Creating a Consistent Multi-Decadal Oceanic TRMM-GPM Brightness Temperature Data Record

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Abstract

The Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI) and the Global Precipitation Measuring (GPM) Microwave Imager (GMI) have been used as the radiometric transfer standard one after another for the GPM constellation radiometers, during the past nearly two decades. Given that GMI and TMI share only a 13-month common operational period, for the time there is no overlap in between, WindSat can serve as the calibration bridge to provide additional intercalibration for the realization of a consistent multi-decadal oceanic brightness temperature (Tb) product. Thus, we conducted the intercalibration of TMI/GMI for 13-month period, TMI/WindSat for >9 years' overlap period, and WindSat/GMI XCAL for one year, to assess the Tb bias of one to another. A multi-decadal oceanic Tb dataset was thereafter achieved to ensure a consistent long-term precipitation record that covers TRMM and GPM eras. Moreover, a generic uncertainty quantification model (UQM) was developed by taking various sources of uncertainties into account rigorously and orderly. This UQM model was then applied to quantify the uncertainty estimates associated with these Tb biases. This allows the unified high-sampling-frequency and globally-covered Tb product with associated boundary uncertainties to be much improved for scientific utilization as compared to existing Tb products that are with ad-hoc uncertainties estimates. Moreover, based upon the results of uncertainty quantification process, it is recognized that there is room for improvement in the intercalibration for the water vapor sensitive channels. Further analysis indicates that the issue may be associated with the atmospheric water vapor profile input to the radiative transfer model. Suggestions are subsequently made to use water vapor profile retrieved from millimeter radiometer sounders' measurements (rather than numerical weather predictions) to determine the impact on the Tb biases of these problematic channels.

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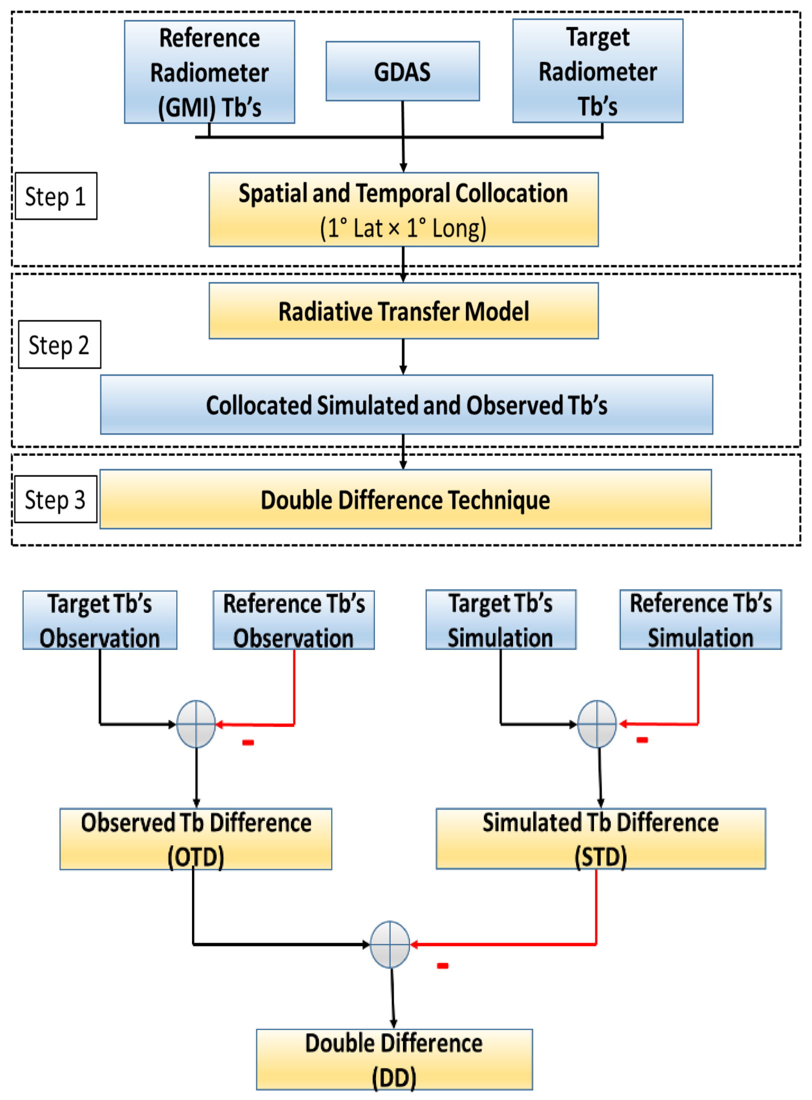
ABSTRACT

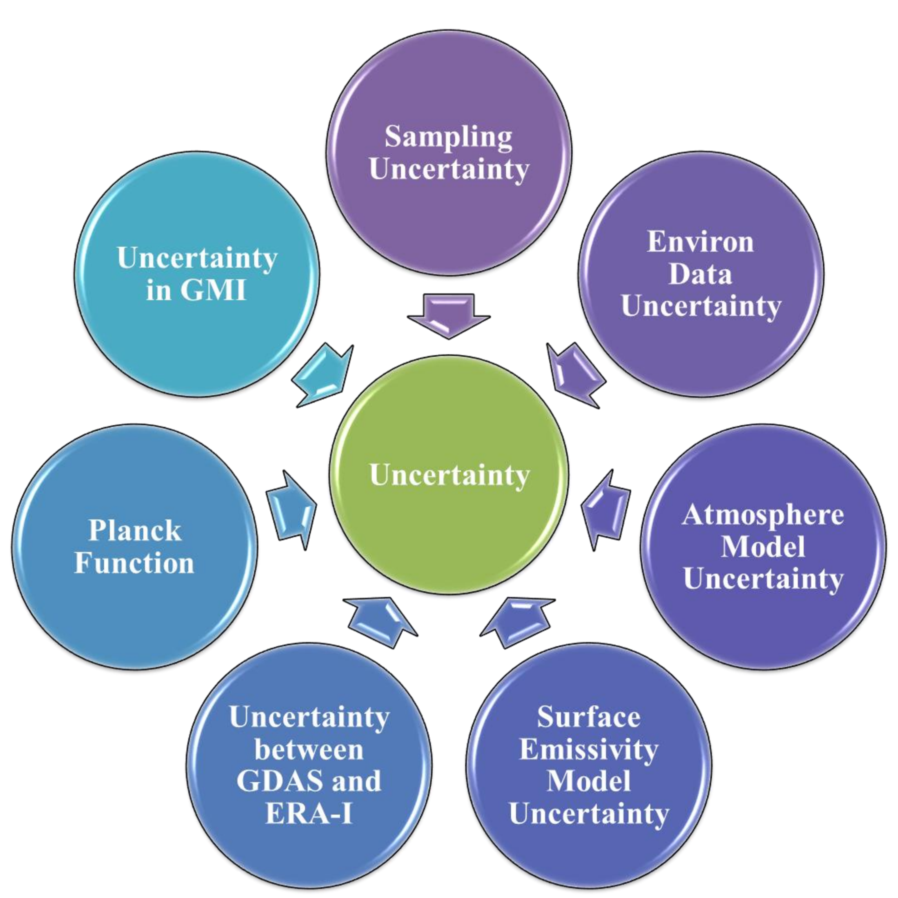
During the past nearly two decades, the Tropical Rainfall Measurement Mission Microwave Imager (TMI) and the Global Precipitation Mission Microwave Imager (GMI) have been used as the radiometric transfer standards for the NASA PPMM constellation radiometers.
Since GMI and TMI share only a 13-month common operational period, the WindSat radiometer serves as the calibration bridge to provide additional intercalibration for the realization of a consistent multi-decadal oceanic brightness temperature (Tb) product.
Thus, we conducted the intercalibration of TMI/GMI/WindSat to develop a multi-decadal oceanic Tb dataset, which ensures a consistent long-term precipitation record that covers TRMM and GPM eras.
Moreover, a generic uncertainty estimation model (UEM) was applied to quantify the uncertainty estimates associated with these intercalibration Tb biases, which enhances the scientific utilization as compared to existing Tb products with ad-hoc uncertainties estimates.

CFRSL XCAL TECHNIQUE



UNCERTAINTY ESTIMATION MODEL

Uncertainty Sources



Minimum Sample Size

- $n \geq \left[\frac{z_{\alpha/2} \times \sigma}{E}\right]^2 \cong \left[\frac{z_{\alpha/2} \times s}{E}\right]^2$
  - $(1-\alpha)$ is the confidence level
  - $z_{\frac{\alpha}{2}}$ can be found when α is known
  - E (margin of error) is maximum difference allowed between sample mean and true mean
  - σ (true standard deviation) is usually unknown, but can be estimated from the sample standard deviation s given the large sample size

A Type

- Repeated measurement

$$u = s(v) = \sqrt{\frac{\sum_{i=1}^{n}\left(v_i - \bar{v}_n\right)^2}{n-1}}$$

B Type

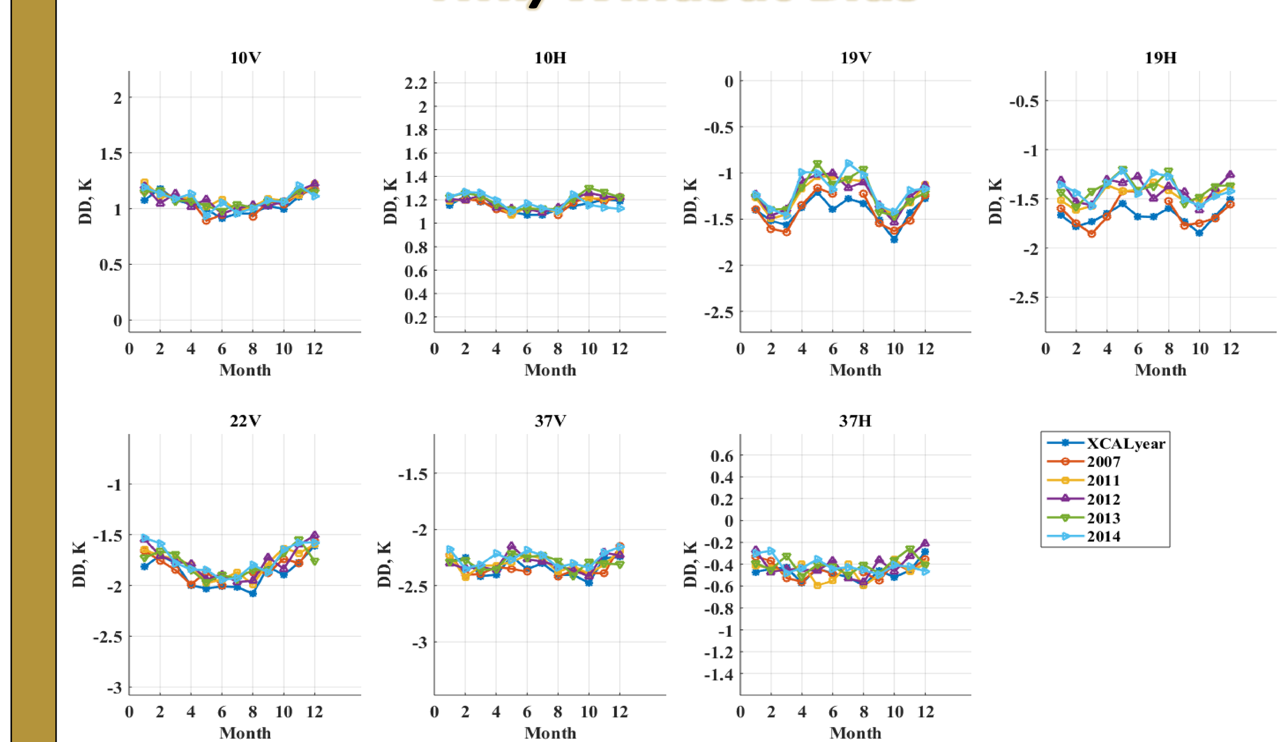
- Without repeated measurements:

$$u = s(v_n) = \frac{s(v)}{n}$$

$$u_{combined} = \sqrt{(u_1)^2 + (u_2)^2 + (u_3)^2 + \ldots etc.}$$

RESULTS

TMI/WindSat Bias

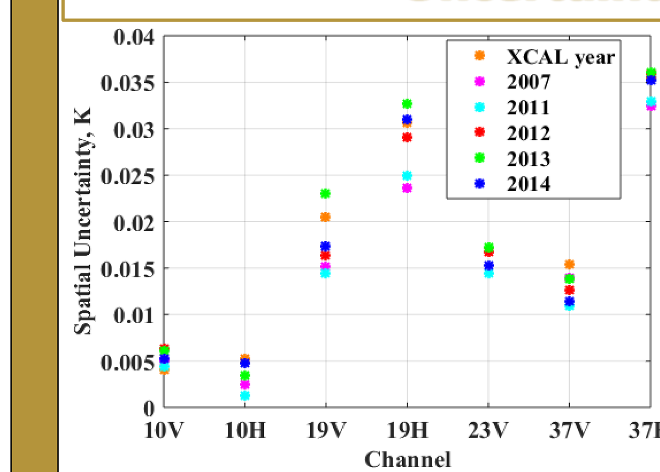


Monthly calibration bias of TMI relative to WindSat for 6 years between 2005 and 2014. XCAL year is 2005 July - 2006 June.

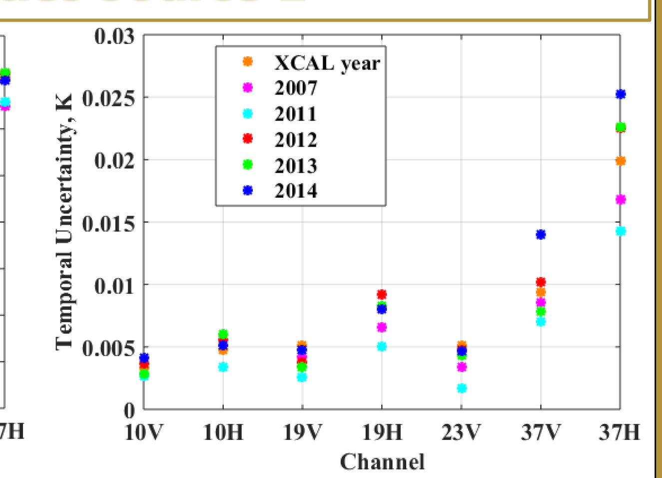
Bias (Mean / STD) of 13-month overlap

	10V	10H	19V	19H	23V	37V	37H
TMI-GMI	0.69/0.32	0.59/0.36	0.06/0.52	0.68/0.75	0.03/0.68	-0.85/0.52	1.14/0.87
TMI-WS	1.04/0.35	1.16/0.35	-1.33/0.53	-1.44/0.76	-1.70/0.73	-2.29/0.51	-0.40/0.87
WS-GMI	-0.35/0.22	-0.57/0.30	1.39/0.41	2.12/0.71	1.74/0.54	1.44/0.41	1.54/0.74

Uncertainties Source 1

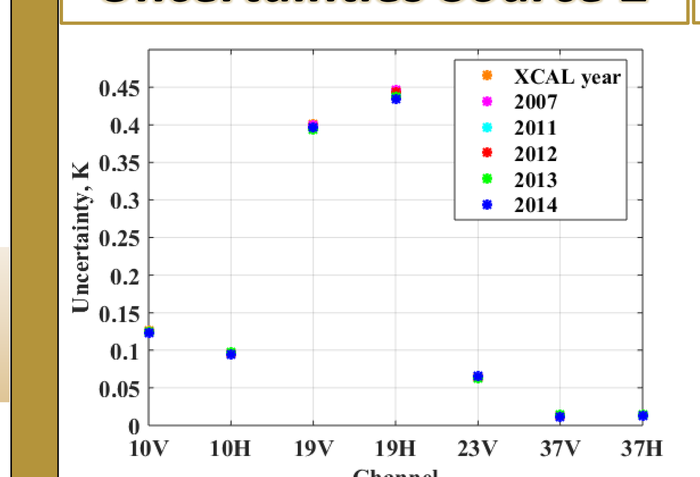


Spatial uncertainties of TMI/WindSat DD biases



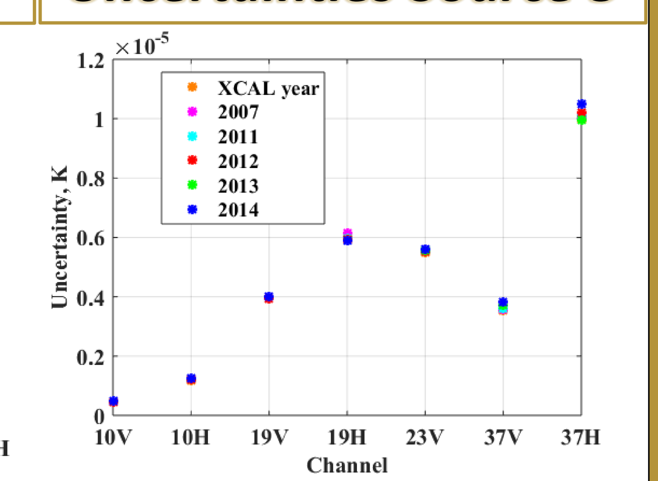
Temporal uncertainties of TMI/WindSat DD biases

Uncertainties Source 2



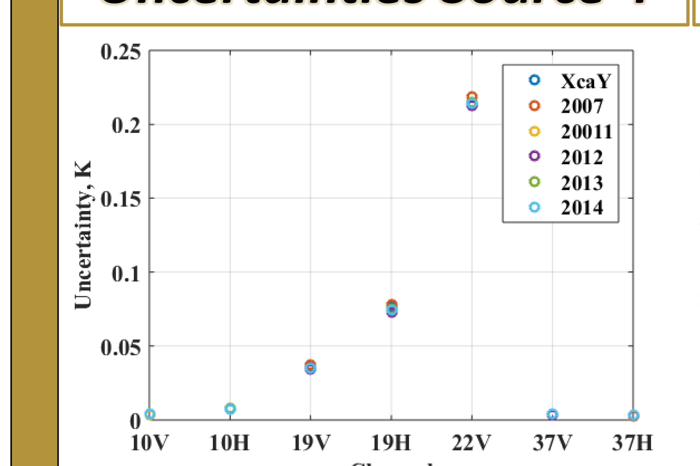
GDAS Uncertainty Estimates for TMI/WindSat

Uncertainties Source 3



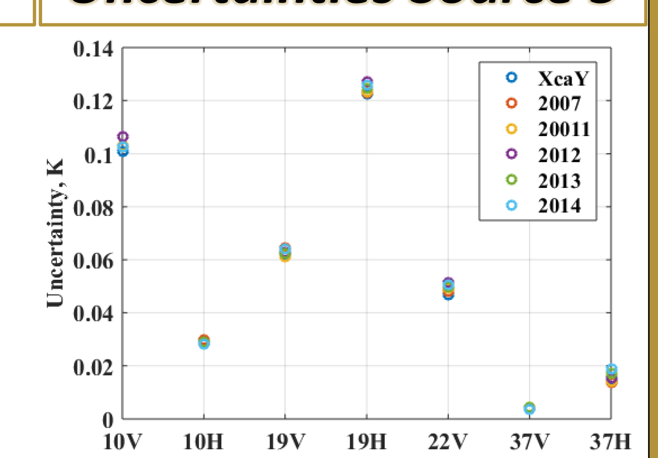
Rayleigh-Jeans Approximation Uncertainty for f TMI/WindSat

Uncertainties Source 4



Uncertainty Estimates in MONO & Rosenkranz atmos. absorp. models for TMI/WindSat

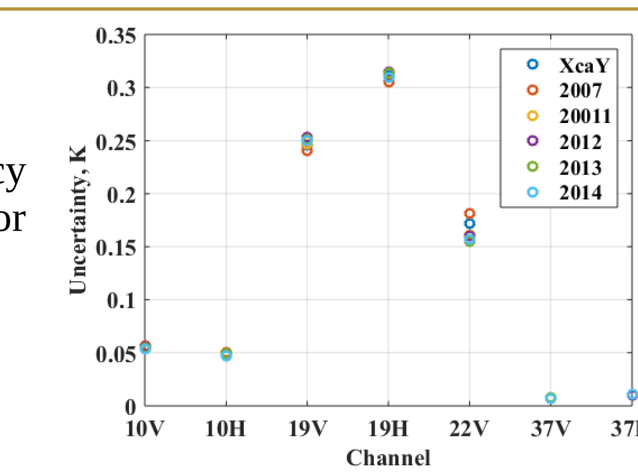
Uncertainties Source 5



Uncertainty Estimates in Elsaesser and RSS surf. emis. models for TMI/WindSat

Uncertainties Source 6

Uncertainty Estimates in discrepancy between ERA-I and GDAS models for TMI and WindSat intercalibration



Total Uncertainty

Combined Standard Uncertainty of TMI/GMI and TMI/WindSat Intercalibration

Channel		10V	10	19V	19H	23V	37V	37H	89V	89H
TMI/GMI		0.402	0.402	0.610	0.954	0.431	0.270	0.275	0.372	0.415
TMI/WindSat	XCAL year	0.435	0.415	0.635	0.703	0.432	0.261	0.264	--	--
	2007	0.435	0.416	0.632	0.701	0.438	0.261	0.263	--	--
	2011	0.435	0.415	0.632	0.699	0.428	0.261	0.264	--	--
	2012	0.436	0.415	0.634	0.703	0.427	0.261	0.264	--	--
	2013	0.435	0.416	0.632	0.698	0.426	0.261	0.265	--	--
	2014	0.434	0.415	0.634	0.695	0.427	0.261	0.265	--	--
Stability		0.002	0.001	0.004	0.009	0.013	0.000	0.002	--	--

CONCLUSION & FUTURE WORK

- In this study, we used WindSat as a calibration bridge to cover the period of 2005 into the next decade. This was accomplished by performing XCAL between TMI and GMI during their 13-month overlap period and then between TMI and WindSat from 2005 to 2014.
- Results demonstrate exceptional stability in the DD biases, which infers that both TMI and WindSat are stable. Thus, combining the 17-plus-year legacy Tb product with the on-going GMI measurements, it is likely to provide a superior multi-decadal product for studying climate change
- Also, results were presented for the Uncertainty Quantification Model that calculates uncertainties associated with the intercalibration Tb biases. Based upon these results, it is recognized that improvement in the intercalibration for water vapor sensitive channels is desired.