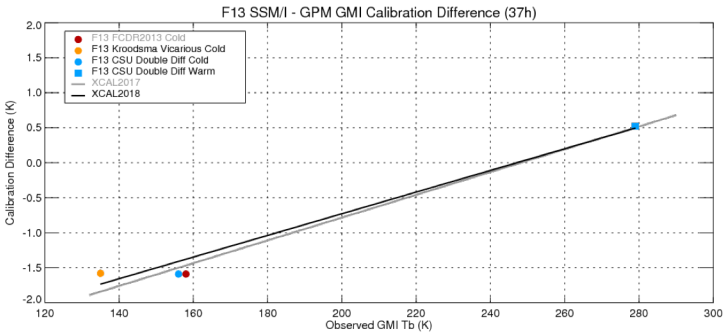

| Satellite | Roll | Pitch | Yaw | Cone |
|---|---|---|---|---|
| F08 | 0.05 | 0.07 | -0.63 | -0.02 |
| F10 | -0.08 | -0.10 | 0.11 | 0.15 |
| F11 | 0.00 | -0.06 | -0.23 | -0.05 |
| F13 | -0.06 | -0.08 | -0.05 | -0.40 |
| F14 | -0.07 | -0.09 | -0.74 | -0.27 |
| F15 | 0.00 | -0.03 | 0.13 | -0.37 |



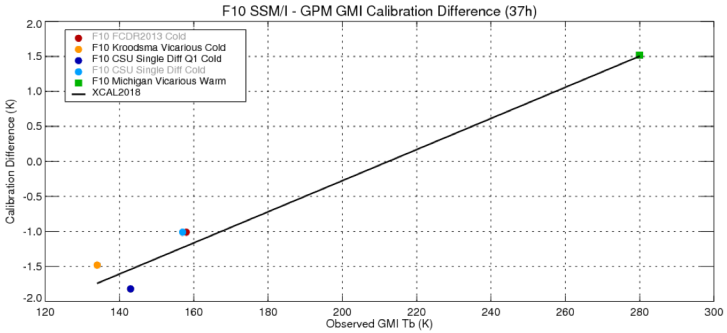
**F08**



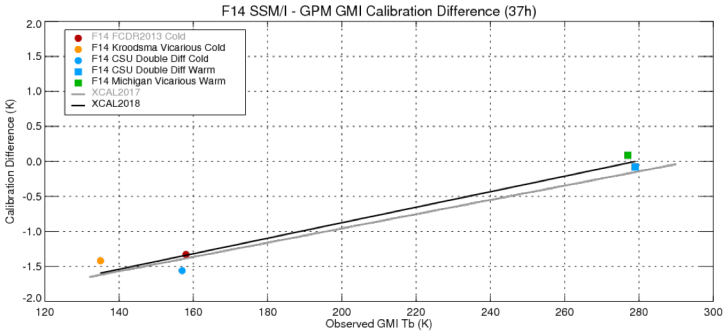

**F13**



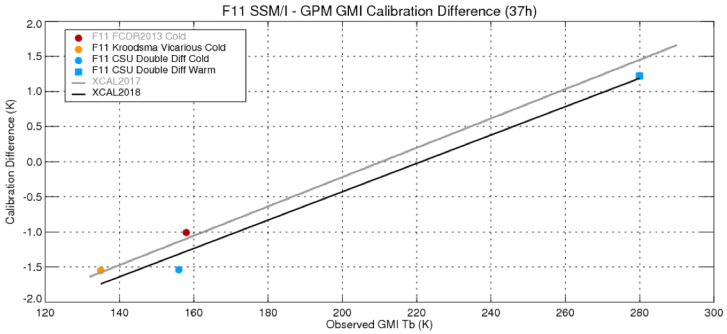

**F10**



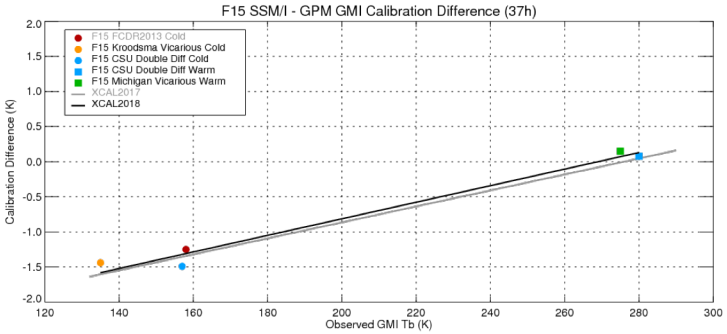

**F14**




**F11**

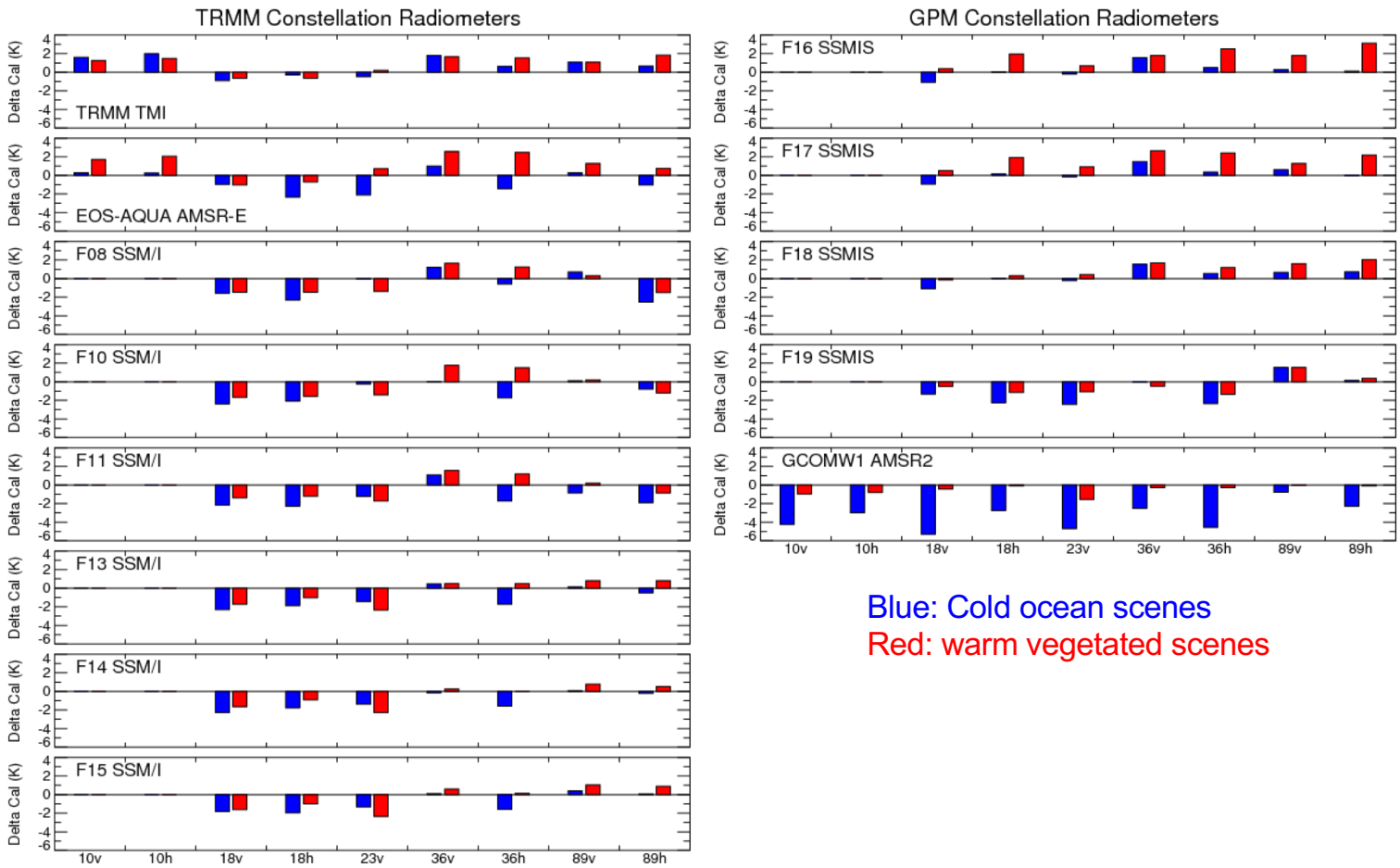



**F15**



# TRMM/GPM Radiometers Calibration Differences

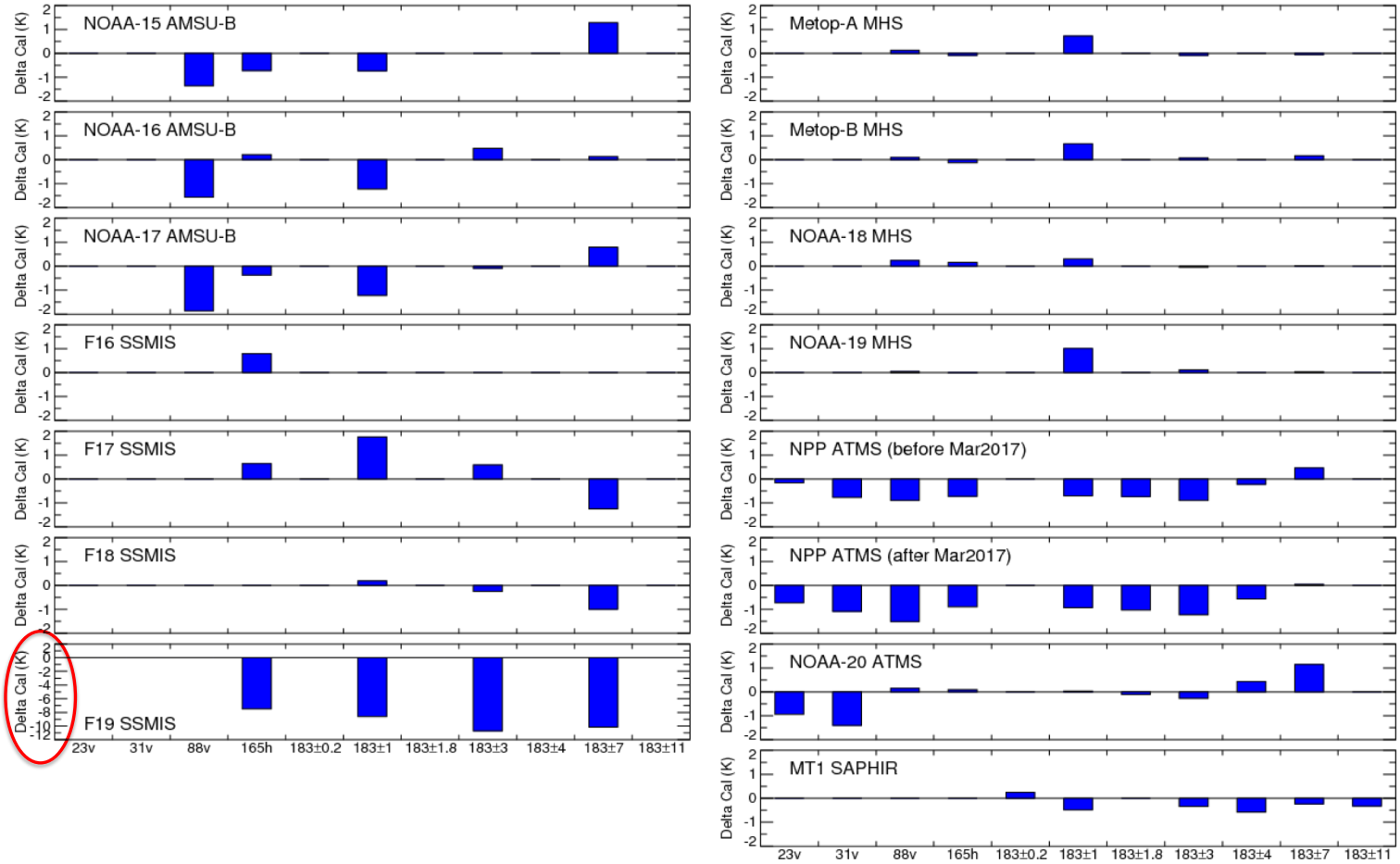
## Conical-Scanning Imagers




Blue: Cold ocean scenes
Red: warm vegetated scenes

# TRMM/GPM Radiometers Calibration Differences

## Cross Track Scanning Water Vapor Sounders

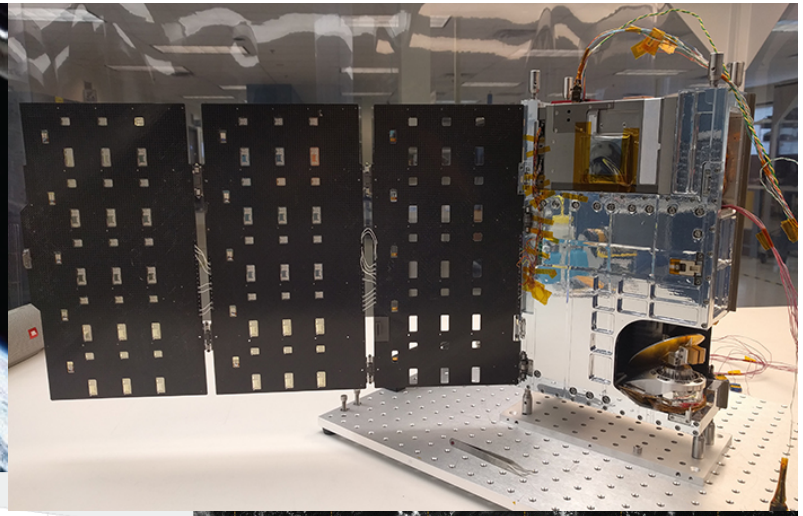


# XCAL Priorities and Plans

- Monitor/respond to sensor issues
- Incorporate new sensors
- Revisit corrections and quality flags for SSMIS, AMSU-B, etc.
- Coordinate with algorithm teams
  - Data quality issues
  - Radiative transfer models
- Uncertainties: Continue to improve techniques and quantify residual calibration uncertainties
- Documentation: Develop report on lessons learned

## Future Radiometers

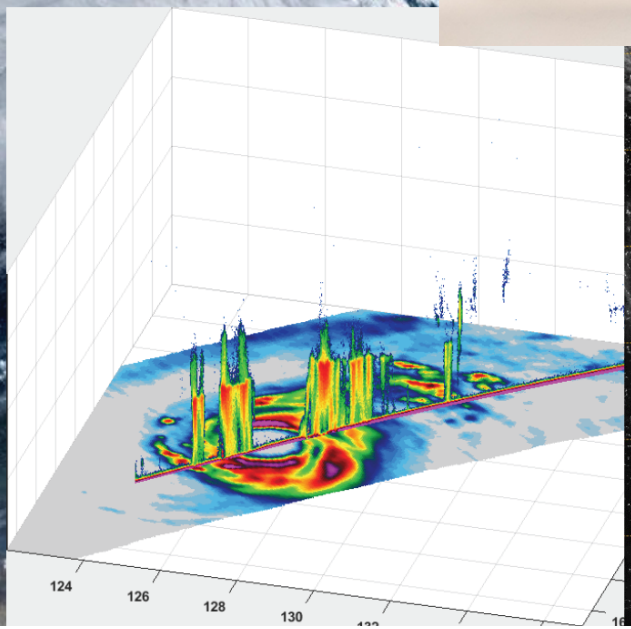
| Satellite | Sensor | Status | Launch Date |
|---|---|---|---|
| MetOp-C | MHS | Approved | Dec 2018 |
| JPSS-2 (NOAA-21) | ATMS | Approved | Dec 2021 |
| MetOp-SG-a1 | MWS | Approved | Sep 2021 |
| MetOp-SG-b1 | MWI, ICI | Approved | Dec 2022 |
| Weather System Follow-On Microwave | WSF-M | Approved | Late 2022 |
| GCOM-W2 | AMSR3 | Considered | ? |
| CubeSats? | | | |

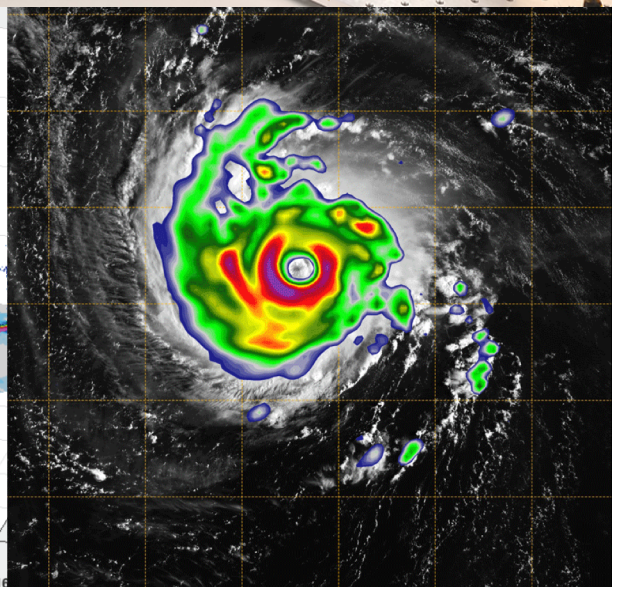


- September 28, 2018, TEMPEST-D and RainCube overflew Typhoon Trami < 5 minutes apart

- RainCube nadir Ka-band reflectivity shown overlaid on TEMPEST-D 165 GHz brightness temperature illustrating complementary nature of these sensors in constellation for observing precipitation

- Trami observed shortly after it had weakened from Cat 5 to Cat 2



# Summary

- Instruments on the GPM core satellite are operating nominally with 4 ½ year data record
- GMI is extremely well calibrated and stable, providing an ideal calibration reference for the constellation radiometers.
- The current Level 1C Tb dataset for 24 sensors has been intercalibrated to GMI V05 and is available from the PPS.
- Berg, W. et al., 2016: Intercalibration of the GPM Radiometer Constellation, *J. Atmos. Oceanic Technol*., 33, 2639-2654, https://doi.org/10.1175/JTECH-D-16-0100.1.
- Berg, W., R. Kroodsma, C. D. Kummerow, and D. S. McKague, 2018: Fundamental Climate Data Records of Microwave Brightness Temperatures, *Remote Sensing*, 10(8), 1306; https://doi.org/10.3390/rs10081306.

# Level 1C Status and Plans

- GPM V05 reprocessing (April 2017)
  - Changes to GMI calibration, primarily low frequency channels
  - Level 1C Tb data available for GPM constellation radiometers
- TRMM reprocessing (October 2017)
  - TMI calibration updates
  - Intercalibrated to GMI V05
  - Includes constellation sensors back to December 1997
- ATMS (July 2018)
  - NPP Update for March 2017 calibration change
  - NOAA-20 Added
- DMSP SSM/I reprocessing (October 2018)
  - July 1987 forward
- Future instruments
  - MetOp-C MHS (Dec 2018)
  - JPSS2 ATMS (Nov 2019)
  - MetOp-SG-a1 MWS (Sep 2021)
  - MetOp-SG-b1 MWI & ICI (Dec 2022)
  - WSF-M (2022?)