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Accuracy verification of spaceborne radar estimates of rain rate

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Abstract

The distribution of rain rate is of great concern for many hydrological applications. Probability distribution functions (pdf) of rain rate can now be obtained from spaceborne radar observations. Effort to evaluate these pdfs using ground observations is described.
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Keywords: spaceborne radar; ground-based radar; rainfall intensity; validation; probability distribution; rain type classification; TRMM

1. Introduction

The distribution of *rain rates* (R) is of great interest in many fields. For example, hydrological applications such as flood forecasting depend on an accurate representation of the excess rainfall — driven by R — that does not infiltrate the soil. Better estimation of the spatial probability distribution function (pdf) of R is also crucial for better evaluation of rainfall products from space-based radars. The evaluation of instantaneous rainfall products and rain-rate estimates from space is quite a challenge. Scatter plots of direct comparisons of rain rates with ground-based radar estimates (pixel by pixel) are extremely noisy because of sample volume discrepancies, timing and navigation mismatches and uncertainties in the observed-radar reflectivity rain-rate Z_e-R relations. Furthermore, comparisons of rainfall over daily, weekly or even monthly time scales suffer from the temporal sampling errors of the satellite where the revisit time is on the order of hours or days (e.g. the Tropical Rainfall Measuring Mission (TRMM) satellite, the future Global Precipitation Measurement (GPM) mission satellite). Consequently, an alternative approach (Liao *et al.*, 2001; Amitai *et al.*, 2003) of comparing space-based radar pdfs with pdfs derived from co-located ground-based radar observations is attractive for evaluating satellite-based precipitation products, such as those from TRMM precipitation radar (PR).

A framework for physical validation of spaceborne radar estimates of rain rate has been developed. The framework demonstrates how a hydrologic approach that uses statistical properties of the precipitation to estimate the uncertainties can be combined with a meteorological approach that uses physical properties of the rainfall. It is based on comparing pdfs of R from ground-based and space-based radar observations. The framework includes the use of pdf comparisons before and after rain type classification. The classification will allow for better evaluation of the satellite algorithms under different conditions, and potentially will allow for 'extrapolation' of the uncertainties to regions not covered by validation data sets, but characterized by the same rain type. The framework also focuses on determining and reducing the uncertainties in the ground validation pdfs. This letter presents the results from initial comparisons of pdfs of rain rate from the TRMM PR and co-located data from the TRMM ground validation (GV) radar, obtained over central Florida during five years of observations. It provides a brief review of how well the TRMM satellite validation estimates compare to TRMM PR retrieved estimates.

2. Comparisons of pdfs of rain rate from the TRMM PR and co-located TRMM GV radar data

The pdfs shown here represent the distribution of rain volume by rain rate, i.e. they are constructed according to the relative contribution made by each rain intensity to the total rain volume. Such pdfs are less sensitive to the instrument rain detection limits than the pdfs of occurrence, and have direct hydrological significance. The rain rates used to derive the pdfs are based on co-located TRMM PR and TRMM GV radar observations taken from a range interval of 15 to 100 km from the Melbourne, Florida National Weather Service Radar (WSR-88D). The rain-rate estimates are taken from the NASA TRMM standard products (version 5) and pixel-matched in both time and space after averaging to the highest common horizontal resolution of 4×4 km^2.

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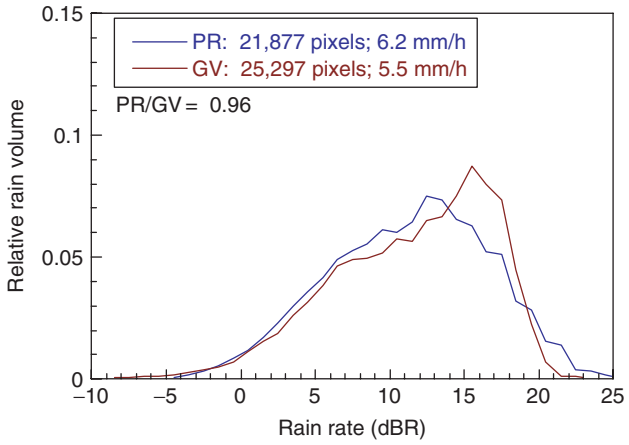

Figure 1. Distribution of rain volume by R for the Melbourne, Florida, WSR-88D (GV) and TRMM PR datasets based on 105 overpasses during 1998 to 2002 and co-located GV data within 100 km of Melbourne. The GV R estimates are taken from TRMM standard product 2A-53 version 5 based on WPMM with 2×2 km^2 pixel resolution, averaged to 4×4 km^2. The number of rainy pixels, their averaged rain rate, and the PR/GV rain volume bias are indicated in the legend. Note, dB$R = 10 \log(R/1 \text{ mm h}^{-1})|[R] = [\text{mm h}^{-1}]$

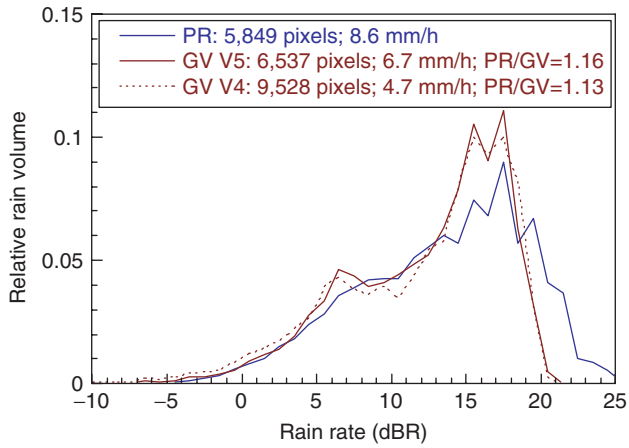

Figure 2. Distribution of rain volume by R for the Melbourne, Florida, WSR-88D (GV) and TRMM PR datasets based on 24 overpasses during 1998 and co-located GV data within 100 km of Melbourne. The GV R estimates are taken from TRMM standard product 2A-53 version 5 (V5) based on WPMM and version 4 (V4) based on a power law with 2×2 km^2 pixel resolution, averaged to 4×4 km^2

Figure 1 presents a comparison of the pdfs based on all TRMM overpasses found during 5 years of mission over central Florida (105 overpasses during rain). Overall, PR underestimates the rain by 4% compared to the GV estimates. Calculation of rain amounts, in situations in which one instrument detected rain and the other did not, reveals that 7.5% of the rain amount measured by the GV radar occurred in regions where the PR registered no rain. In these pixels, the GV averaged R was found to be 1.8 mm/h as compared to the value 6.1 mm/h, based on all GV rainy pixels ($R > 0$). Is it rain that cannot be detected by the PR due to its low sensitivity? We believe that this is in fact the case, although some of the discrepancy appears to be caused by registration errors. It was also found that 3% of the PR rain was detected in pixels in which the GV radar registered no rain, and was also characterized by weak rain rates ($\langle R \rangle = 1.6$ mm/h as compared to $\langle R \rangle = 5.5$ mm/h based on all PR rainy pixels). As a first-order estimate, we assume that of the 7.5% of the events where GV detects rain and the PR does not, 3% is associated with mismatches due to wind sorting and navigation and timing errors, while the remaining 4.5% is the result of the lower detection threshold of the PR relative to the GV. Assuming the GV radar estimates are true, the comparisons suggest that the PR not only underestimates the rain by 4% but also does not detect 4.5% of the rain. Therefore, when the PR detects rain, it compares well with the ground radar estimates.

Explanation for the shift in the GV pdf curve toward high rain rates at low and medium rain intensities and vice versa for higher rain intensities, as seen in Figure 1, requires further analysis. An analysis based on rain type classification will be described in the following section.

4. Summary

A comparison of rain-rate estimates from the TRMM PR and TRMM GV radar based on 53 months of observations over central Florida is provided. Overall, the PR not only underestimates the rain by 4% but also does not detect 4.5% of the rain as compared to the GV radar. Therefore, when the PR detects rain, it compares well with the ground radar estimates. Results from initial comparison of pdfs of rain rate from TRMM PR and TRMM GV estimates demonstrate how well the TRMM satellite validation pdfs compare with TRMM PR retrieved estimates. This comparison effort is part of a developing framework for physical validation of spaceborne radar estimates of rain rate. The framework includes the use of pdf comparisons before and after rain type classification. The classification allows for better evaluation of the satellite algorithms under different conditions, and potentially will allow for 'extrapolation' of the uncertainties to regions not covered by validation data sets, but characterized by the same rain type. The framework also focuses on determining and reducing the uncertainties in the GV pdfs. While uncertainties in the determination of the ground-based radar pdfs are reduced upon adjustment with those from gauge data (Amitai *et al.*, 2004) — a major motivation for NASA TRMM validation program's product generation based on WPMM $Z - R$ relations — utilizing super dense gauge network for accuracy verification of the derived pdfs will further reduce the uncertainties.

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