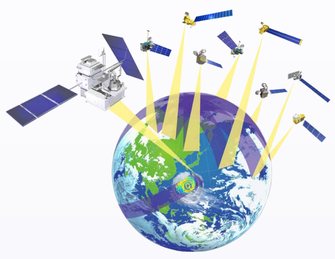
Recent Advances Of The TRMM PR Beam-Mismatch Correction After The Orbit Boost



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Purpose

In August 2001, the Tropical Rainfall Measuring Mission (TRMM) satellite was boosted to conserve its fuel keeping the altitude. As a result, observation by the Precipitation Radar (PR) occurred beam-mismatch. Although the PR level 1 algorithm in version 7 employs a correction of beam-mismatch, its error causes discontinuities of rain estimates comparing to pre-boost. In this study, we improve the method of beam-mismatch correction and evaluate its improvement.

Summary

The current method of beam-mismatch correction is confirmed using external calibration data. The current method integrated into level-1 algorithm and mitigates artificial bias of not only sigma-zero but also bright band. The asymmetric bias of resultant rain estimates sorted in angle-bin number is well mitigated in current method comparing to V7. The improvement is obtained for 95.9 (72.6) % over oceans (land). The current beam-mismatch correction will be adopted in PR's V8 product.

Mechanism of beam-mismatch

The mechanism of PR's beam-mismatch is introduced by Takahashi and Iguchi (2004). The downlinked data of PR is logarithmically averaged for 32 pulses, which is,

$$\overline{P}_{r,\mathrm{obs}}(n,r) = \sum_{i=1}^{32} P_{r,i}(n,r) \Big/ 32,$$

P_r: Received power [dBm]
n: angle-bin number
r: range-bin number

After the orbit-boost at August 2001, PR occurred beam-mismatch and averaged with a pulse of mismatched beam in 32 pulses. This is,

$$\overline{P}_{r,\mathrm{BMobs}}(n,r) = \left[\sum_{i=1}^{31} P_{r,i}(n,r) + P_{r,\mathrm{mb}}\right] \Big/ 32,$$

$P_{r,\mathrm{mb}}$: Received power of mismatched beam [dBm]

The beam-mismatch correction is to remove the contamination of mismatched-beam, so that corrected received power is obtained as

$$\overline{P}_{r,\mathrm{BMcor}}(n,r) = \frac{32\overline{P}_{r,\mathrm{BMobs}}(n,r) - P_{r,\mathrm{mb}}}{31}.$$

The problem of the beam-mismatch correction is <u>how to estimate correctly received power of mismatched beam</u>.

Beam-mismatch correction method

In version 7 (V7) or Takahashi and Iguchi (2004) method, mismatched beam power is estimated as

$$\hat{P}_{r,\mathrm{mb(TI04)}} = 10\log(p'_r) - 6,$$

Gain bias between mismatch between transmitted and received antenna directions.

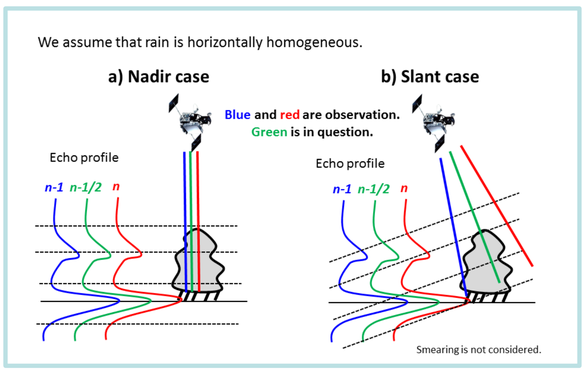
$$p'_r = \frac{1}{2}\left[\overline{p}_{r,\mathrm{BMobs}}(n,r) + \overline{p}_{r,\mathrm{BMobs}}(n-1,r)\right].$$

r_s: range-bin number at surface

We propose new method of beam-mismatch correction, which is

$$\hat{P}_{r,\mathrm{mb(Current)}} = 10\log(p'''_r) - 6, \qquad \Delta r_s = [r_s(n) - r_s(n-1)]/2$$

$$p'''_r = \frac{\overline{p}_{r,\mathrm{BMobs}}(n, r+\Delta r_s) + \overline{p}_{r,\mathrm{BMobs}}(n-1, r-\Delta r_s)}{2},$$



In nadir case, mismatched beam in V7 is accurately estimated, but V7 method occurs errors in slant case. In off-nadir angles, same range-bin numbers between current and adjacent beams are different against Earth surface and a origin of error. The current method estimates mismatched beam profile against Earth surface using two beams.

Figure. Schematic of echo profile against Earth surface.

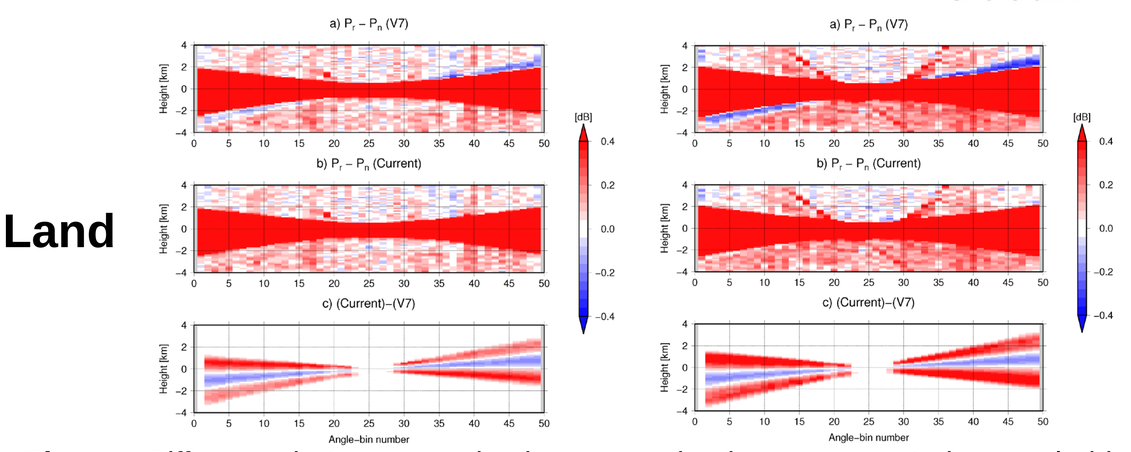


Figure. Difference between received power and noise power sorted as angle-bin number and height from Earth surface. top) V7, middle) Current, bottom) Current-V7. left) is over land, and right) is over oceans in 2001/09/01.

Impact for rain estimates

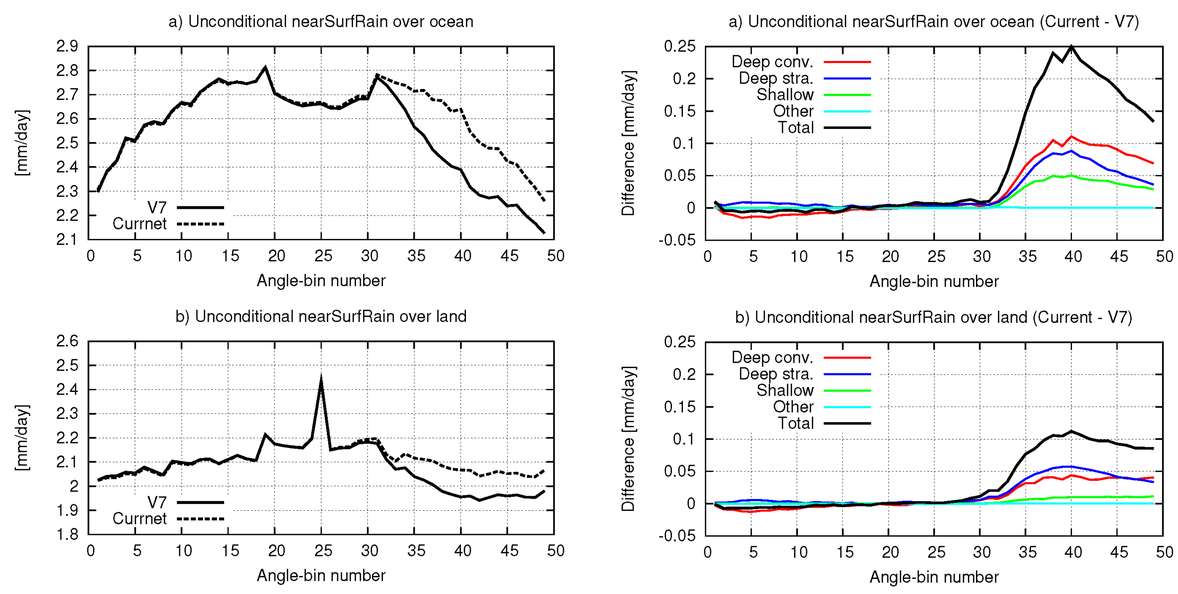


Figure. left) Angle-bin dependency of rain estimates between V7 and current from 2001/09 to 2002/08. right) Difference between V7 and current divided into rain-types (deep convective, deep stratiform, shallow, other, and total).

Table. Statistical result of asymmetric bias between first half (FH) and later half (LH). Bias is obtained from rain estimates of (LH-FH)/FH [%].

(LH -FH)/FH	Ocean [%]	Land [%]
V7 PreBoost (1998-2000)	-0.363	+0.073
V7 PostBoost (2002-2008)	-5.259	-4.007
Post - Pre	-4.896	-4.080

(LH -FH)/FH	Ocean [%]	Land [%]
V7 (2001/09-2002/08)	-6.311	-3.252
Current (2001/09-2002/08)	-1.614	-0.286
Current - V7	+4.697	+2.966

Validity of beam-mismatch correction

Here, we simulate the beam-mismatch using external calibration mode before the TRMM boost, which is spatially over-sampled with cross-track direction,

$$\overline{P}_{r,\mathrm{BMsim}} = \frac{31\overline{P}_{r,\mathrm{obs}}(n,r) + \overline{P}_{r,\mathrm{obs}}(n-1/2,r)}{32},$$

The estimate of mismatched beam profile using simulated data are compared between V7 and current method.

Land and rain case

Ocean case

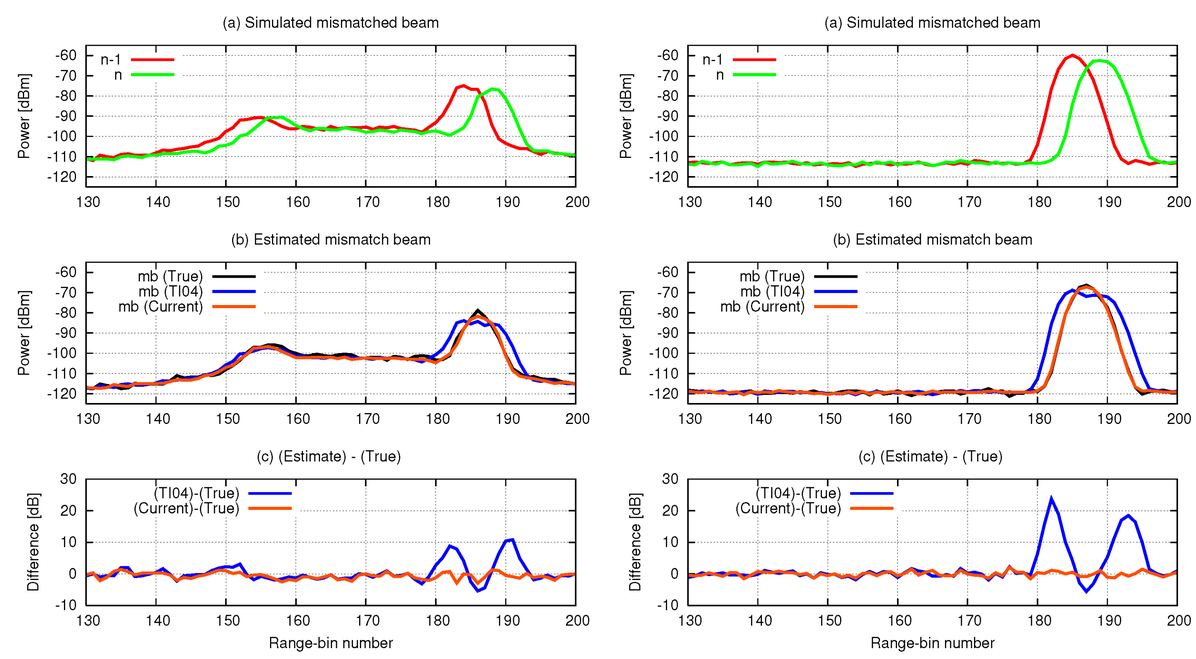


Figure. Simulation of beam-mismatch and its correction. Scan-angle is 7.1 degree in 2001/07/17. (a) beam-mismatched profile (b) estimates of mismatch beam and actual profile used in simulation (c) estimate errors from true.

References

N. Takahashi and T. Iguchi. Estimation and correction of beam mismatch of the precipitation Radar after an orbit boost of the tropical rainfall measuring mission Satellite. IEEE Trans. Geosci. Remote Sens., 42(11):2362–2369, Nov 2004.