AN EVALUATION OF THE CURRENT STATE OF CALIBRATION AND RAIN RETRIEVAL CONSISTENCY FOR THE GPM RADIOMETER CONSTELLATION

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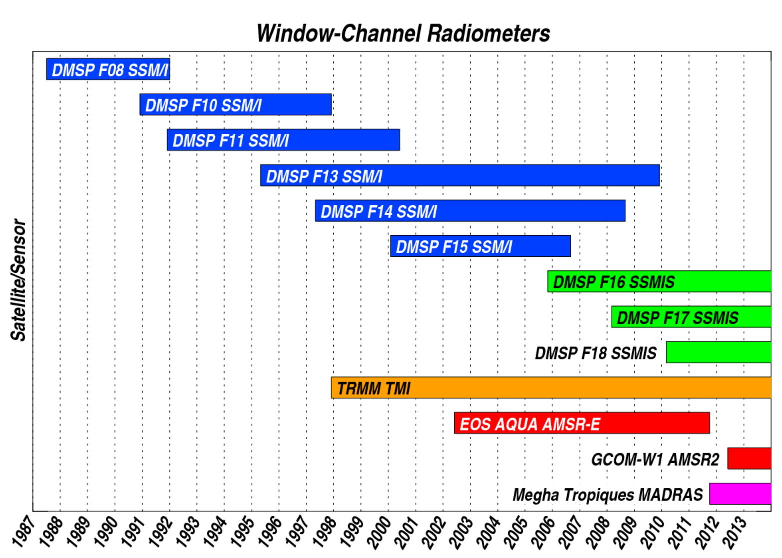
INTRODUCTION



The figure on the left shows a time series of availability of both historical and current window-channel radiometers used for precipitation retrievals. For GPM the current DMSP F16, F17, and F18 sensors along with AMSR2 and MADRAS will be critical elements of the radiometer constellation. Characterizing intercalibration differences between these sensors and the GMI instrument on board GPM core will be extremely important for producing consistent high-quality global precipitation estimates. Work has been ongoing for some time to intercalibration existing sensors extending back to the for SSM/I instrument launched on board DMSP F08. While the long-term record is important for climate applications, it is also valuable for investigating and understanding calibration issues affecting the GPM constellation.

SSMI/SSMIS FCDR Intercalibration

Relative to F13 SSM/I (> 1K in red)

Sat	19V	19H	22V	37V	37H	85V/91V	85H/91H
F08	0.7	0.2	1.4	0.8	1.6	1.9	-0.5
F10	0.1	0.2	1.3	-0.2	0.5	0.4	0.1
F11	0.2	-0.2	0.2	0.7	0.4	-0.6	-1.2
F13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F14	0.3	-0.2	0.1	-0.2	0.0	0.5	0.4
F15	0.3	-0.3	-0.1	0.2	0.0	0.3	0.1
F16	0.7	-0.8	0.4	-2.0	-2.1	1.6	0.4
F17	0.3	-1.0	-0.4	-2.4	-1.5	3.6	2.5
F18	0.7	0.3	0.1	-1.4	-0.8	3.0	2.3

Radiometer Constellation Intercalibration

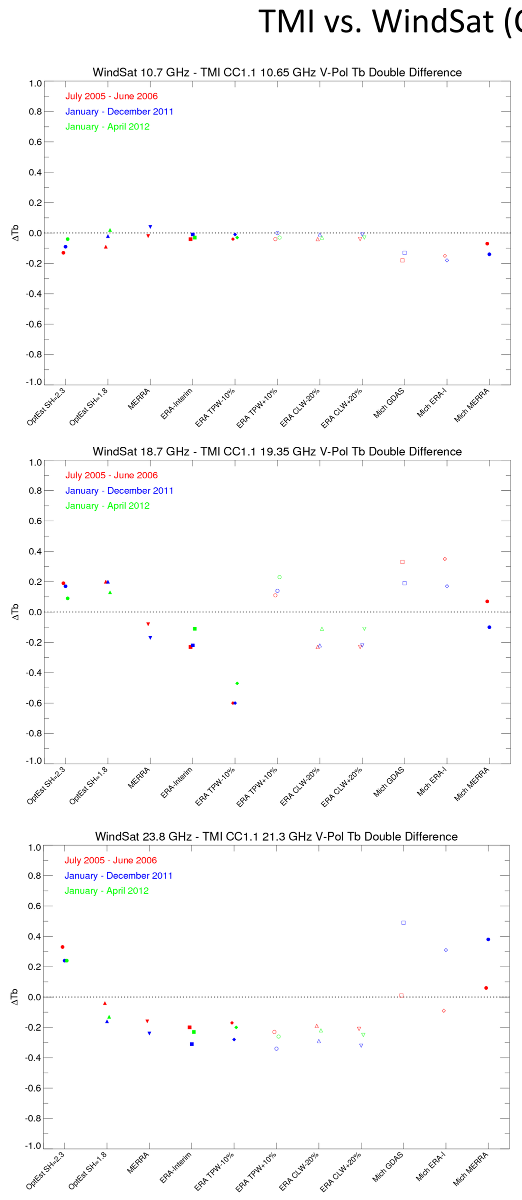
Relative to TMI 1B11 V7 (> 2K in red)

Sat	10V	10H	19V	19H	22V	37V	37H	85V/91V	85H/91H
TMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSM/I F13	N/A	N/A	-1.2	-2.0	-1.8	-1.2	-2.2	-0.8	-1.4
SSMIS F16	N/A	N/A	0.0	2.3	1.7	3.3	4.1	-1.0	0.8
SSMIS F17	N/A	N/A	0.9	2.9	3.0	3.7	3.7	-2.6	-1.5
SSMIS F18	N/A	N/A	0.2	1.3	2.2	2.7	3.0	-2.5	-1.3
AMSR-E	0.0	0.4	-0.6	0.0	-0.5	-2.1	-0.4	-4.3	-3.5
AMSR2	4.1	5.1	4.0	2.8	4.6	4.4	5.2	2.7	3.7
WindSat	-0.3	1.6	0.6	2.9	2.0	3.1	2.4	N/A	N/A
FY3B	-3.5	-2.1	-1.5	-1.8	-1.0	-2.3	0.4	0.4	0.6

The table on the left shows a comparison of intercalibration differences determined as part of the development of a long-term intercalibrated Fundamental Climate Data Record (FCDR) of the nine window-channel radiometers on board the Defense Meterological Satellite Program (DMSP) satellites. The table on the right shows initial intercalibration differences for the currently available constellation members, many of which will comprise the GPM constellation. It is critical to characterize and adjust for these inconsistencies before running the precipitation retrieval algorithm or the result will be substantial inconsistencies in the retrieved precipitation estimates.

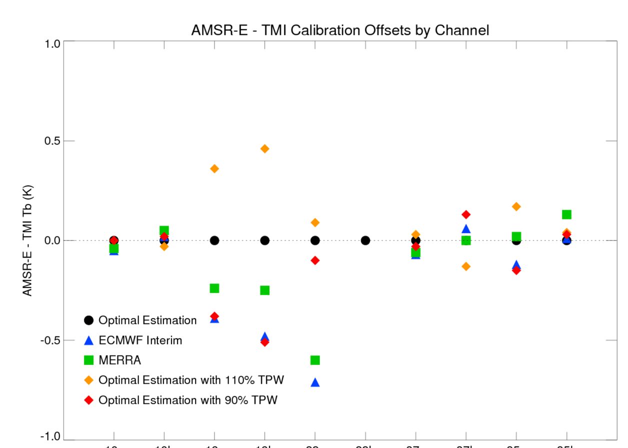
Intercalibration of GPM Constellation

TMI vs. WindSat (Comparison of Intercalibration Techniques)



The three panels on the left show a comparison of intercalibration differences, or offsets, between the 10.7v, 18.7v, and 23.8v channels on WindSat vs. the comparable TMI channels. The various techniques include an optimal estimation approach to estimating non-precipitating geophysical parameters for simulating the expecting differences between the two sensors and using MERRA, and ECMWF interim reanalysis (ERA). Variations to the total precipitable water (TPW) and cloud liquid water (CLW) estimates are also made using the ERA data. All of these approaches rely on a double difference approach that differences simultaneous observed Tb over non-precipitating ocean scenes with simulated differences. In addition, however, results from the University of Michigan's vicarious cold calibration analysis are included, which also use different sources for the geophysical parameter retrievals and do not rely on simultaneous observations. Results from three different periods shows by the different colors are compared for each different techniques.

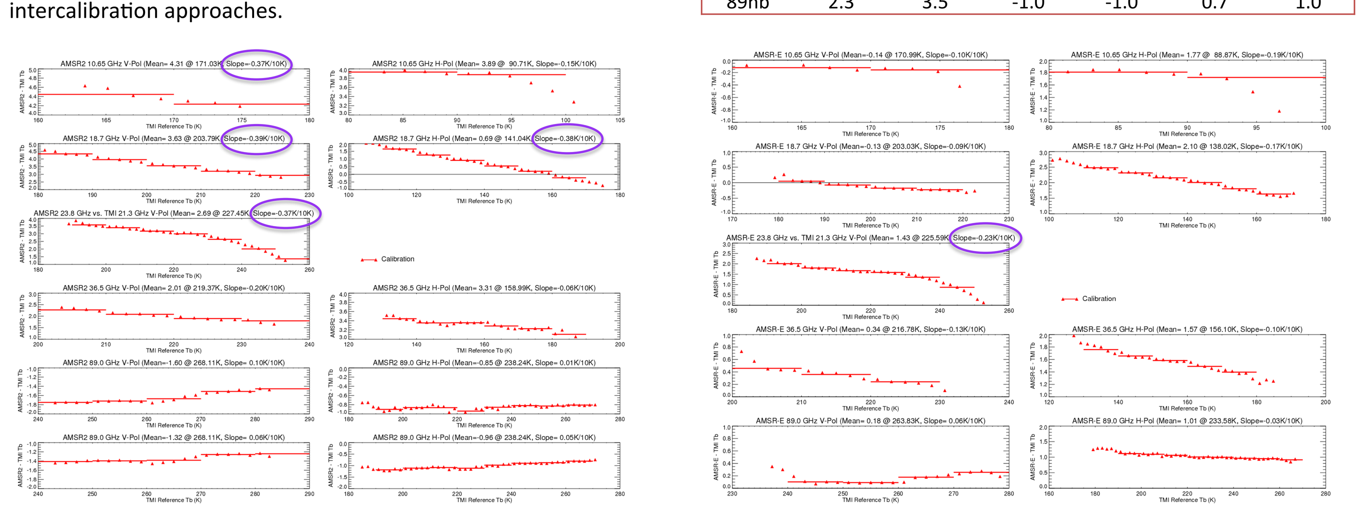
Due to the similarity of the 10v channels on WindSat and TMI, the results are very similar among the techniques and quite consistent between the three observing periods. Differences in the 18v and 23v channels, however, lead to much larger sensitivity to the intercalibration technique/assumptions. A similar comparison for AMSR-E vs. TMI is shown below with a subset of these techniques, but for all nine common channels. These results shown significant sensitivity for the 19 GHz channels to TPW changes and sensitivity for the 22v channel to differences in the TPW profile between the OE and reanalysis results.



AMSR-2 and AMSR-E vs. TMI

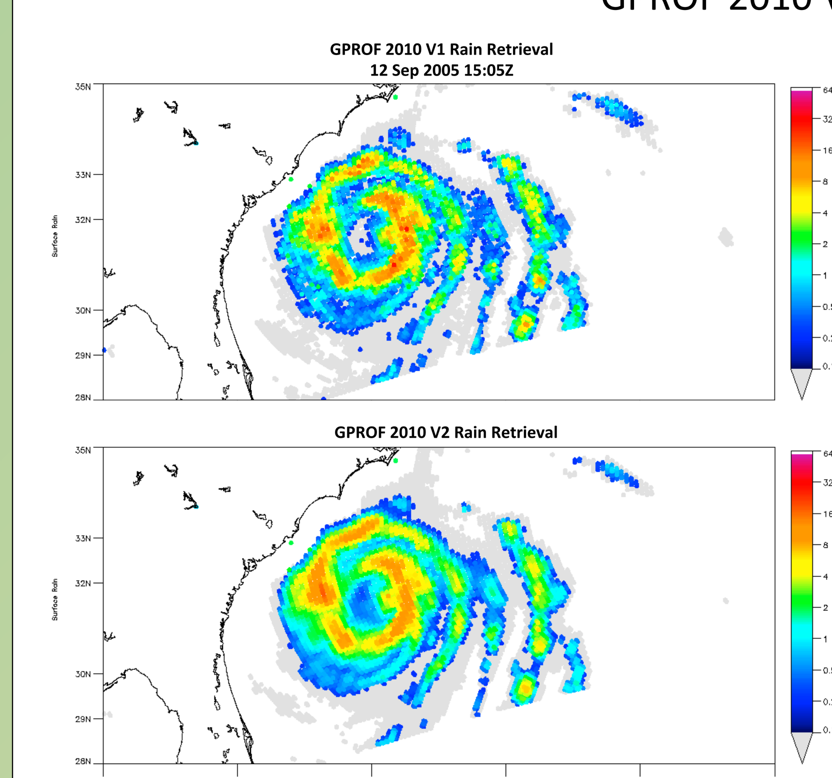
A comparison of intercalibration offsets between the recently launched AMSR2 instrument on board GCOM-W1 and TMI is shown along with AMSR-E vs. TMI results in the table on the right. Results from the Japanese using a similar double difference technqiue are also given. Although the Japanese results are based on the V0 calibration of the AMSR2 data, vs. V1 for the CSU results, the values are quite consistent showing significant differences in the calibrations between AMSR-E and AMSR2 even though the instrument is almost identical. The intercalibration plots shown below show significant scene-temperature dependence in the results for several of the AMSR2 channels. Such large differences beween warm and cold scene calibration for AMSR2 as well as other constellation sensors is a significant issue requiring further development of warm-scene intercalibration approaches.

Channel	AMSR2 Japan	AMSR2 CSU OptEst	AMSR2 CSU OptEst (cc1.1)	AMSR2 CSU ERA-I (cc1.1)	AMSR-E Japan	AMSR-E CSU OptEst
10v	4.3	4.1	4.3	4.2	-0.2	-0.1
10h	5.0	5.1	3.9	3.9	1.4	1.8
18v	3.5	4.0	3.6	3.2	-0.1	-0.1
18h	2.7	2.8	0.7	0.1	1.9	2.1
23v	5.5	4.6	2.7	1.8	1.5	1.4
23h	N/A	N/A	N/A	N/A	N/A	N/A
36v	3.9	4.4	2.0	1.9	0.4	0.3
36h	4.5	5.2	3.3	3.4	1.2	1.6
89va	1.9	2.7	-1.6	-1.8	-0.1	N/A
89ha	2.8	3.7	-0.9	-0.9	0.7	N/A
89vb	1.9	3.0	-1.3	-1.5	-0.1	0.2
89hb	2.3	3.5	-1.0	-1.0	0.7	1.0



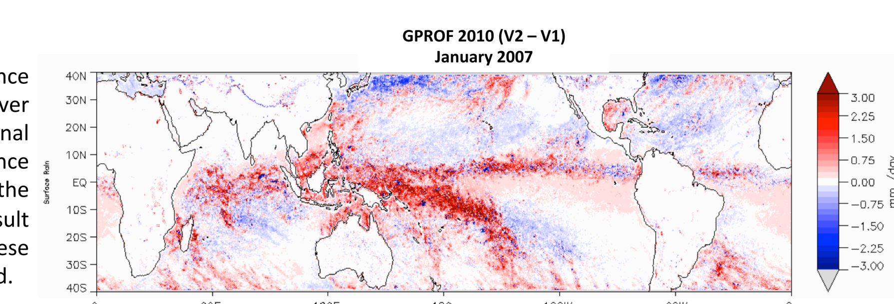
Rainfall Retrieval

GPROF 2010 V2

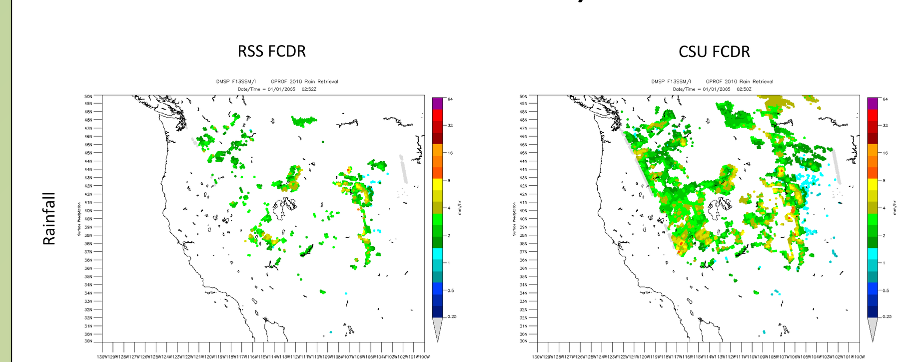


GPROF 2010 V1 is the generic name for the operational microwave rain retrieval algorithm. This algorithm corresponds to the 2A12 V7, which is the TMI implementation of this algorithm. In applying this retrieval to other sensors problems were found in the implementation of the Bayesian weighting used in the retrieval as well as the clustering of the apriori database. Changes to the retrieval to correct for these issues as well as to better account for differences in the channel uncertainties for the various sensors has led to the development of V2. The figure on the left shows the difference between V1 and V2 for a hurricane. While the rain area and intensity of the rain rate estimates has changed very slightly, the rain patterns are much smoother in the new version due to the changes in the Bayesian weighting. These changes also lead to better agreement between sensors, although work to apply the new algorithm to SSM/I, SSMIS, and AMSR-E is currently ongoing.

The figure on the right shows the difference between V1 and V2 of GPROF 2010 averaged over the month of January 2007. There are clear regional differences with more rain over the convergence zones and less in the subsidence areas and in the Northern mid-latitude regions. Note that this result is preliminary and more investigation of these changes will be done once the retrieval is finalized.



Sensitivity of the Retrieval to Input Tb



The figure on the left shows the sensitivity of the GPROF 2010 land algorithm to differences in the input Tb data. The panel on the left is based on using Remote Sensing Systems (RSS) V6 Tb dataset and the figure on the right uses the CSU FCDR input Tb data. While substantial effort is being made to develop a new land-based retrieval for GPM, it will be important to investigate the sensitivity of the retrieval algorithm over various surfaces to uncertainties in the calibration of the input Tb dataset.

Impact of Differences in Sensor Characteristics and Information Content

Radiometer Constellation

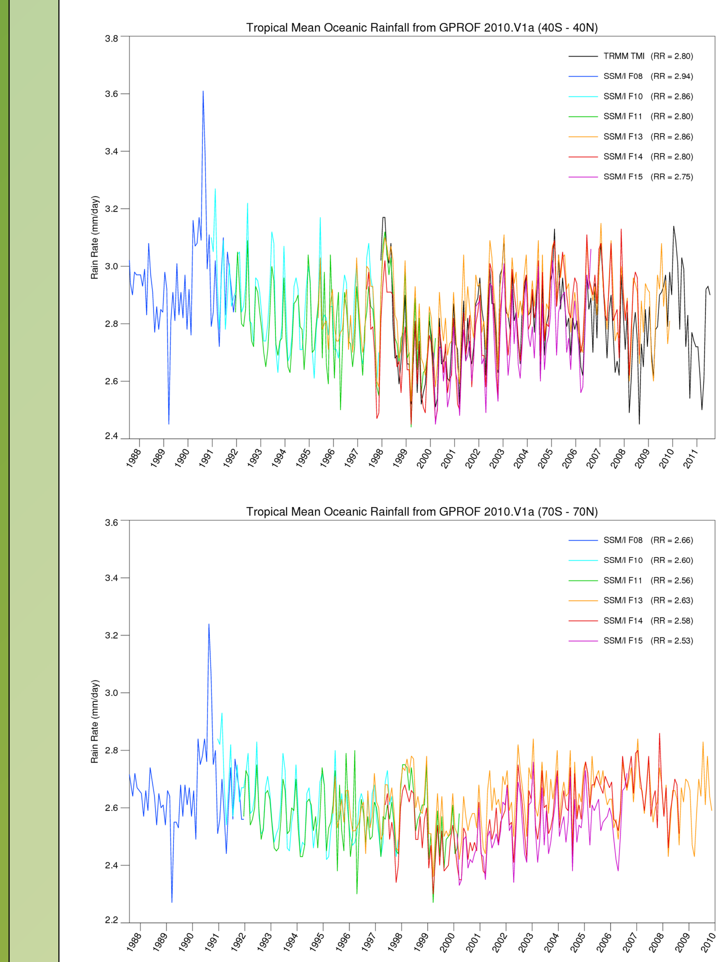
Spatial Resolution Differences

Sat	10 GHz	19 GHz	22 GHz	37 GHz	85 GHz	Area Ratio
TMI pre-boost	60x36	30x18	27x17	16x10	7x4	1.0
TMI post-boost	68x41	35x21	31x19	18x11	8x5	1.3
SSM/I	N/A	69x43	60x40	37x29	15x13	6.1
SSMIS	N/A	74x45	73x45	45x29	16x13	7.2
AMSR-E	51x30	27x16	31x18	14x8	6x4	0.9
WindSat	38x25	27x16	20x12	13x8	N/A	0.6
FY3B	85x51	50x30	45x28	30x18	15x9	3.1

While the goal of the changes in GPROF 2010 is to produce consistent precipitation retrievals in the mean sense, differences in sensor characteristics and information content will impact the retrieval regionally. A sensor with more information (i.e. more channels, higher spatial resolution) will better capture changes from the apriori database. For example, the table on the left shows the substantial differences in spatial resolution between the DMSP sensors and the TMI/GMI/AMSR-E/AMSR2 sensors. Obviously the higher resolution sensor will better capture details within storms, but it can also impact regional differences due to beam filling effects etc.

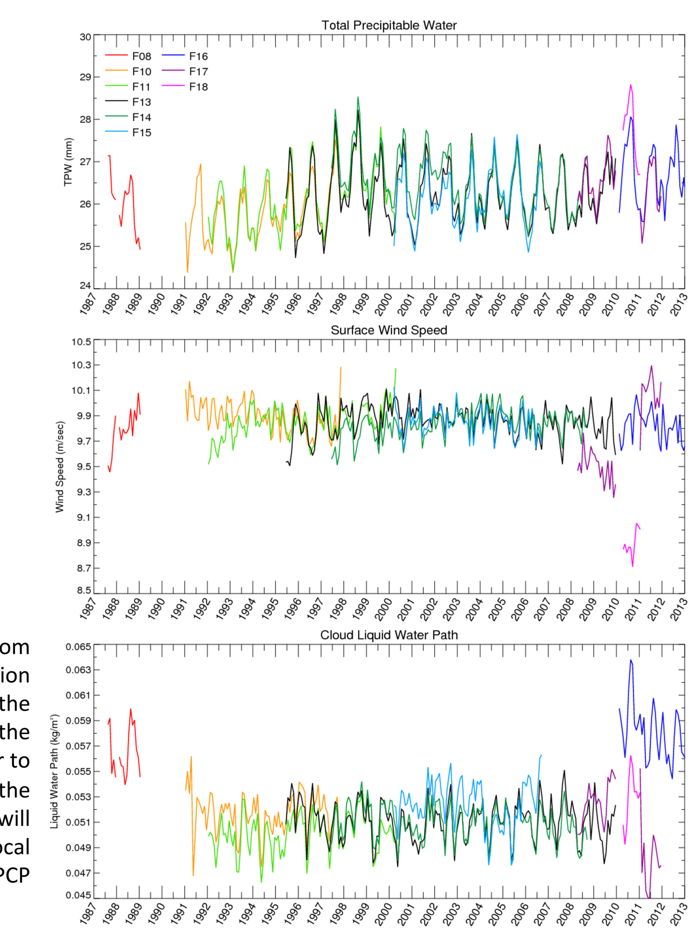
Long-Term Climate Data Record

Precipitation Time Series



While the window-channel radiometers in the GPM constellation will include GMI, the SSMIS on board F16, F17, and F18, AMSR2, and MADRAS, intercalibration efforts with past sensors has proved valuable for developing intercalibration approaches, identifying sensor issues, and determining sources of uncertainties. The long-term data archive available from the DMSP sensors as well as TMI and AMSR-E is also extremely valuable for climate applications. Continuing to apply improved knowledge and techniques to older sensors and long-term data archives is a signficant benefit from the ongoing PMM intercalibration efforts.

Non-Precipitating Retrieval Time Series



The figures above show the 20+ year time series of rainfall from GPROF 2010 V1 for multiple sensors over the TRMM ocean region (top) and between 70S and 70N over the oceans (bottom). With the exception of a significant increase in the F08 rainfall due to the failure of the 85 Ghz channels, these monthly mean values appear to be quite consistent. With the exception of TRMM TMI all of the sensors are in sun-synchronous orbits so diurnal differences will remain. The plot below (courtesy Eric Nelkin) shows the local sampling time for all of the sensors used in the merged GPCP product.

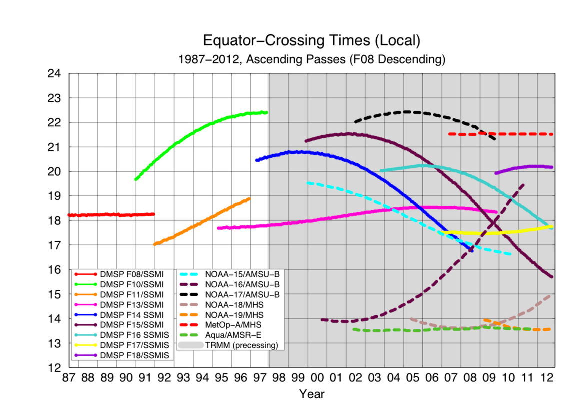


Image by Eric Nelkin (SSAI), 26 October 2012, NASA/Goddard Space Flight Center, Greenbelt, MD.

Retrievals from a non-precipitating optimal estimation retrieval were run over oceans for the sensors in the DMSP satellite series. This retrieval is much more sensitive to differences in the calibration and is thus used as a validation tool to assess the consistency in the intercalibrated DMSP FCDR dataset. Retrieved fields include total precipitable water, surface wind speed, and cloud liquid water. Consistency between the intercalibrated SSM/I sensors appears quite good, with the possible exception of F08, which was more problematic due to a lack of signficant overlap with the other sensors. Differences between the SSMIS sensors as well as with the SSM/I sensors are much larger and work is ongoing to identify and correct for issues leading to these differences.

SUMMARY

1. Intercalibration
   - Differences in current radiometer constellation are greater than several Kelvin in many cases. These inconsistencies between radiometers will have a significant impact on precipitation retrievals if not properly accounted for.
   - Differences in the intercalibration techniques and errors in the geophysical parameters used to estimate expected sensor differences are significant for certain channel combinations.
   - Changes in the intercalibration between sensors as a function of scene temperature are significant in many cases, requiring further development of warm-scene intercalibration approaches.
2. GPROF Precipitation Retrieval
   - GPROF 2010 (i.e. 2A12 V7) had several issues affecting the retrieval consistency between sensors. Changes to the Bayesian weighting and to the database clustering appear to have largely resolved this, although work is ongoing.
   - Differences in the information content of the sensors including spatial resolution, channel complement etc. will affect regional differences. Further investigation of these issues will be performed once the retrieval is finalized.
3. Validation and Long-Term Applications
   - Rain retrievals from SSM/I, TMI, and AMSR-E generally show good consistency over oceans.
   - Non-precipitating optimal estimation retrieval is more sensitive to calibration issues and is thus extremely useful for diagnosing calibration issues. A comparison of the SSM/I sensors shows good agreement, but differences with the SSMIS sensors indicates more work needs to be done prior to the GPM launch.

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