COMPARISON OF TRMM PR V6 AND V7 FOCUSING HEAVY RAINFALL[1]

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ABSTRACT

The Tropical Rainfall Measuring Mission (TRMM) / Precipitation Radar (PR) has been working for more than 12 years, and the latest version (Version 7; V7 in short) of the standard product is published in 2011. A test product (called ITE233), which is essentially the same with the final product of V7, is compared with the previous version (Version 6; V6 in short). Generally, rain rate estimates are larger in V7 than in V6 both over land and over ocean. Histogram, the incident angle dependence, and the geographical distribution of heavy rainfall events are shown and the reasons why rain rates are increased over land in going from V6 to V7 are discussed.

Index Terms— TRMM, PR, SRT, heavy rainfall

1. INTRODUCTION

The standard algorithm for the Tropical Rainfall Measuring Mission (TRMM) / Precipitation Radar (PR) is updated to Version 7 (V7 in short) in 2011. A test product (called ITE233), which is mostly the same with the final product of V7, is compared with the previous version (Version 6; V6 in short).

2. SURFACE REFERENCE TECHNIQUE (SRT)

The standard algorithm for the TRMM/PR applies a hybrid method of the following two methods to retrieve rain rates; Histchfeld-Bordan (H-B) method and surface reference technique (SRT). However, only H-B method is used for lighter rainfall, for which SRT is unreliable to estimate path integrated attenuation (PIA). The SRT can employ three references for over ocean; along-track spatial reference (ATSR), temporal reference (TR), and hybrid spatial reference (HSR). If all the pixels in a swath are over-ocean pixels, the HSR is selected. In V6, the angle bin dependence of surface backscattering cross section (σ^0) is assumed to follow a quadratic function, but this assumption is not very appropriate and causes unnatural angle bin dependence of rain rate estimates [1]. In V7, two quadratic functions are used separately for inner swath and outer swath to fit σ^0 more accurately.

For land pixels, HSR is never selected. Between ATSR and TR, one with higher reliability is selected in V6. ATSR generally refers neighboring pixels, which are expected to have similar land surface conditions with the current pixel. However, ATSR in V6 sometimes refers pixels far from the current pixel and large biases in PIA and rain rates are resulted. Heavy rain rate estimates (more than 50 mm/h, hereafter in this paper) are found mostly in the center of the swath, where σ^0 is unstable, and a lot of heavy rain rate estimates are found near the western coast of continents, where referred pixels can be located in different continents. In V7, not only forward reference but backward reference is applied in ATSR and the distance between the current pixel and referred pixels is limited.

TR refers the database of 1 by 1 degrees in V6, and gives relatively stable estimates; few suspicious heavy rain rates are estimated when TR is selected. However, soil moisture effects [1] are not well explained in TR and the underestimation in rain rates is partly caused. In V7, to explain soil moisture effects, an artificial increment of 0.5 dB is given for all over-land pixels. Moreover, the database is reproduced by 10-year observations and for higher spatial resolutions of 0.1 by 0.1 degrees in V7.

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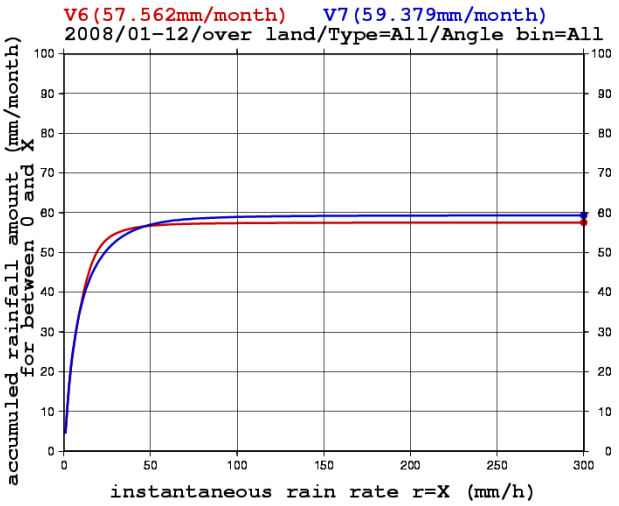
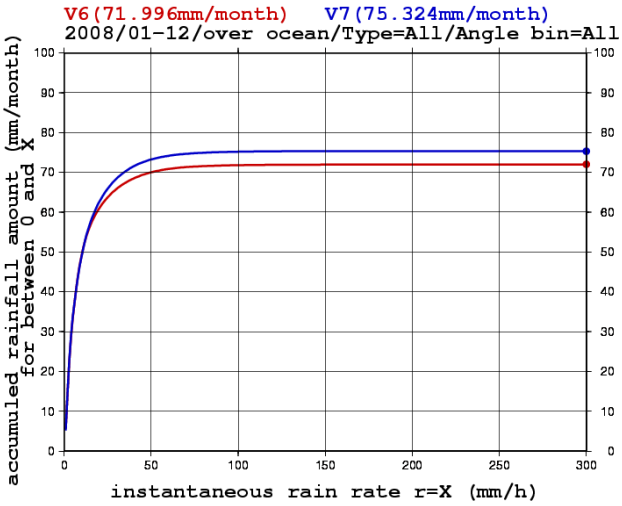


(a) over land



(b) over ocean

Fig. 1 Cumulative histogram of instantaneous rain rates.

3. COMPARISON BETWEEN V6 AND V7

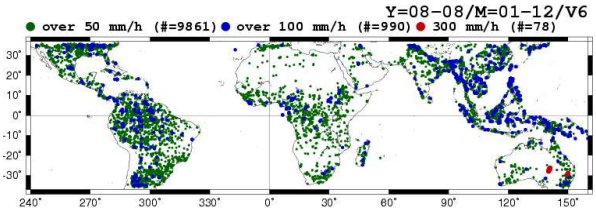
For comparison between V6 and V7(ITE233), all the data in the year of 2008 are taken.

3.1. Histogram of instantaneous rain rates

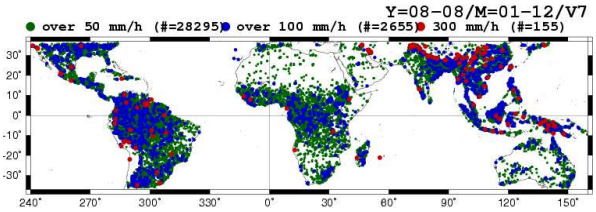
Figure 1 shows cumulative histograms of instantaneous rain rates (x mm/h). The vertical axis shows the contribution of instantaneous rain rates between 0 and x to the total rain amount [mm/month]. Fig. 1(a) is for all over-land pixels. The total rain amount (accumulation from x=0 to x=300) is 59.4 mm/month in V7 and is larger than in V6 (57.6 mm/month). Heavy rainfall events contribute to the increase of the total rain amount from V6 to V7. The cumulative rain amount from x=0 to x=50 is almost the same between V6 and V7. Fig. 1(b) is for all over-ocean pixels. The total amount is 75.3 mm/month in V7 and is larger than V6 (72.0 mm/month). This difference is not mainly caused by heavy rainfall events.

3.2 Geographical distribution of heavy rainfall events

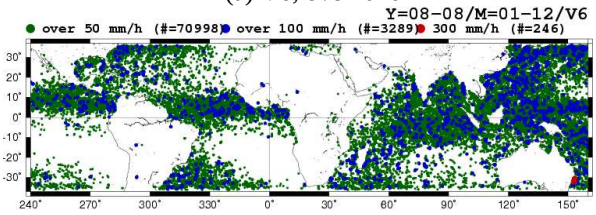
Figure 2 shows where heavy rainfall events are detected. Over land, rain rates of 300 mm/h are found both in V6 (Fig. 2(a)) and V7 (Fig. 2(b)). However, they are found only in the specific orbits and regions in V6, and they are probably caused by algorithm bugs. In V7, 300 mm/h estimates are found in various regions, but many are located along steep mountains and near coast. There are possibilities that SRT misleads to these ultimately heavy rain estimates in V7 as ATSR in V6 caused false heavy rain estimates. Over ocean, the number and geographical distribution of heavy rain rates are not very different between in V6 (Fig. 2(c)) and V7 (Fig. 2(d)), except for some 300 mm/h estimates in V6, which are probably caused by bugs.



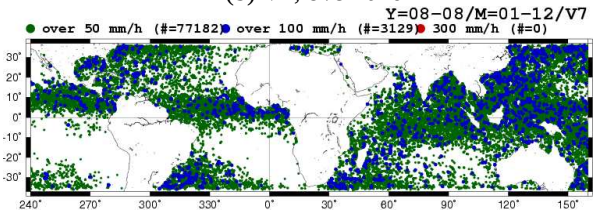
(a) V6, over land



(b) V7, over land

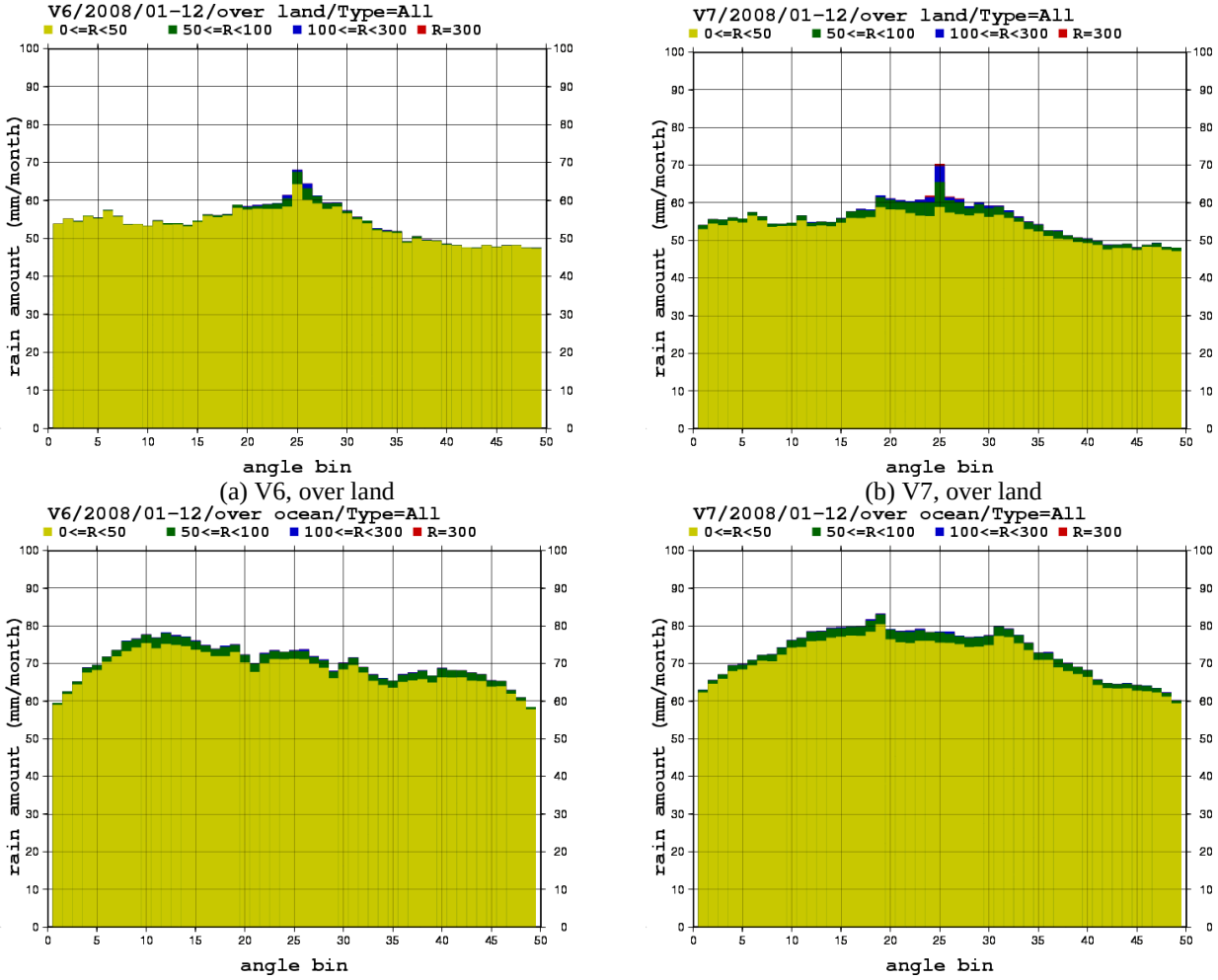


(c) V6, over ocean



(d) V7, over ocean

Fig. 2 Geographical distribution of heavy rainfall events.



(a) V6, over land (b) V7, over land

(c) V6, over ocean (d) V7, over ocean

Fig. 3 Incident angle dependence of the total ra in amount with the contribution of heavy rainfall events.

3.3. Incident angle dependence of the total rain amount

The total rain amount is calculated for each angle bin and is shown in Fig. 3 with the contribution of heavy rainfall events.

3.3.1. Over land

In V6, heavy rain rates are found mostly in the center of the swath and the total rain amount is larger at smaller incident angles (Fig. 3(a)). In V7, rain rates between 50 and 100 mm/h are found even in the edges of the swath, but extremely heavy rain events (larger than 100 mm/h) is found mostly at angle bins 24, 25, and 26 (Fig. 3(b)). At angle bin 25, the total rain amount is apparently larger than those at surrounding angle bins.

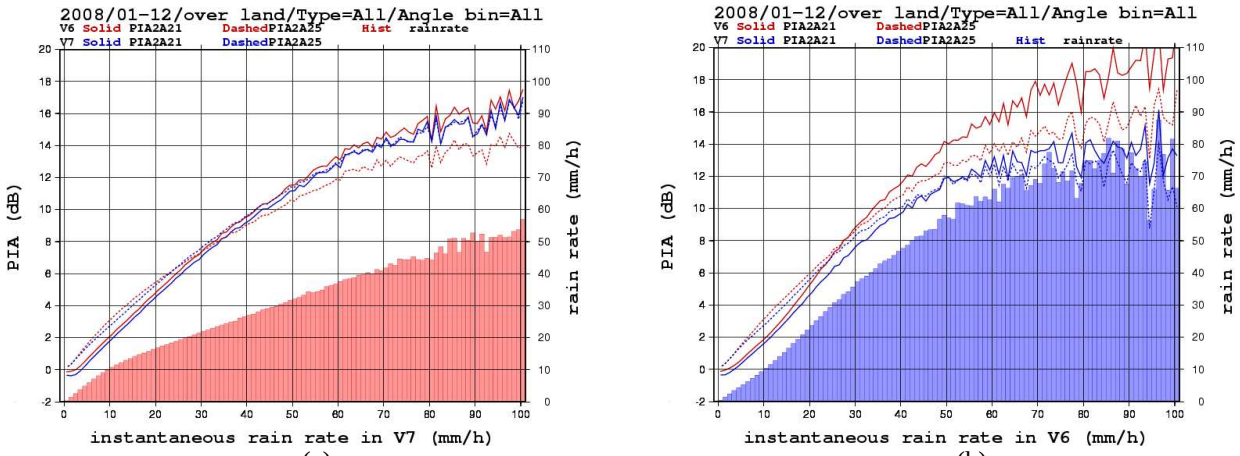
3.3.2. Over ocean

In V6, the total rain amount is highest around angle bin 10 (Fig. 3(c)). This is probably caused by the inappropriate fitting in HSR. Heavy rainfall events do not affect the shape of incident angle dependence. In V7, modification in HSR may improve the incident angle dependence (Fig. 3(d)); the total rain amount tends to be larger at smaller incident angles.

4. THE INCREASE OF HEAVY RAINFALL IN V7

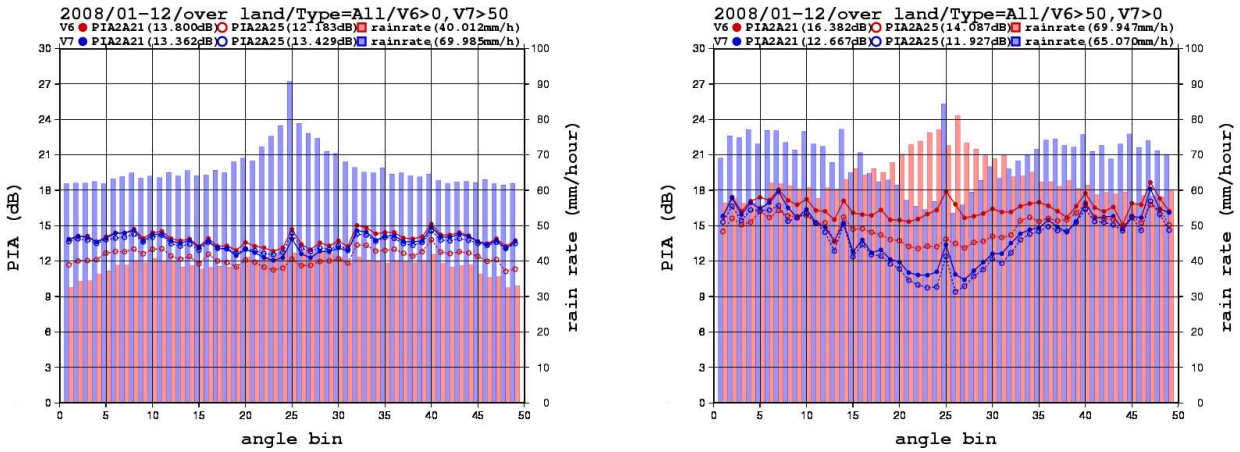
As is shown in the previous section, over land, heavy rainfall events are more frequent in V7 than in V6. In this section, it is examined if the increase of over-land heavy rainfall is caused by the modification in SRT.

As is shown in Fig. 1(a), the total rain amount increases in going from V6 to V7 by 1.8 mm/month. At some pixels, only V6 detects rain and the corresponding rain amount is 0.6 mm/month. On the contrary, only V7 detects rain at some other pixels and the corresponding rain amount is 0.1 mm/month. In most cases, both V6 and V7 detects rain, and the difference of the total rain amount at the matched pixels is 2.3 (=1.8+0.6-0.1) mm/month. Later in this section, rain rates are compared only at matched pixels.



(a) (b)

Fig. 4 Comparison of PIA2A21, PIA2A25, and rain rates between V6 and V7.



(a) for heavy rainfall in V7 (> 50mm/h) (b) for heavy rainfall in V6 (> 50mm/h)

Fig. 5 Incident angle dependence of PIA2A21, PIA2A25, and rain rates between V6 and V7.

4.1. Heavy rainfall events in V7

Fig. 4(a) compares V6 and V7 for PIA estimates by SRT (PIA2A21), the final PIA estimates (PIA2A25), and rain rate estimates. Pixels are categorized by rain rate estimates in V7 with the step of 1 mm/hour, except that the highest bin is prepared for rain rates more than 100 mm/hour. Let us focus heavy rainfall events in V7. PIA2A21 are slightly higher in V6 than V7, but PIA2A25 are higher in V7 than in V6 as rain rates are. In other words, PIA2A25 become closer to PIA2A21 in V7, while PIA2A25 and PIA2A21 are not close in V6. This suggests that SRT is much relied in V7 than V6. The increase of heavy rainfall in going from V6 to V7 is not caused by the increase of PIA2A21 but the increase of the reliability of SRT. The above explanation is applied irrespective of angle bins (Fig. 5(a)).

4.2. Heavy rainfall events in V6

Fig. 4(b) is the same with Fig. 4(a), but the horizontal axis is instantaneous rain rates in V6. Let us focus on heavy rainfall events in V6. PIA2A21 is much higher in V6 than V7 and PIA2A25 is also higher in V6 than V7. This tendency is apparently seen when the incident angle is small (Fig. 5(b)). This suggests that suspicious heavy rain estimates in V6 are caused by overestimated PIA2A21 and they are not supported by V7 with improved SRT.

5. SUMMARY

TRMM/PR V6 and V7 (ITE233) are compared. Over land, heavy rainfall events are more frequent in V7 than V6, which is partly caused by the increase of reliability of SRT. On the other hand, suspicious heavy rainfall events in V6 are generally not supported by V7.

[1] Seto, S., T. Iguchi, “Rainfall-induced changes in actual surface reference backscattering cross sections and effects on rain rate estimates by spaceborne precipitation radar.”, J. Atmos. Oceanic Technol., Vol. 24, pp1693-1709, 2007.

[2] Seto, S., T. Oki, T. Iguchi, “Evaluation and improvement of surface reference techniques for the TRMM PR”, IGRASS, 2008.