SATELLITE BASE APPLICATION FOR FLOOD SIMULATION

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ABSTRACT: Flooding causes significant damage when heavy rainfall occurs. Flood protection is difficultly because of social and also investments. However, location, time, and quantity of rainfall information can be used for awareness and preparation approach that are efficiently represented for minimize damages from disaster. The size of flood disaster depends on topography, land cover and rainfall. Rainfall is normally difficult for predicting but it is possible for flood forecasting in the near future, when the magnitude and distribution of rainfall over the basin area are measured in a real-time. The rain-gauges are limited in rural areas; therefore it is necessary to use satellite technology precipitation data in precipitation measurement and its distribution over basin area real time.
This paper uses satellite precipitation data in combination with other remote sensing data to include a flood simulation model in which a large basin scale is concentrated. The Tropical Rainfall Measuring Mission (TRMM) is used for estimation rainfall in ungauged areas. Daily TRMM data is applied in the rainfall-runoff-inundation model (RRI) on the upper part of the Nan River Basin in Thailand. In a simulation, Shuttle Radar Topography Mission (SRTM) and Hydrology data and maps based on Shuttle Elevation Derivatives at multiple Scales (HydroSHEDS) indicated topography scaled to 15 arc-seconds (500 meters) and Global Land Cover Characteristics (GLCC) illustrated land cover classified by 4 types. TRMM data from 2010 to 2012 are applied to this flood simulation because it covered 3 main of flood type in study area; great, medium and exiguous respectively. The results revealed that runoff was analysed with TRMM, which was under estimation when it was evaluated with measurement runoff station along the main river. The assessment found that the peak bias was closely about 20-25% and the correlation was nearly about 0.67-0.72. This approach can be using for flood warning and flood hazard map leading to the recommendation of sustainable flood management.

1. INTRODUCTION

1.1 Background

Floods are one kinds of disaster that affect human lives and make economic losses. Flood protections have two methods, structural and nonstructural, in which social and investment are main issue for selecting. To minimize resist from stakeholder, the nonstructural is the essential for decreasing flood damage using flood forecasting for which rainfall data is the main component. Since the rain gauged data is limited to some specific areas and also requires a period of time to process which cannot provide the real-time data for flood simulation.

One way to get a special and up-to-date rainfall data is to use satellite rainfall data for which there have explored more ten years ago. Tropical Rainfall Measuring Mission (TRMM), which is one type of satellite rainfall, has been operated in near real time. Therefore this study aims to use TRMM data for establishing the flood simulation application. In this paper, we organize as follows. Section 1 explains the TRMM, conceptual of flood simulation model (RRI model) and study area; Section 2 provides methodology; section 3 present results; section 4 reports our final conclusions and discussion.

1.2 Tropical Rainfall Measuring Mission (TRMM)

In the present day the satellite based rainfall that locates in the tropical zone is TRMM, which is a joint mission between NASA of USA and JAXA of Japan under the cooperation project in monitoring and exploration of space. TRMM is the first satellite for monitoring variables, dynamic of precipitation, and latent heat of the precipitation process. The precipitation in the tropical zone is two-third of the total precipitation in the world, which plays an important role of the weather cycle. TRMM measurement is the combination between visible infrared and microwave sensor with high frequency for monitoring and recording data both space and time. The satellite operation has been built for measuring the occurrence of precipitation both in the earth and the equatorial since

1997. It has features and details as shown in Figure 1. The satellite is consisted by 5 main type sensor of Precipitation Radar (PR), TRMM microwave Image (TMI), Visible Infrared Scanner (VIRS), Clouds and the Earth's Radiant Energy System (CERES) and Lighting Imaging Sensor (LIS). It has a circular and non-sun-synchronous orbit. The satellite observes from 305 km above the ground and 35 degree of orbit angle to equator, and it moves around the earth in 90 minutes or 16 times a day.

1.3 Rainfall-Runoff-Inundation Model

Rainfall-runoff-inundation (RRI) model, which is a new developed model in a two dimension, was used for simulation in this study (Sayama et al., 2012). Figure 2 is shown that the model deals with slopes and river channels separately. The river channel is located on the grid cell while the model assumes that both slope and river are positioned within the same grid cell. A channel is discretised as a single vector along its centreline of the overlying slope grid cell. The channel represents an extra flow path between grid cells lying over the actual river course. Lateral flows are simulated on slope cells on a two dimensional basis. Slope grid cells on the river channel have two water depths: one for the channel and the other for the slope (or floodplain). The inflow-outflow interaction between the slope and river is calculated based on different overflowing formulae depending on water-level and levee-height conditions. RRI model was simulated on the 2011 flood in Sukothai province of Thailand. The simulation, which has closed by observation data, was used for estimating damage cost (A. Sriariyawat et al., 2013). Pakistan flood in 2010 in the Kabul River Basin was simulated with RRI model. The model results showed a good relationship with an inundation map produce base on satellite data (MODIS) (Sayama et al., 2012).

1.4 Simulation Area

Either upper part of Nan River Basin or upper part of SIRIKIT dam is the important area because release of the SIRIKIT dam has provided a supply to the central plain including Bangkok area. The upper part of Nan river basin locates in the northern region of Thailand with the total catchment area of 13,000 square kilometres that is shown in figure 3. The basin, which originates from Bor Klua District, Nan Province, is situated between latitude 17 42' 12" to latitude 19 37' 48" N and longitude 100 06' 30" to longitude 101o 21' 48" E.

2. METHODOLOGY

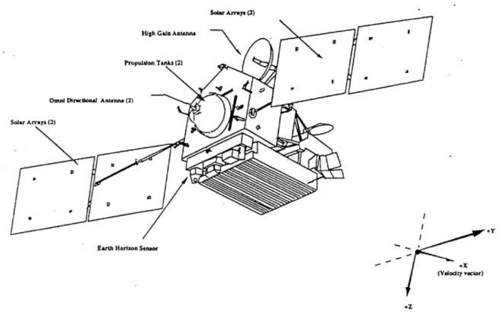
Rainfall, topography, river channel parameters and land-use are Input data to simulate in the RRI model. Rainfall data was collected from the Thai Meteorological Department (TMD) and Royal Irrigation Department (RID) that was located in figure 4. Daily rainfall data, which was shown in figure 5, was used for calibrating in year 2011 and verifying in year 2010 and 2012; and also the TRMM of the upper part of Nan river basin is applied to the RRI model.

The topography data was represented by Digital Elevation Model (DEM) from Shuttle Radar Topography Mission (SRTM) to provide by U.S. Geological Survey (USGS). This data was occurred by a joint project between the National Imagery and Mapping Agency (NIMA) and the National Aeronautics and Space Administration (NASA). SRTM are made from radar interferometry which used a two radar images from a slightly different location from the shuttle. It has resolution about 15 x 15 arc-second or about 500 x 500 km as shown in Figure 6, while flow direction and flow accumulation data was provided from Hydrological data and maps based on shuttle elevation derivatives at multiple scales (HydroSHEDS) of USGS as shown in Figure 7 for flow accumulate. The width and depth of the main channels river were obtained by Royal Irrigation Department (RID) in 1996, while width and depth of tributary were calculated by the flow accumulate data using equation (1) and (2) (Sayama et al., 2012).

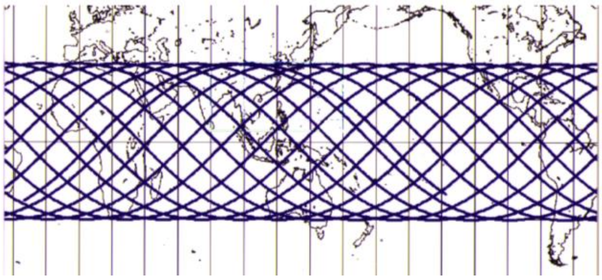
$$W = 16.93 \cdot A_{basin}^{0.186} \tag{1}$$

$$D = 16.93 \cdot A_{basin}^{0.120} \tag{2}$$

where $\boldsymbol{W}$ is the channel width in metre, $\boldsymbol{A_{basin}}$ is the catchment area in square kilometre, and $\boldsymbol{D}$ is the channel depth in metre. The land use was collected by Global Land Cover Characteristics (GLCC) in 2008 as shown in Figure 8 that was divided by 4 types, i.e. grass land, forestation, urban and water body areas. GLCC is one kilometre of Advanced Very High Resolution Radiometer (AVHRR) NDVI composites which are core data set to use in a land cover characterization. Table 1 show the calibrated parameter of surface roughness and Green Ampt. Calibration duration began from 1st January to 31st December 2011 for extreme flood in 2011. The verification duration began from 1st January to 31 December in 2010 and 2012 for normal and dry year in water year of Thailand respectively. Figure 9 show a methodology stream line.



a) TRMM spacecraft



b) TRMM Orbit

Figure 1 TRMM information

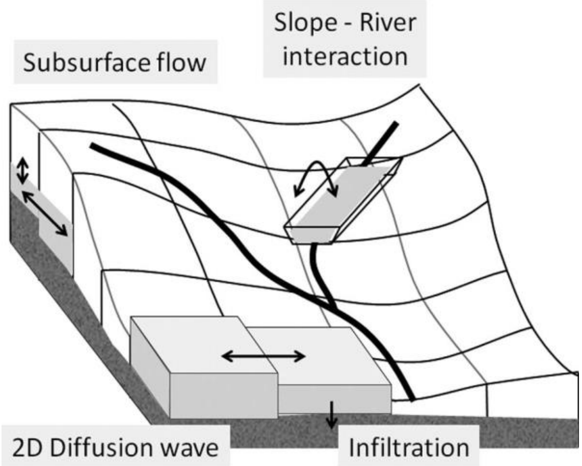


Figure 2 RRI model

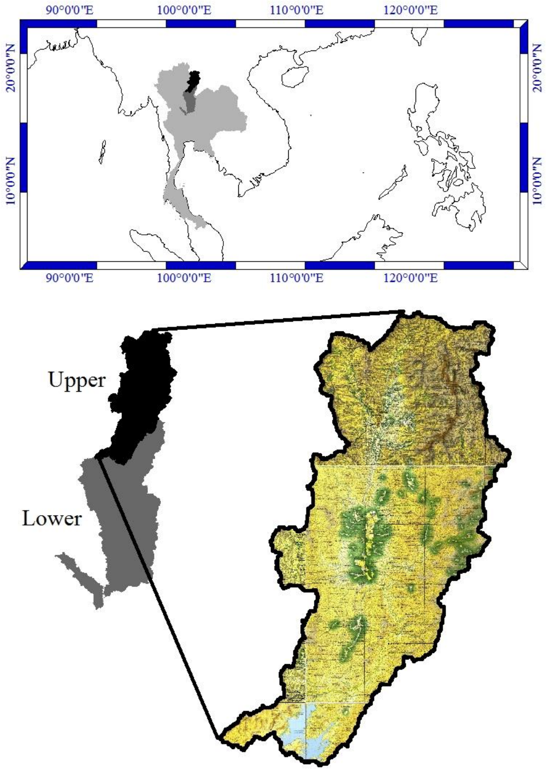


Figure 3 Upper part of Nan River Basin area

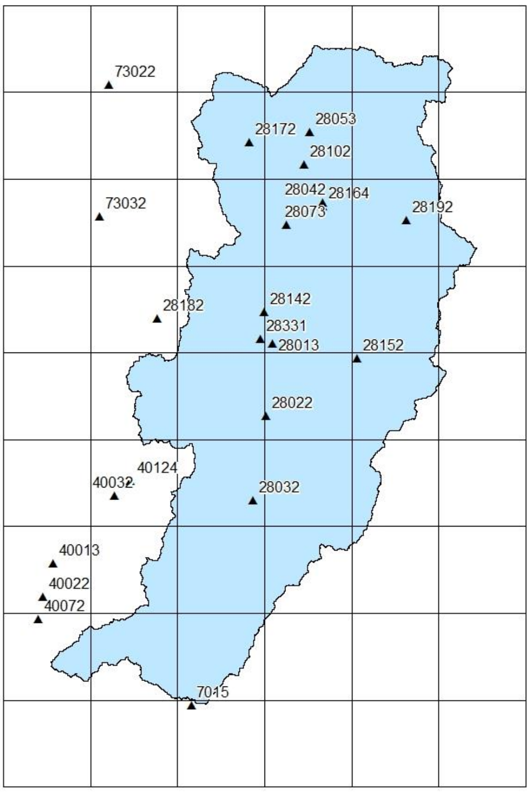


Figure 4 rain gauge and TRMM grid locations in study area

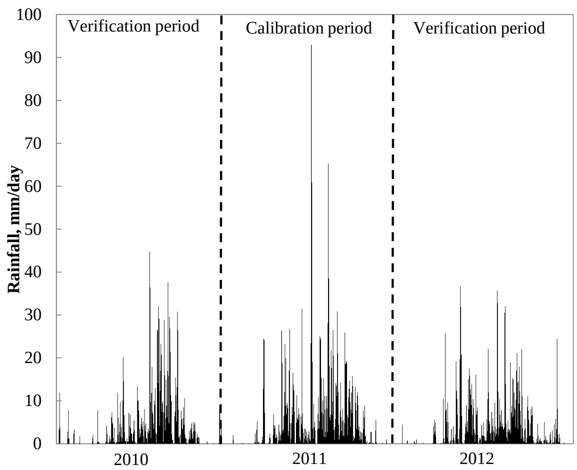


Figure 5 Daily rainfall data for calibration and verification

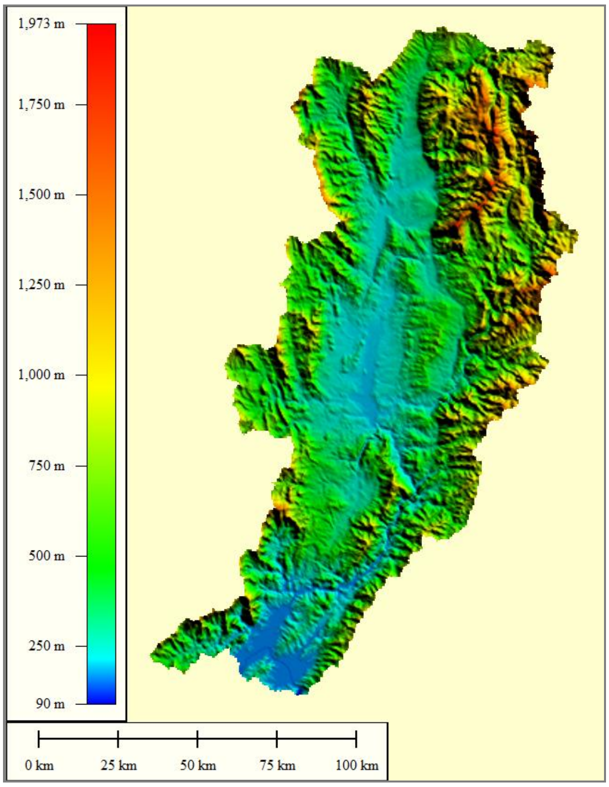


Figure 6 SRTM DEM of study area

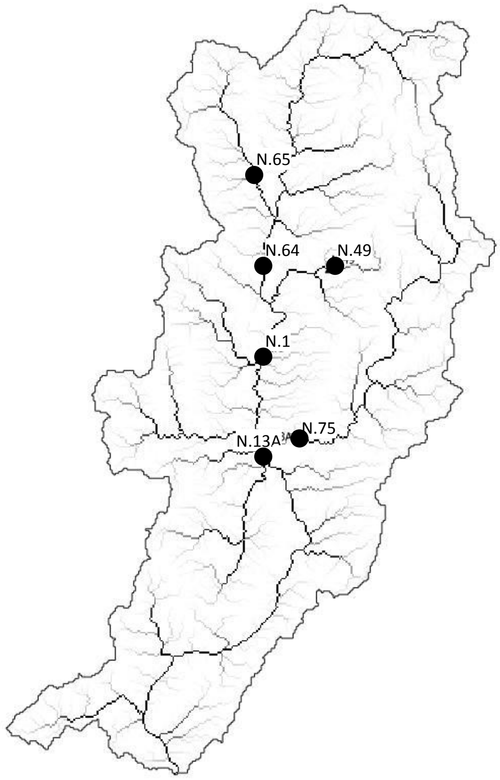


Figure 7 Flow accumulation based on HydroSHEDS and runoff station

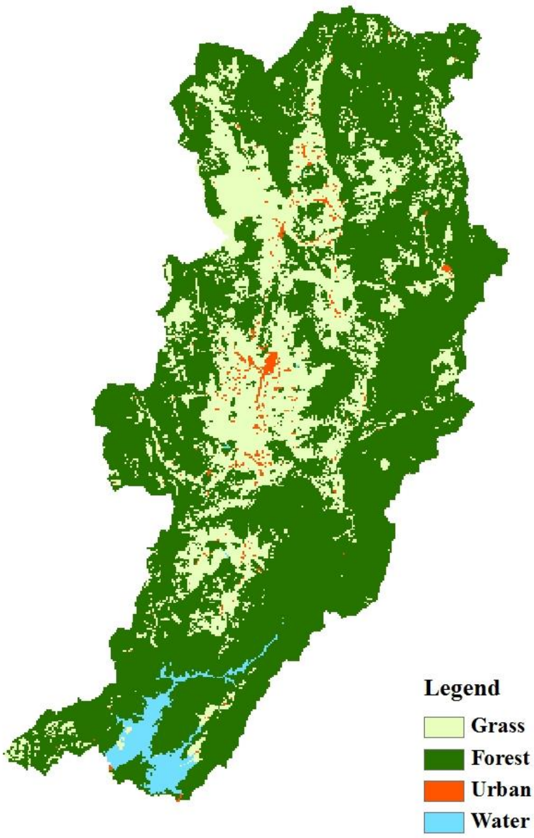


Figure 8 Land cover in study area divided into 4 types

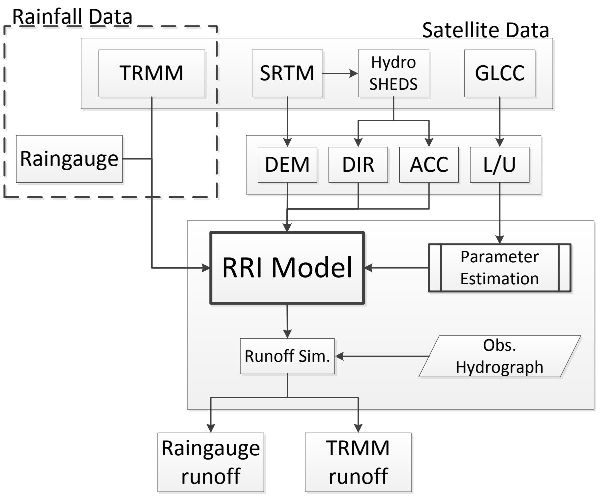


Figure 9 Methodology flowchart

Table 1 Calibrated land cover parameter

Land cover type	n's maning coefficient	Hydraulic conductivity ,m/s	GAmpt parameter		
			k, 10^{-7} m/s	delta	f, 10^{-3} m
Grass	0.05	1.00	8.3	0.463	218.0
Forest	0.40	0.10	5.5	0.479	88.9
Urban	0.17	0.01	8.3	0.475	292.0
Water	0.035	0.10	0.0	0.463	316.0

3. RESULT

A simulation result was shown in figure 10 for a comparison between observations, raingauge and TRMM; while correlation, peak bias and root mean square error (RMSE) were shown in table 2. In the dry season, the discharge at beginning and end of year (January until May and October until December) agreed reasonably well with observed data. However, the peak can be captured in rainy season between June until September of a year, but discharge from simulation was lower than that observed for all simulation for the raingauge and the TRMM. Discharge could be caused underestimating observed discharge from extrapolation of the rating curve. In Summary, the result comparisons are very similar in term of discharge, which have a correlation about 0.725- 0.875 and a peak bias 30- 82 percentage for the raingauge but TRMM have a correlation about 0.523- 0.712 and a peak bias 10.7-69.9 percentage. Rainaguge present a value about 22.332-118.627 for the RMSE in which TRMM shows a range about 23.849-381.065. Runoff volume, which is important parameter, is calculated by simulation results. It is a total volume of water along simulation time (2010-2012) which is presented by bias percentage with observation data. A range between 4.43-21.73 percentage are an over estimation, while an under estimation is 13.37-38.26 percentage for runoff volume bias parameter of raingaue. A TRMM simulation result, a higher assessment is 60.07 percentages, while its lower is 3.61-50.89 percentages. However, the flood area is still not closed to the observation data. These results still required more parameter calibrations in the flood forecasting model, which is the following in the future study.

Table 2 Correlation RMSE and bias of simulation result

Sta.	Raingauge				TRMM			
	Correlation, R	Peak bias*	RMSE, cms	Runoff volume bias*	Correlation, R	Peak bias*	RMSE, cms	Runoff volume bias*
N.64	0.875	-50.0%	82.495	+21.73%	0.712	+10.7%	109.399	-3.610%
N.1	0.857	-46.7%	118.627	+11.15%	0.696	+53.3%	163.487	-11.58%
N.13A	0.848	-65.7%	282.642	-13.37%	0.669	-32.9%	381.065	-22.58%
N.65	0.829	-30.8%	22.332	-38.26%	0.666	+53.8%	26.849	-50.89%
N.49	0.725	-82.2%	28.660	+102.1%	0.523	-68.9%	23.602	+60.07%
N.75	0.856	-60.0%	66.772	+4.43%	0.704	+40.0%	87.354	-6.380%
AVR.	**0.831**	**-55.9%**	**100.254**	**+87.78%**	**0.662**	**+9.22%**	**131.959**	**-34.97%**

Remark: '+' over and '-'under estimation

4. CONCLUSIONS AND DISCUSSIONS

This study has presented approaches for estimating runoff from the satellite using the RRI model data simulation. The estimated runoff has been closely underestimated compared to observation data from the Royal Irrigation Department (RID) in each runoff station. Summary correlations of comparison are 0.831 and 0.662 for raingauge and TRMM of which the RMSE are 100.254 and 131.595 cubic metre per second. A 55.9% and 43.3% total error of peak bias is believed in a range acceptable for a basin scale in discharge value from the raingauge and the TRMM. Similarly, an 87.78 percentages of raingauge is opposite to TRMM which is 34.97 percentages. Correlation parameters in each station are a quite same value in raingauge and also TRMM. In term of RMSE, raingauge are a little than TRMM but N.49 is difference. In raingauge simulation results, peak discharges are under estimation; while 4 station of TRMM are over estimation but the under estimation has 2 station, N.13A and N.49. Runoff volume of raingauge data has allowable range 30 percentages but N.49 is over estimation. TRMM runoff volume parameters show that the parameters are under estimation about 25 percentages when these are compared with observation data but N.49 is difference. N.13A and N.49 have some error because of resolution and characteristic in geography data. When a rough resolution size was used, N.13A becomes a junction of 3 branches, which has affected to simulation results. Then, a high resolution of geography data will be applied in a future work. N.49 has more error because DEM and land cover in its watershed area might be rapidly changed, when the data is not up-to-date. This data was provided in 2000, but modelling simulate in 2010-2012. TRMM data could be useful in assessing runoff that is claimed by runoff volume parameter. It has some error that can be taken a bias collection for becoming a high accuracy data in term of time series and special in future work.

5. ACNOWLEDGMENTS

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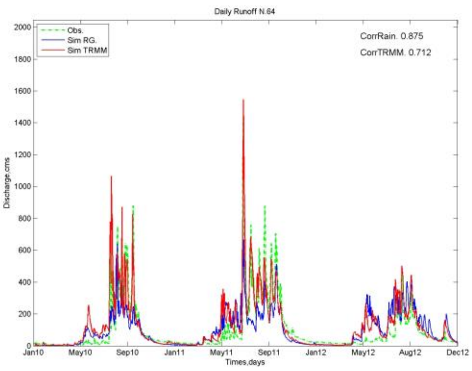
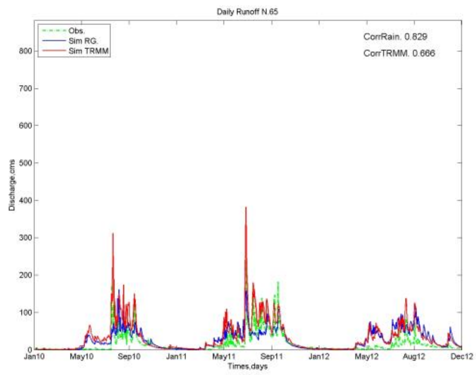
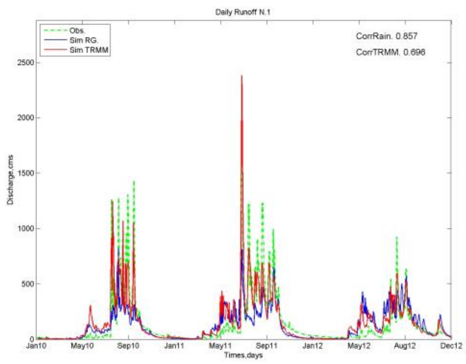


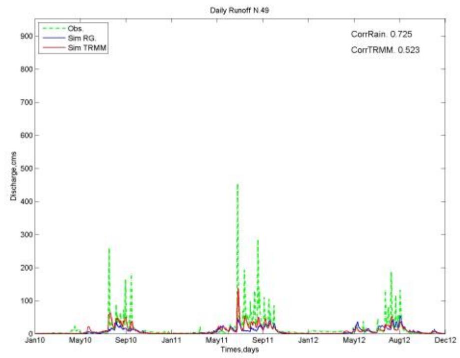
a) N.64



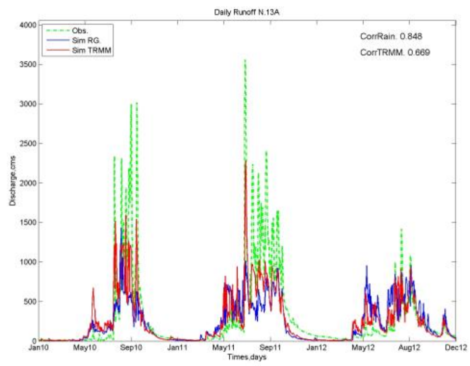
d) N.65



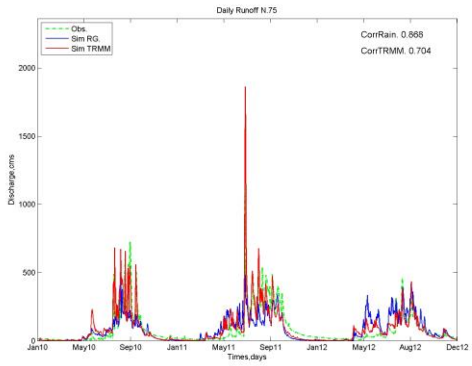
b) N.1



e) N.49



c) N.13A



f) N.75

Figure 10 Comparison of discharge at runoff station between observation data and simulation results

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