GROUND VALIDATION OF SATELLITE-BASED PRECIPITATION MEASUREMENT FOR FLOOD SIMULATION IN SOUTHEAST ASIAN RIVER BASINS

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ABSTRACT

River-basin flood simulation can be enhanced by combining Satellite-Based Precipitation (SBP) measurements with actual rain-gauge measurements on the ground. The present study attempts to show feasible approaches in terms of time, space, and pattern at selected basins in Southeast Asia. In terms of temporal downscaling, it was possible to detect flood timing and magnitude with high temporal resolution at basins with low rain-gauge coverage. This approach was tested at the upper part of the Huong River basin in Vietnam and the Ping River basin in Thailand. Both catchments are located in steep, humid, and heavily vegetated areas. Two SBPs were employed: the Global Satellite Mapping of Precipitation (GSMaP) MVK version and the Tropical Rainfall Measuring Mission (TRMM) 3B42 version 6. The results indicate that SBP products tend to underestimate precipitation intensities, but they seem to be able to depict spatial and temporal patterns. The evaluated SBPs were found to be useful at the basin scale, and river discharge simulation was enhanced with corrected SBPs. This approach might be applied to other basins, not only in the Southeast Asia region.

Keywords: Satellite-based precipitation, Flood, Rainfall, Southeast Asia

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1. INTRODUCTION

Water assessment based on hydro-meteorological observations plays a key role, not only in water resources management, but also in flood damage protection. However, rain-gauge networks can be sparse in developing countries because of high maintenance costs and problems with accessibility. On the other hand, as satellite remote sensors can cover large areas of the globe continuously, the exploitation of these products in such countries has great potential. For example, in poorly gauged regions, such as in Thailand and the Amazon, the availability of a global data set has been assessed by using error evaluations (Chokngamwong and Chiu [1] and Su et al.,[6]). Recently, efforts have been made in South America to improve SBP (namely TRMM) measurements with statistical evaluation (Vila et al.[8]). However, this product is calibrated monthly using the global hydrology networks (e.g. long-term variability of rainfall), and therefore, it does not have enough capability to accurately specify local flood events with a short duration (Huffman[2]). The possibility of quantifying biases or tendency at regional and local scales is still under investigation. Biases might be associated with the type of rainfall events within the basin and surrounding areas. Taking the bias into consideration, the correction factor could be applied to SBP and thus increase the accuracy of local precipitation measurements. For example, in Bangladesh, correction factors were extrapolated over regions with no in-situ data (Saavedra et al.[4])

This study aims to investigate the applicability of Satellite Based Precipitation (SBP) measurements in combination with local rain-gauge networks to improve the spatial and temporal resolution of measurements in Southeast Asian river basins. The process was carried out in three steps: 1) evaluation of SBP products by scale difference in regions with few gauges; 2) validation of the SBP correction method; 3) application of corrected products as input for a hydrological model. The improved measurement product may enable determination of precipitation patterns and quantification of the risk of flooding.

2. STUDY AREA

Because of the diversity in geomorphology, ecology, and dominant weather, we proposed the application of satellite-based precipitation estimates in combination with rain-gauge measurements to simulate hydrological processes in two test basins in the Southeast Asia region: Chao Phraya (Thailand) and Ping (Vietnam).

Ping River

This catchment is located in upper Chao Phraya basin, Thailand (Fig. 1). The basin has an area of 26,200 km^2 and the rainy season extends from May to October. TRMM products were employed with promising results following Tanuma et al.[7]. A higher variability of precipitation in the basin in the future has been identified based on TRMM analysis (Ogata et al.[3]).

Huong River

The Huong River basin in central Vietnam (Fig. 1) has an area of 1,513 km^2. The flood control point at Kim Long is set as the outlet of the basin. The Huong River experiences an average of 3.5 floods per year with the threat of high water levels. Flood season normally begins in October. The area is predominantly evergreen forest and shrub land.

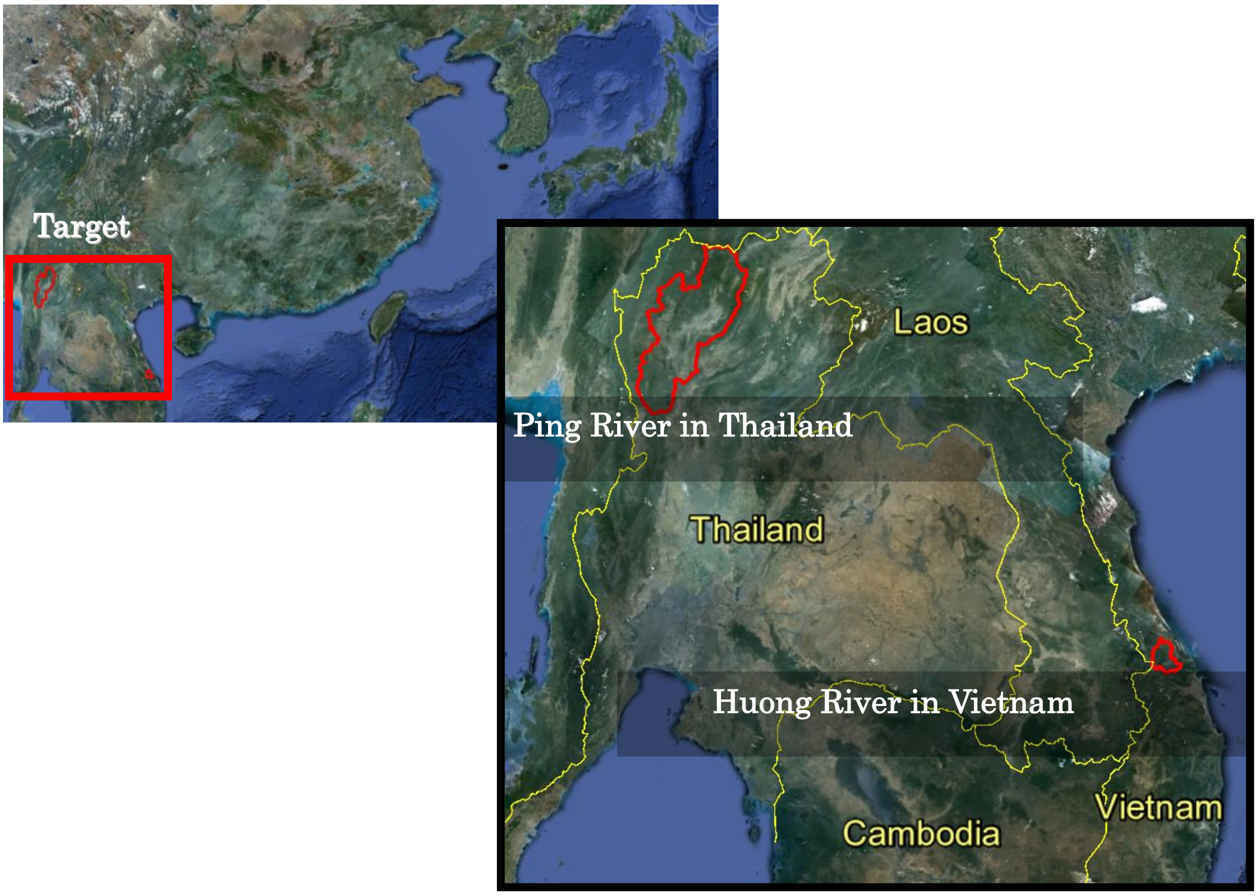

Fig. 1: Location of test River basins in South-East Asia region

3. METHODS

In order to measure precipitation intensity at ground level, data from available local rain-gauge networks were used, along with data from TRMM and GSMaP_MVK. TRMM was launched by the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) in 1997, and provides 3-hourly rainfall data in tropical areas with quasi-global coverage. The spatial resolution is 0.25 degrees. Additionally, the Global Satellite Mapping of Precipitation version MVK (GSMaP_MVK) delivers hourly precipitation data. The different sensor-algorithms were merged to retrieve intensities: passive microwave radiometers of TRMM/TMI, Aqua/AMSR-E, ADEOS-II/AMSR, DMSP/SSMI; and infrared brightness temperature provided by NCEP/CPC. Version MVK was re-analyzed with bias retrieval from the near real-time product. The spatial resolution is 0.1 degrees.

Once the rain gauge and SBP precipitation data was prepared, river discharge simulation was obtained using a Distributed Hydrological Model (DHM). The DHM employed in this study was a physically based semi-distributed hydrological model set up at each test basin. The model takes into account spatially distributed hydrological processes in the basin and the routing of water in the streamline. The Geomorphology-Based Hydrological Model (GBHM) developed by Yang [9] was chosen because of its high applicability to a steep mountainous area See Fig. 2. The GBHM compounded from two modules to solve the continuity: energy and momentum equations. Firstly, a hillslope module calculates entire water budgets, including canopy interception, evapotranspiration, infiltration, surface flow, and exchanges of water between ground and surface. The module simulates surface runoff and subsurface flow into the main river channel. Water flow in unsaturated stratified ground is governed by the Richards equation. Darcy’s law is applied to saturated zones. Secondly, the water routing of the river is determined by solving one-dimensional kinematic wave equations. The simulation sequence is performed at each sub-basin and then water is gathered to the outlet along the direction of the streamline.

It was then possible to apply corrected products as input for the hydrological model following Tanuma et al. [7]. The improved measurement product may allow detection of the precipitation pattern and quantification of the risk of flooding.

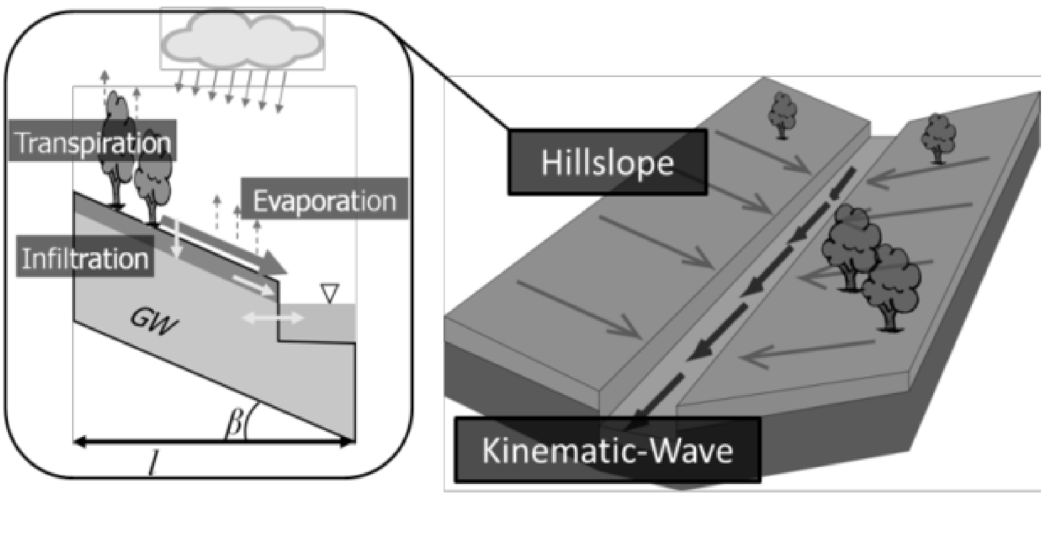

Fig.2: The concept of hillslope based hydrological model

4. RESULTS AND DISCUSSIONS

Flood simulation using a DHM was performed with satellite-based precipitation measurement products GSMaP_MVK and TRMM at the two river basins. The precipitation with MVK was first compared against rain-gauge data at the Huong River during the monsoon season (September–November) between 2006 and 2009, as seen in Fig. 3. It should be noticed that better agreement can be expected at lower intensities. Conversely, at higher intensities estimations might be scattered.

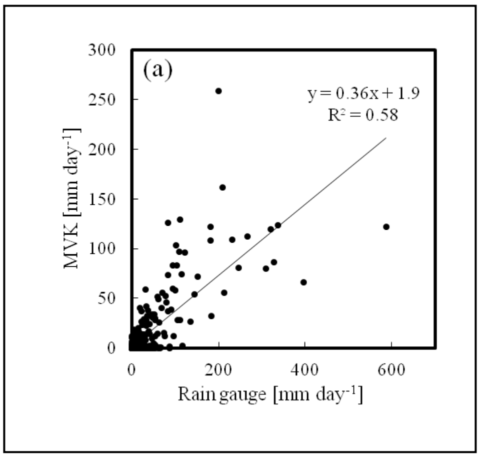

Fig. 3: GSMaP performance at Huong River basin, Vietnam

Simulation of stream flow was possible by forcing the hydrological model, as seen in Fig. 4, where results using GSMaP_MVK are able to represent the pattern of flood peaks. However, the magnitudes of the peaks show underestimations for 2008, as shown in Fig. 4.

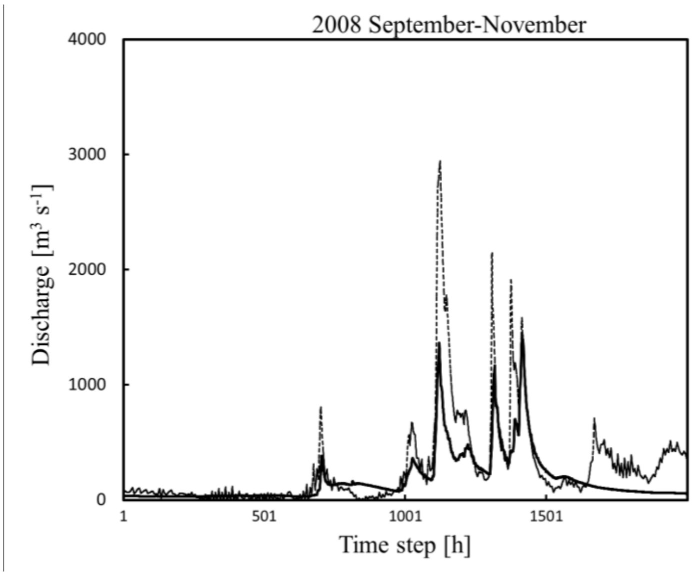

Fig. 4: Underestimation of river discharge simulation using GSMaP_MVK (in continuous black) at Huong River basin, Vietnam. Dashed line shows the observations.

Similar procedures were applied to 2006, 2007 and 2009 and the results are summarized using simple bias, RMSE and NSE, as in Table 1 where the 2008 pattern is also seen.

Table 1. Three efficiency criterions using GSMaP_MVK at Huong River, Vietnam

	GSMaP_MVK		
Year	BIAS [%]	RMSE [m^3s^{-1}]	NSE
2006	-43	398	0.31
2007	-70	987	0.04
2008	-60	462	0.32
2009	-48	539	0.36
Mean	-55	596	0.26

On the other hand, river discharge simulation at Ping River was obtained by comparing the raw TRMM data and the corrected data. The correction factors were developed for 2008 and 2009 and then validated for 2010, as seen in Fig. 5. The comparison of simulated total volumes indicates that corrected TRMM can improve the result. This result indicates the possibility of adjusting correcting factors of TRMM by using information from past years for actual flood management.

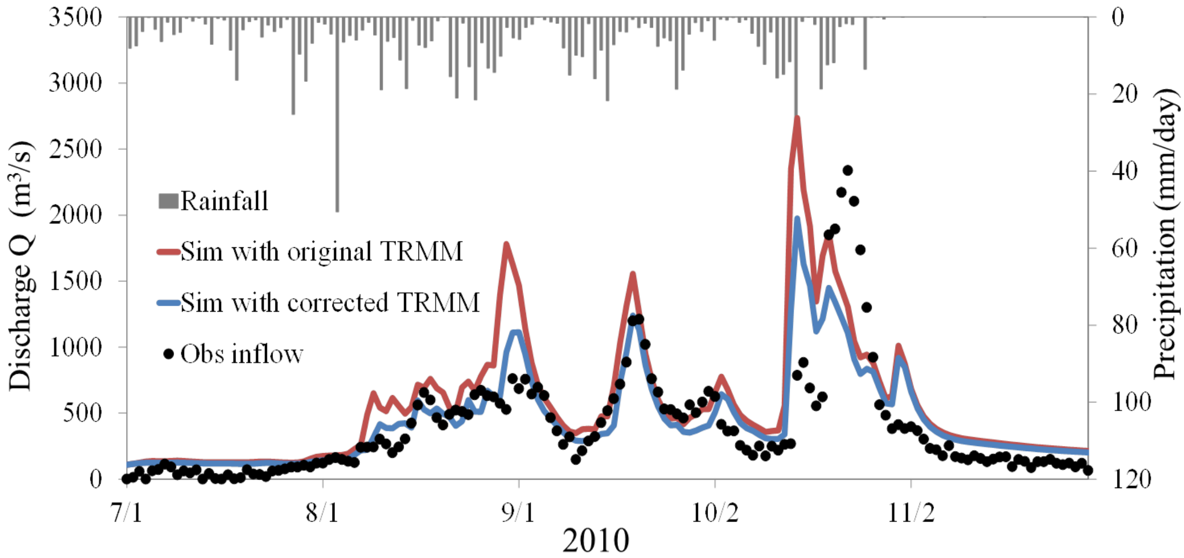

Fig. 5: Enhanced inflow to Bhumipol dam using corrected TRMM at Ping River basin, Thailand

5. CONCLUSIONS

In this study two popular satellite-based precipitation measurement products, TRMM and GSMaP_MVK were used at the Ping and Huong Rivers in Thailand and Vietnam respectively. The results indicate that SBP products tend to underestimate precipitation intensities, but they seem able to depict spatial and temporal patterns. The evaluated SBPs at basin scale were found to be useful and river discharge simulation was enhanced with corrected SBPs. This approach might be applied to other basins, not only in the Southeast Asia region.

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