GROUND VALIDATION OF SATELLITE-BASED PRECIPITATION FOR FLOOD SIMULATION IN SOUTH-EAST ASIAN RIVER BASINS

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ABSTRACT

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

Keywords: ground validation, flood simulation, satellite based precipitation, distributed hydrological model

1 INTRODUCTION

The water assessment based on hydro-meteorological observations plays a key role not only in water resources management, but also in flood damage protection of the society. However, rain gauge networks might be sparse in developing countries due to maintenance costs and accessibility. On the other hand, as remote sensors installed at satellites can cover large areas over the globe continuously, the exploitation of these products in those countries has shown high potential. For example, in poorly gauged regions like in Thailand and the Amazon, the availability of a global data set was assessed by using error evaluations (Chokngamwong and Chiu, 2008; Su et al., 2007). Nowadays, there is an attempt to improve SBP, namely Tropical Rainfall Measuring Mission (TRMM) measurements with statistical evaluation in South America (Vila et al., 2009). However, this product is monthly calibrated using global hydrology network (e.g. long term variability of rainfall); therefore, it doesn't have enough capability to accurately specify local flood events with short duration (Huffman, 2007). The possibility to quantify the biases or tendency at regional and local scales is still under investigation. The biases might be associated to the type of rainfall events within the basin and surroundings. The correction factor considering the biases could be applied to SBP and increase local precipitation measurements' accuracy. For example, in Bangladesh, the correction factors were extrapolated over regions with no in-situ data (Saavedra et al., 2010)

This study aims to investigate the applicability of Satellite Based Precipitation (SBP) in combination with local rain gauge network to improve the spatial and temporal resolution of measurements in Asian River basins. The process can be carried out in three steps: 1) evaluation of

SBP products in regions with few gauges by scale difference; 2) validation of SBP correction method; 3) application of corrected products as input for hydrological model. The improved measurement product may allow us to detect the precipitation pattern and to quantify the risk of flooding.

2 STUDY AREA

Due to the diversity in geomorphology, ecological steps, and dominant weather, we would propose two test basins: Chao Phraya (Thailand) and Ping (Vietnam) in Asia region. Application of satellite-based precipitation in combination with rain gauge measurements to simulate hydrological processes is proposed.

Ping River:

This catchment is located in upper Chao Phraya basin, Thailand (Fig.1). The basin encompasses 26,200 km^2 and rainy season extends from May to October. The TRMM products were employed with promising results following Tanuma et al (2012). A higher variability of precipitation in the basin in the future has been identified based on TRMM analysis (Ogata et al. 2012).

Huong River:

Huong River basin in the central Vietnam was chosen (Fig. 1). The basin area is 1,513 km^2. The flood control point called Kim Long is set as the outlet of the basin. The Huong River experiences an average of 3.5 floods per year with threat water level. Each flood season begins normally in October. The area is dominantly composed by evergreen forest and shrub.

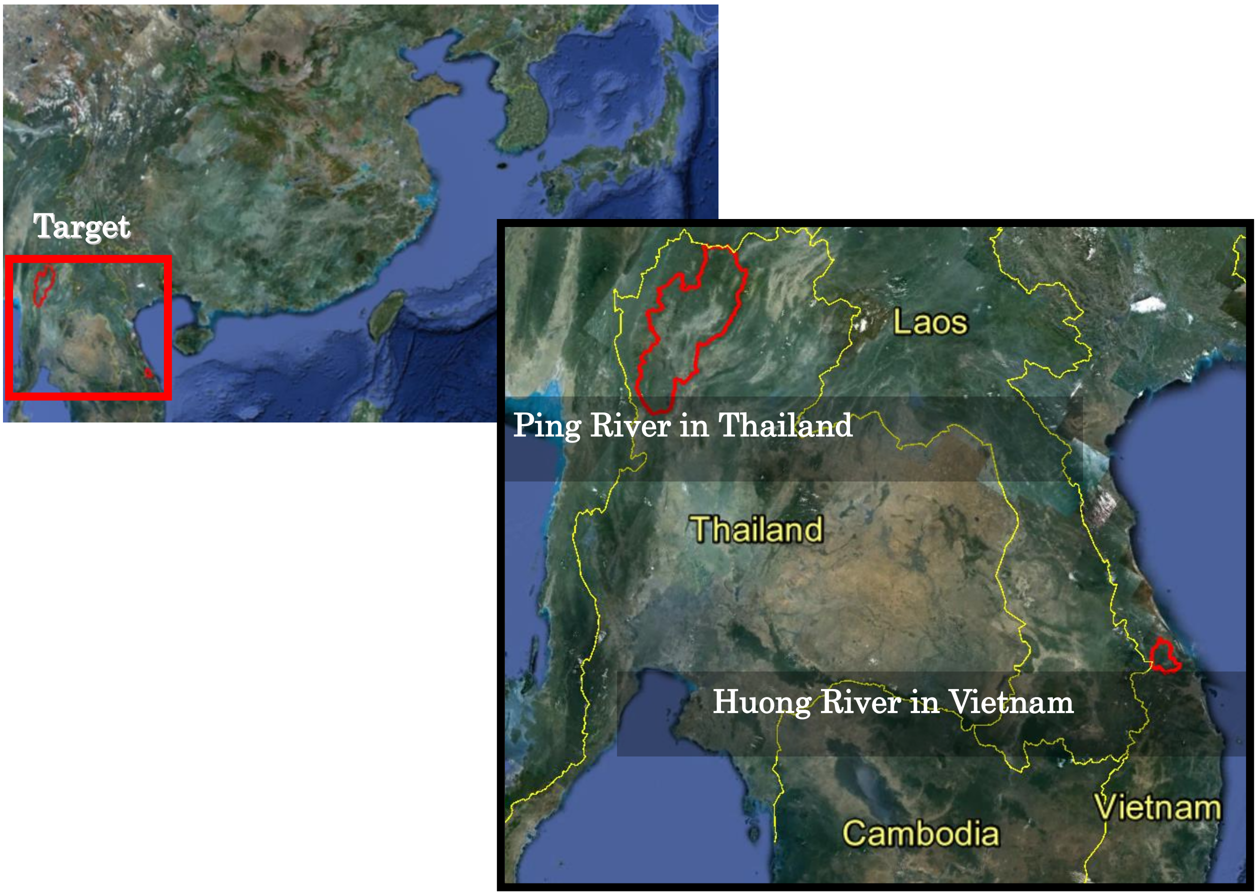

Figure 1. Location of test River basins in South-East Asia region

3 METHODS

In order to measure precipitation intensities at land surface, data from available local rain gauge network systems were used. In this study, TRMM product was launched by the National Aeronautics and Space Administration (NASA) and Japan Aerospace Exploration Agency (JAXA) in 1997 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) was used. This product delivers hourly precipitation data. The different sensor-algorithms are 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. The version MVK is 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 physically-based semi-distributed hydrological model set-up at each test basin. The model takes into account for the spatially distributed hydrological process in the basin and the routing of water in the streamline. Geomorphology-based hydrological model (GBHM) developed by Yang (1998) was chosen because of its high applicability to a steep mountainous area (e.g. Yang 2002). 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 drift into the main river channel. Water flow under the ground divided by several layers is governed by the Richards equation on the unsaturated condition. Otherwise, Darcy's law is applied to the saturated zone. 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.

Then, it was possible to apply of corrected products as input for hydrological model following Tanuma et al (2012). The improved measurement product may allow us to detect the precipitation pattern and to quantify the risk of flooding.

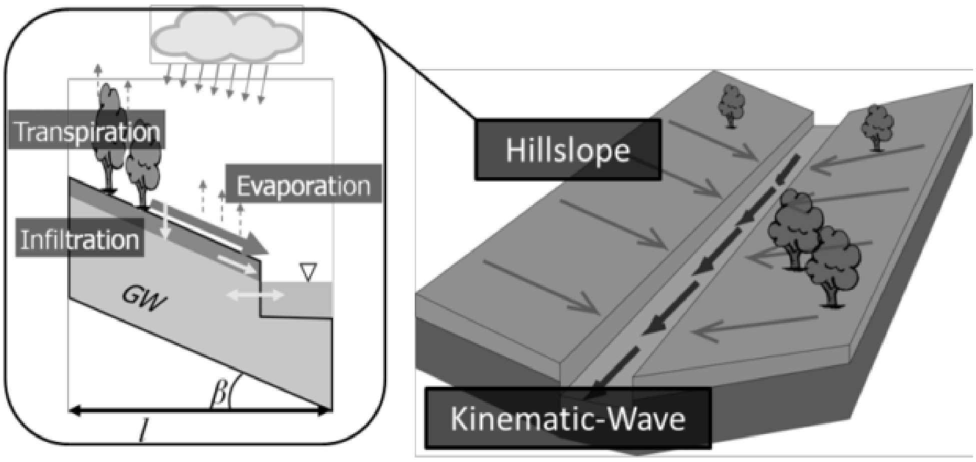

Figure 2. The concept of hillslope based hydrological model

4 RESULTS AND DISCUSSIONS

Flood simulation by using DHM was performed with both satellite based precipitation products: GSMaP_MVK and TRMM at the two river basins. The precipitation with MVK was first compared against rain gauge at Huong river during monsoon season (Sept-Nov) in 2006-2009 as seen in Fig. 3. It can be noticed that at lower intensities better agreement can be expected. Opposite, at higher intensities the estimations might be scattered.

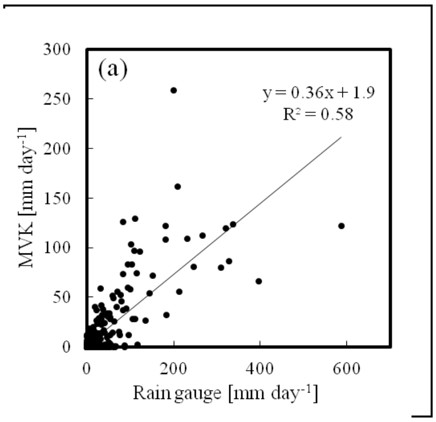

Figure 3. GSMaP performance at Huong River basin, Vietnam

Then, 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 peaks show underestimations not only for 2008 as in Fig. 4.

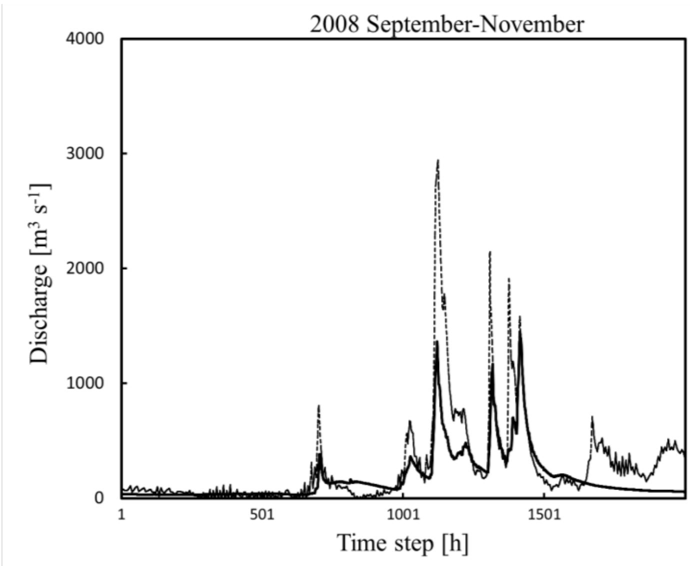

Figure 4. Underestimation of river discharge simulation using GSMaP_MVK (in continuous black) at Huong River basin, Vietnam. Dashed line shows the observations.

Similar procedure was applied for 2006, 2007 and 2009. Then, results are summarized suing simple bias, RMSE and NSE as in Table 1 where the pattern of 2008 can also be noticed.

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

	GSMaP_MVK		
	BIAS	RMSE	NSE
Year	[%]	[m^3s^{-1}]	
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, at river discharge simulation at Ping River was obtained by comparing the raw TRMM and the corrected one. Actually, 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 to adjust correcting factors of TRMM by using information from the past years for actual flood management.

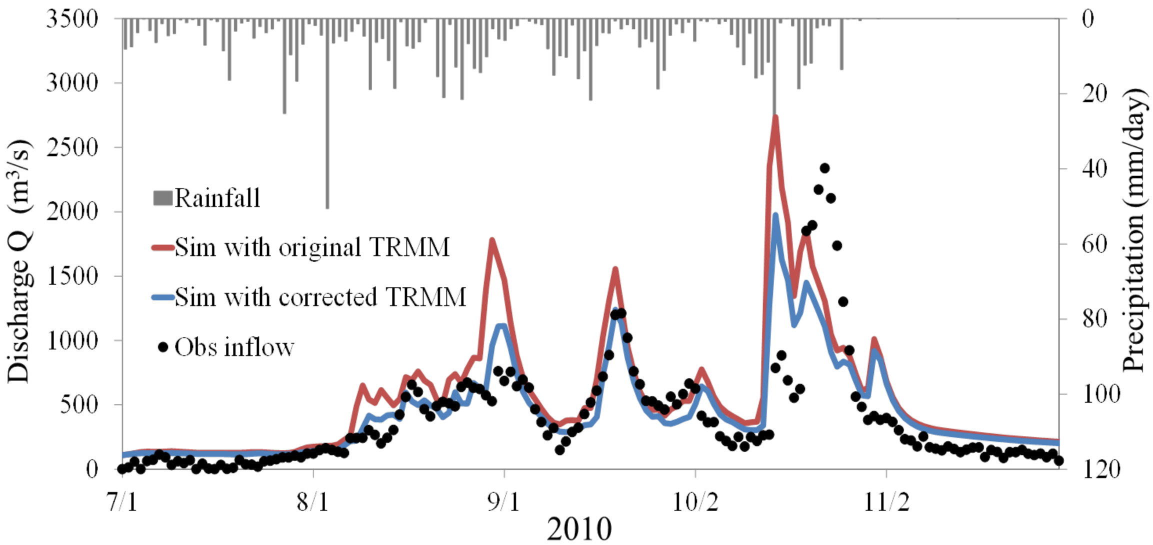

Figure 5. Enhanced inflow to Bhumipol dam using corrected TRMM at Ping River basin, Thailand

CONCLUSIONS

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

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