Performance of Global Satellite Mapping of Precipitation estimate over northern Vietnam

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1. Introduction

The Red River, whose basin occupies main part of northern Vietnam, is an important river running through Hanoi, the capital of Vietnam. It sometimes makes floods in the flat delta region. The upstream is surrounded by complex topography with several mountain ranges on a scale of 10–100 km. Therefore, satellite-borne radar observation of rainfall plays a crucial role in flood forecasts in this region. The Global Satellite Mapping of Precipitation (GSMaP) dataset is based mainly on the microwave radar and imager observation on the Tropical Rainfall Measuring Mission (TRMM) and the Global Precipitation Measurement (GPM) satellites (Aonashi et al. 2009; Ushio et al. 2009). We investigated reproducibility of hourly- and daily-scale rainfall in the GSMaP with in situ rain gauge data (hereafter gauge rainfall) in northern Vietnam. Moreover, the reproducibility was related with vertical profiles of precipitation and lower tropospheric winds. The purpose of this study is to validate the GSMaP for hydrological forecasting.

2. Data and methods

Gauge rainfall at eight gauge stations observed by the Vietnam Meteorological Hydrological Administration (VMHA) and the GSMaP data were used in the hourly-scale validation. The used GSMaP products were the MVK version 7 (MVKv7), 6 (MVKv6), NRT version 6 (NRTv6) for 2014, and the RNL version 6 (RNLv6) and the NRTv6 for 2010. The analyzed months are from April to October. The GSMaP data were validated at the closest grid points to the gauges. Daily rainfall of 50 mm is the flood warning criterion by the VMHA and corresponds to the top 4.49% amount. Therefore, we mainly analyzed reproducibility of 95-percentile rainfall.

Vertical rainfall profiles from the TRMM 2A25 data were employed for examining effects of rainfall top height on the GSMaP RNLv6 performance in 2010. The rainfall top is defined as the height with rainfall of 0.5 mm $hour^{-1}$.

The Vietnam Gridded Precipitation (VnGP) Dataset (Nguyen-Xuan et al. 2016) and operational radiosonde data at Hanoi were used for investigating combined effects of the topography and lower tropospheric winds on the performance of the GSMaP RNLv6 for the daily rainfall exceeding 50 mm in rainy seasons from May to September in 2000–2010. The horizontal resolution is 0.1° in both datasets. The day border in the VnGP is at 12 UTC (19 LT), thus, we used radiosonde data at 00 UTC corresponding to the middle time of the VnGP data.

3. Results

At first, we describe performance of the GSMaP for hourly-scale rainfall in 2010 and 2014. In 2014, the products MVKv7 and NRTv6 showed comparable values with the gauge rainfall as a whole, on the other hand, the MVKv6 showed lower values than the gauge. In 2010, both the NRTv6 and RNLv6 showed lower values than the gauge. It is implied that the GSMaP NRTv6 reproducibility improved in the GPM era in 2014 compared to that in the TRMM era in 2010, unless we consider effects of interannual variation of winds which may affect the GSMaP performance as shown in the later. The GSMaP had larger and smaller rainfall than the gauge data in the cases of lighter and heavier rainfall in the rain gauge observation, respectively. Probability of detection (POD) was higher for accumulated interval shorter than 12 hours and longer than 48 hours. The higher POD in the accumulated rainfall for the shorter intervals indicated the possibility to improve heavy rainfall reproducibility, although the main reason seems that the accumulated rainfall is smaller for the shorter intervals than for the longer intervals at the 95 percentile. However, false alarm ratio (FAR) had higher values for shorter-interval rainfall than 24-hour rainfall. The FARs showed similar values among the products.

The RNLv6 GSMaP rainfall was more strongly related to the rainfall top than the gauge rainfall in 2010 (Fig. 1). It is implied that the GSMaP estimation was strongly influenced by the convection height. A microwave imager often underestimates shallow orographic rainfall (e.g. Kubota et al. 2009). Such rainfall often occurs on the windward side, therefore, we examined the relationship between the GSMaP performance and winds in the next part.

We describe the relationship between the GSMaP RNLv6 performance and combined effects of topography and lower tropospheric wind in daily-scale rainfall for heavy-rain days with rainfall exceeding 50 mm day^{-1} in rainy seasons from 2000 to 2010. Windward rainfall is roughly regarded as orographic rainfall. The rainfall was generally lower in the GSMaP data than in the VnGP data over northern Vietnam, however, both data had comparable values on days with westerly wind in the lower troposphere at Hanoi. On a tributary basin scale, the GSMaP had relatively larger and smaller rainfall and to the VnGP along the northeastern and southeastern foots of the mountain ranges, respectively (Fig. 2). The results imply that the estimation algorithm in the GSMaP (Yamamoto and Shige 2015) did not fully evaluate orographic convection. Therefore, the accuracy of rainfall reproducibility by the GSMaP can be improved by using a more appropriate wind dataset and examining topography effects in detail in the algorithm.

4. Summary

The rainfall reproducibility in the GSMaP dataset was evaluated based on rain gauge observation. The GSMaP showed improved rainfall in the newer products and in the GPM era. The near real time products also showed comparable performance with the standard products. Shorter-term heavy rainfall indicated higher POD than 24-hour accumulated rainfall and this result suggests the possibility to improve the performance for longer-term heavy rainfall. Weak points of the GSMaP estimation algorithm were the strong dependency on rainfall top height as indicated from the analyses with rainfall profiles from the TRMM 2A25. The analysis relating the GSMaP performance with the radiosonde winds and the topography implied that a part of the weak points is due to insufficient modification by the algorithm evaluating orographic convection.

Keywords: validating satellite observation of precipitation, orographic precipitation, GSMaP, TRMM

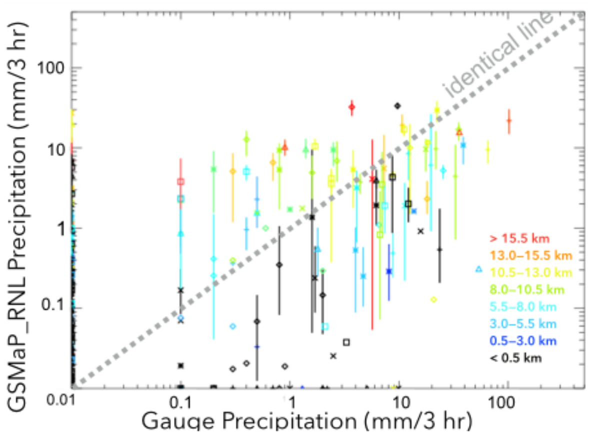

Fig. 1: Comparison between the gauge and the GSMaP rainfall from April to October in 2010 in cases that vertical profiles of rainfall in the TRMM 2A25 existed within 0.15° of the gauge stations with time lags less than 1.5 hours. Rainfall was 3-hourly accumulated. Marks show 9-grids mean of the GSMaP rainfall and vertical bars show ranges of the rainfall at the 9 grids. A color in each case shows rainfall top height (defined at 0.5 mm hour^{-1}). The gray dotted line shows an identical values in the gauge and GSMaP rainfall. The rain gauge stations are shown by different marks. (+: Bac Quang, ∗: Cho Ra, ×: Phu Yen, ◇: Sin Ho, △: Chi Ne, □: Pho Rang)

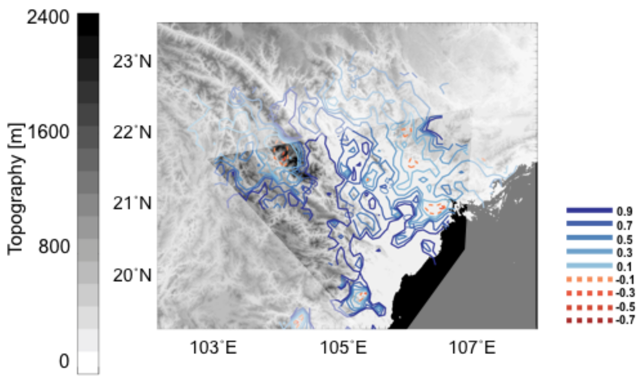

Fig. 2: Horizontal distribution of the GSMaP performance, shown by the difference between mean GV-ratio in westerly 850-hPa wind cases at Hanoi and that in southerly cases with contours (interval 0.2) in May—August from 2000 to 2010. Broken and solid lines show negative and positive values starting at values of -0.1 and 0.1, respectively. The region outside the quadrilateral region enclosed by four rawinsonde stations (Vinh, Bach Long Vi, Dien Bien Phu and Nanning, see Table 2) are shown with pale colors.