Brightness Temperature Validation for RapidScat using Microwave Imager (GMI)

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Introduction

- NASA RapidScat is the first satellite scatterometer that flew in non-Sun-synchronous orbit. It's unique orbit enabled collocated measurements with multiple satellite remote-sensing instruments mostly flying in Sun-synchronous orbits. Fig. 1 illustrates the geometry of RapidScat's pencil beams sweeping the Earth's surface in a circular footprint.
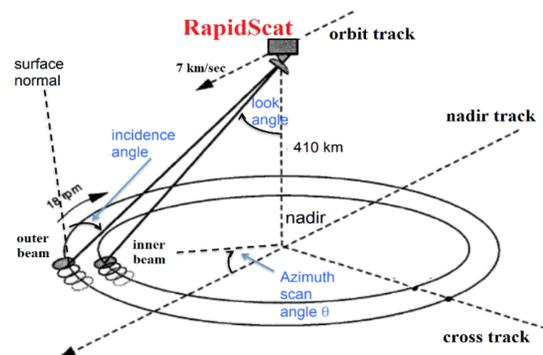
Fig. 1: RapidScat pencil beam geometry

- RapidScat's dual active/passive mode, simultaneously measures both the radar surface backscatter and microwave emission (brightness) from the system noise temperature.
- To assure Tb's measurement accuracy in passive mode, careful radiometer calibration and validation is required.
- This work explores the radiometric cross-calibration using the GPM Microwave Imager (GMI), to eliminate brightness temperature measurement biases between a pair of radiometer channels operating at slightly different frequencies and incidence angles..
- The GMI brightness temperatures were translated using the Radiative Transfer Model (RTM) to yield an equivalent Tb prior to direct comparison.
- Seasonal biases between two radiometers have been calculated for both polarizations as a function of atmospheric and ocean brightness temperature models.

Calibration Method

The steps for the RapidScat/GMI cross-calibration process are:

- The Tb measurements are spatially selected within collocated 1º X 1º latitude/longitude boxes using a conservative land, rain, and a cloud mask.
- These boxes were quality controlled and edited to remove non-homogenous ocean scenes and/or transient environmental conditions.
- The RTM is used to calculate the equivalent RS Tb's from GMI channels (10.65 and 18.7 GHz), to produce the equivalent 13.4 GHz at the corresponding RapidScat incidence angles.

- This process involved using a spectral ratio (Sr) parameter for both polarizations:

$$S_r(wv, clw, sst) = \frac{RS_{rtm}13.4 - GMI_{rtm}10.65}{GMI_{rtm}18.7 - GMI_{rtm}10.65}$$

- Using this ratio, the GMI brightness temperatures (10.65 and 18.7 GHz) were translated to the RapidScat equivalent Tb (13.4 GHz):

$$Tb\ GMI_{13.4} = Tb\ GMI_{10.65} + S_r(Tb\ GMI_{18.7} - Tb\ GMI_{10.65})$$

- By having the equivalent 13.4GHz Tb's (TB GMI eqv), the difference between the observed RapidScat and the equivalent GMI Tb's can be calculated.

$$Tb\ Dif = Tb\ RS_{obs} - Tb\ GMI_{eqv}$$

- Figure 2 summarizes the calibration procedure
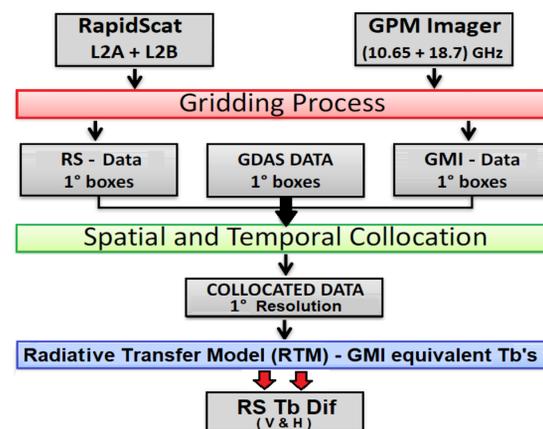
Fig. 2. RapidScat Radiometric Calibration Process.

Results

- To assess the Tb difference affected by each parameter, geometry and environmental factors were examined.
- Table 1 shows results of the Tb difference as a latitude series (Zonal average over 360 degree longitude).
- It shows the mean values for RapidScat's biases in both polarizations is less than $\pm$ 1K for most months

Table 1. Global averaged Tb difference as a function of zonal latitude and Water vapor.

Month	Mean Tb_Dif (zonal lat)		Water Vapor< 30 m/s		Water Vapor> 30 m/s	
	Dif_V	Dif_H	Dif_V	Dif_H	Dif_V	Dif_H
2015-Jan	-0.69	-0.15	0.67	0.3330	-4.38	1.59
2015-Feb	0.1	0.82	-2.13	-1.25	-5.99	-5.46
2015-Mar	0.09	0.1	1.08	-0.31	-5.74	-7.15
2015-Apr	-2.17	-0.6	3.23	0.25	2.23	-0.03
2015-May	-3.50	-0.34	4.15	-2.02	-1.05	-10.14
2015-Jun	-0.8	0.73	4.84	-0.68	-1.69	-4.66
2015-Jul	-2.8	-0.07	5.41	1.09	4.5	1.06
2015-Aug	-3.8	-1.58	8.264	4.67	8.19	3.61
2015-Sep	-0.9	1.4	2.43	-0.21	0.59	-2.33
2015-Oct	-0.05	2.7	-5.02	9.2	-7.2	-8.3

- Moreover the entire period was examined to assess the monthly averaged Tb bias contributed by water vapor in two different ranges (> 30 mm) and (< 30 mm), for both V and H pol.
- The Table also shows that for the low water vapor range, the averaged Tb difference are positive, and the negative pattern for the water greater than 30mm.
- The water vapor is highly correlated to the variation in sea surface temperature (SST). Along the equator, the SST is usually higher and gradually decreases in temperature toward the poles in range 207-310 Kelvin.
- Finally, the dependence of Tb difference on the SST is investigated >290 and <290, this summarized in Fig. 3. (a good agreement for both polarizations).
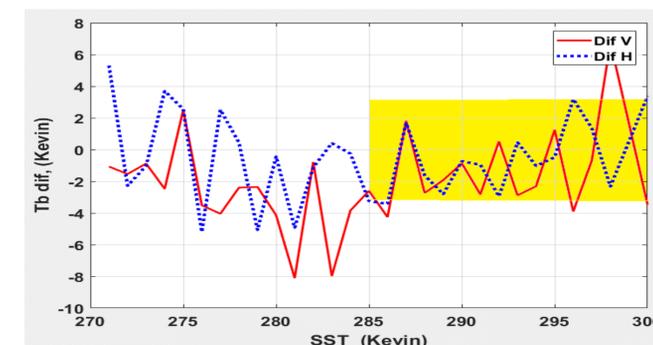
Fig. 3. Tb difference as a function of SST

Conclusion

- RapidScat brightness temperature measurements are reliable and satisfy the accuracy requirements.
- Following the similar method, further analysis of the RapidScat measurement set may help estimate relative validity and stability of other radiometers.