

Hydrological Modeling of Large-scale Ungauged Basin

Case Study: Ayeyarwady (Irrawaddy) Basin, Myanmar

Ali Chavoshian¹, H. Ishidaira², K. Takeuchi¹ and J. Yoshitani¹

¹ International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO

² University of Yamanashi

Email of corresponding author: ali55@pwri.go.jp

ABSTRACT: In the recent years development of global coverage satellite-based data makes them suitable to use for prediction in ungauged or poor data basins. Moreover, a proxy catchment also can closely resemble the hydrological behavior of target basin. This study has presented modeling runoff generation for prediction hydrological responses in large basins with lack of access to observed data. A parsimonious distributed hydrological model (BTOPMC) is used. It is shown that how the proxy catchment can be applied for parameter estimation of an ungauged-large basin. Despite of the underestimation of flow volume by satellite-based precipitation, the overall performance of application is encouraging for long term modeling in large basin. The result gives motivation for application of method in ungauged or poor data basins using proper proxy catchment.

1. INTRODUCTION

There is no doubt that Prediction in Ungauged Basin (PUB) is interesting not only for hydrologist as a research field, but also for water resources manager as a tool for decision making. A blind test of hydrological models in a network of well gauged basins is useful for improvement of models for PUB purposes. Comparison of each model's results with observed data and/or other model's results when modelers use the same methodology and data will be able for them to evaluate goodness or badness of their models for a practical application in ungauged basins. A primary methodology for the "blind testing" was introduced by Ewen and Parkin(1996) with an application using SHE model reported by Parkin *et al.*, 1996). However, they used a dense ground-based measurement as input of the model and their methodology has been considered only blind of observation data for model parameters estimation. Moreover, the application of the method was limited to a small Mediterranean experimental basin (1km²).

In the last few decades, there have been considerable theoretical and technological advances in our ability to predict individual hydrological processes, in scaling up to the basin scale, in physically based hydrological modeling at the basin scale, and in remote sensing.

In the recent years development of globally covered satellite-based data makes themselves suitable to be used for prediction in ungauged or poor data basins. Therefore we are going to introduce a new blind test methodology using this kind of data. This methodology can be used for a model inter-comparison in a well gauged basin and for prediction of hydrological responses in an ungauged basin.

2. STUDY AREA AND DATA

The Ayeyarwady (Irrawaddy) flows through Myanmar (Burma) from the North to the South (Figure 1). It is Myanmar's largest river (about 2170 km long) and it is the most important commercial waterway, with a drainage area of about 411,000 km². The Ayeyarwady River starts in Kachin State, at the confluence of the Mali Hka and N'Mai Hka rivers. The Ayeyarwady River bisects the country from north to south and empties through a nine armed delta into the Indian Ocean. In the delta part, it branches into several mouths, forming an extensive delta, and empties into the Andaman Sea. Although navigable by large vessels to Myitkyina for a distance over 1600 km from the ocean, the river is also full of sandbanks and islands, making such navigation difficult. The largest tributary of the river is the Chindwin River. The Irrawaddy provides the main means of communication between important points in the interior and the southern port cities, especially Yangon (formerly known as Rangoon).

There are a few hydro-climatologically data sets of Ayeyarwady, which are available in public domain. Among those a few data, there is 10-yearly monthly minimum, maximum and average river discharge at Sagaing station, very near to Mandalay in the shown map (Source GRDC data base).



Figure 1. Irrawaddy River

3. METHODOLOGY

The aim of detail description of the methodology using publicly available data is to define a generally applicable framework for testing the fitness of hydrological models, of any type, for Prediction in Ungauged Basin (PUB). An inter-comparison of hydrological models using same method and data make it possible to answer why does one model reproduce hydrologic response of study area better or worse than the others? Which components of the models make such a difference? Moreover we are able to evaluate utility of publicly available data for PUB.

We proposed a four -step prediction in ungauged basin method:

- Identify publicly available input data or generate them that are not based on traditional ground measurement inside of study area.
- Hydrological model selection
- Select values for the model parameters without using observation data of study area, so that the model closely simulates the interest hydrological behavior of basin.
- Indicate object of test and what kind of hydrologic responses are going to be blindly predicted (target variables). Identifying clearly that not everything predicted will be accurate and important for water manager and what is acceptable will vary from test to test.

A blind test can be done in four levels regarding to available input data and method of model's parameter estimation. These four experiments ordering with level of blindness are (Figure 2):

B0: Blind of any ground-based measurement as well as observed data for model's parameter estimation. This is real situation of any ungauged basins. Precipitation data as well as other necessary input data in this level are obtained from satellite-based data. The proxy catchment or expert judgment will be used for model's parameter estimation. This level of test is conducted in Ayeyarwady river basin.

BP: It is almost the same as above level except for precipitation data. In this experiment the precipitation of ground-based measurement will be used as the input of model.

BPR1: In this level of blind test, in addition of precipitation data, a limited time series of observed discharge data are also available for model's parameter calibration.

BPR2: This level of test will be conducted just for validation of previous blind test result in a well-gauged basin. Full series of observed discharge data as well as all other ground-based measurement will be used for a proper modeling of hydrological response of basin.

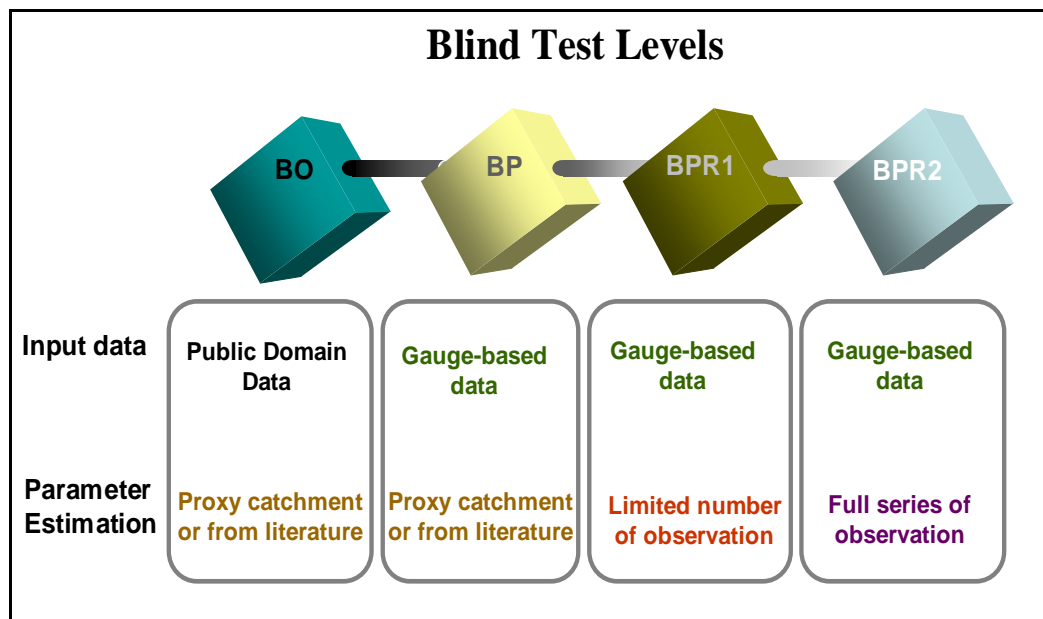


Figure 3. Four steps of a Blind Test Methodology

4. MODEL AND DATA

A parsimonious version of BTOPMC in term of parameters need to be calibrated, is used (Takeuchi *et al.* 1999). As it is described, the BTOPMC is a distributed hydrological model, which is developed based on TOPMODEL concept to overcome the limitation of basin area, by dividing large basin to several blocks. The Muskingum-Cunge method is used for flow routing. Because of no observed snow in study area, number of model parameters reduced to five parameters including: the saturated soil transmissivity T_0 (m^2/h), the decay factor m (m) of T_0 , the maximum storage capacity S_{max} (m) of root zone due to vegetation, the initial value of averaged saturation deficit (m) and the manning roughness coefficient n_0 .

In this study the B0 level of continuous river flow hydrograph of Ayeyarwady river basin is modeled in the Pyay station located in the downstream of basin for a 4-year period from 1998/1/1 to neither 2001/12/31. Neither ground-based measurement nor calibration for observed data is used. All of the input data of model is extracted from satellite-based data with global coverage available in public domain. GTOPO30 developed by USGS is used for topographical data. Horizontal grid spacing of basin is about 4 kilometers using up scaling of 1km original GTOPO30 data. One degree daily-based GPCP (1DD) precipitation data is used because of its acceptable performance in pervious study in this region (Chavoshian *et al.*, 2005). The Shuttleworth-Wallace (S-W) method (1985) developed by Zhou *et al.* (2006) is used for evapotranspiration estimation. In this parameterization of the method, all the necessary data can be obtained from publicly available global data set. 1km resolution IGBP (International Geosphere-Biosphere Program) version 2.0 developed by USGS is used for land cover classification. A 5km girded soil type's data is used which is produced by Food and Agriculture Organization (FAO). Soil types of basin are classified as 50% sand, 30% clay, and 20% silt.

5. RESULT

At first BTOPMC was applied to Mekong River basin (proxy-catchment) for parameters estimation, then the

parameters set has been transferred to Ayeyarwady river basin for simulation of daily-based hydrograph using publicly available data sets including satellite-based precipitation.

Figure 3 shows the simulation result at Pyay station located in the downstream of Ayeyarwady River. For this point two discharge values is observed during a field research trip. These values are shown with red dots in the simulated hydrograph.

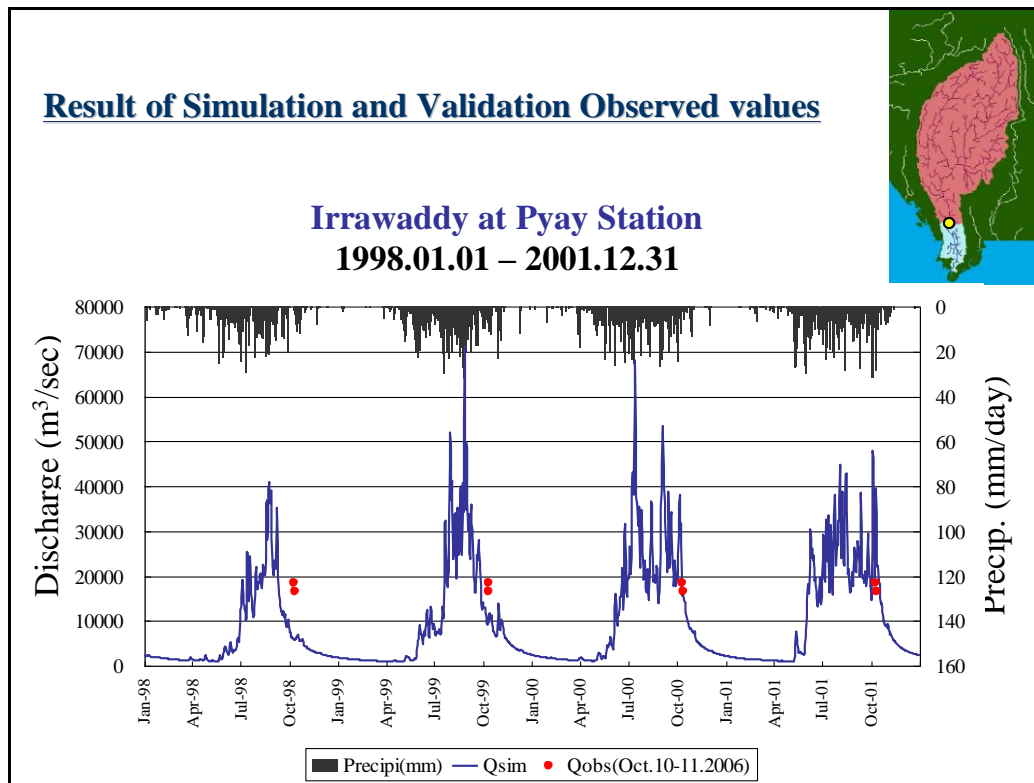


Figure 3. Estimated and two observed discharge values at Pyay

6. DISCUSSION ON RESULT

Two observed discharge values are shown in Figure 3 with red spot. As it is clear from the figure, it shows a very encouraging compatibility with simulated result, except for the first year. The reason of this incompatibility in the first year is effect of initial values. The initial values of the next year will be improved based on simulation result. As a common solution for this problem, the result of first year should be neglected or the model can be run in a cycle run.

In addition result of blind test is validated against available decadal monthly river flow discharge to identify efficiency of the tests. Figure 4 shows this comparison at Pyay station. Despite acceptable fitness of simulation result with observed values in high flow seasons, it is underestimating (15% to 40%) for low flow seasons from November to May. There are three main reasons for this underestimation.

The first and most important one is the role of dam operation at the low flow season. Agriculture is the main sector of the utilization of water in Myanmar as water is very important for cultivation of crops. Dam reservoirs play a major of supplying water to the farmlands in low flow seasons. In the most cases drainage water flows to the Ayeyarwady. This means the stored water in dam reservoirs will be flown to the river and increasing river flow discharge in the low flow seasons. Another reason could be lower estimation of precipitation using satellite-based data. Figure 5 shows less estimation of precipitation using satellite-based GPCP 1dd data compared with observed one, especially in the North and North-east part of basin. The third reason for underestimation of low flow season can be due to neglecting of modeling snowmelt runoff in the current application of BTOPMC. Snow Cover Area (SCA) derived from MODIS 8-day composite satellite data shows effect of snow cover in the upstream of basin (Figure 6). The snowmelt runoff increases low flow from November to May.

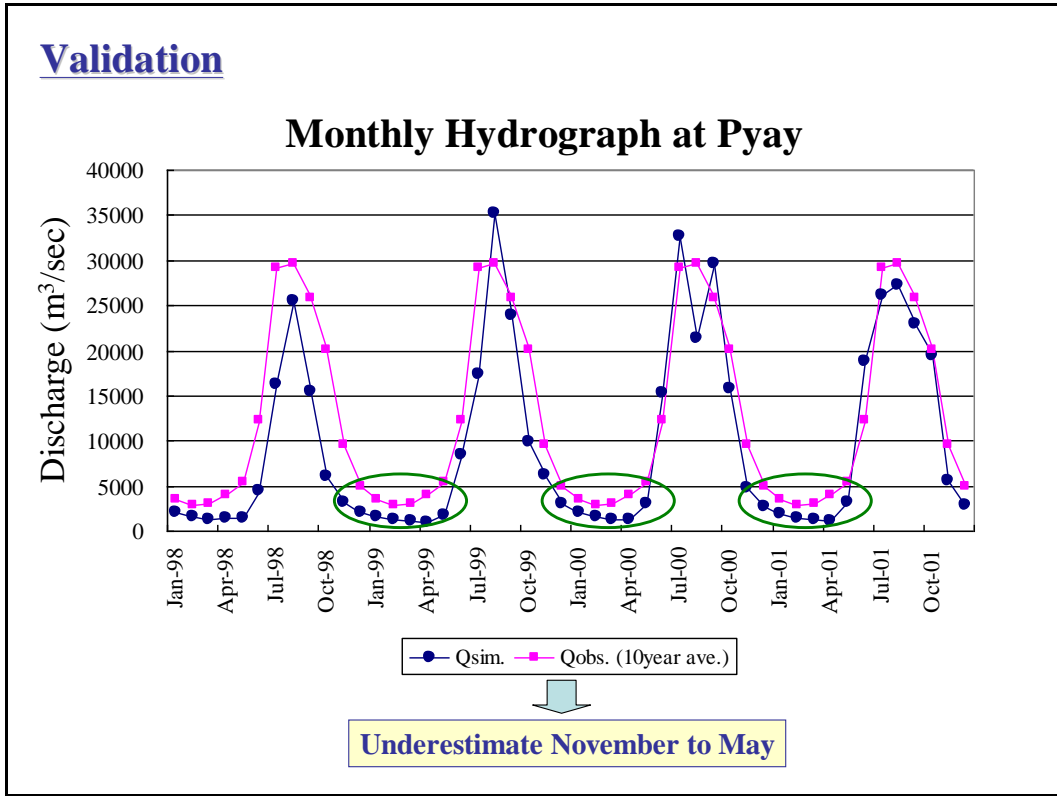


Figure 4. Validation of results against monthly river discharge

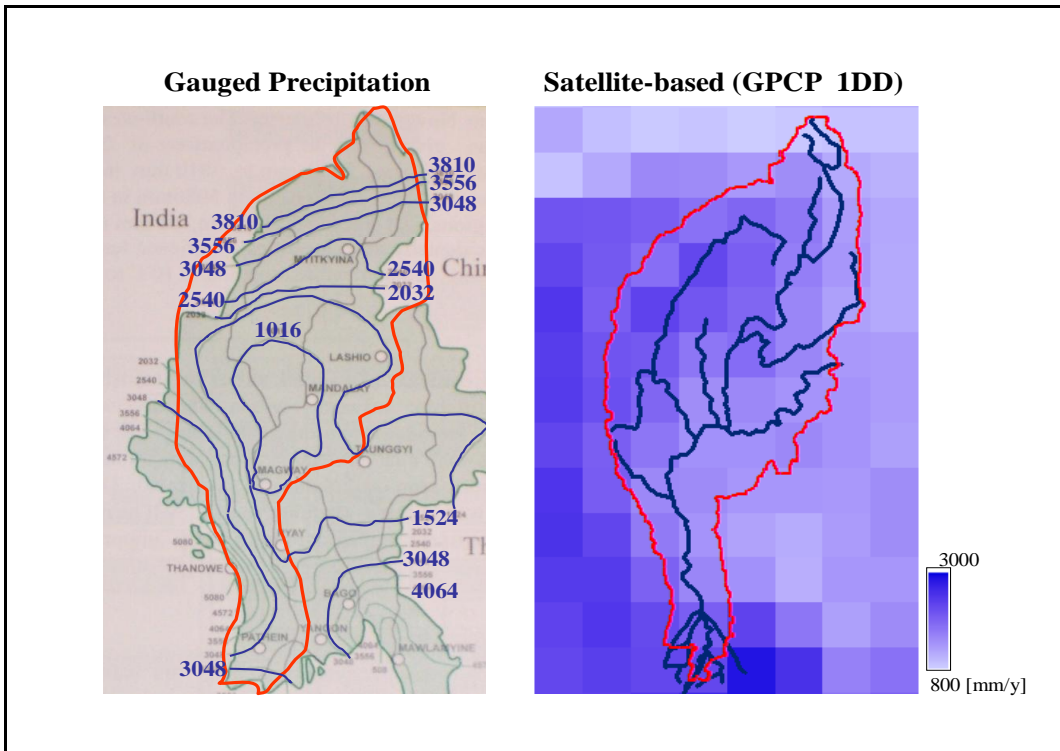


Figure 5. Comparison of satellite-based precipitation with observed one

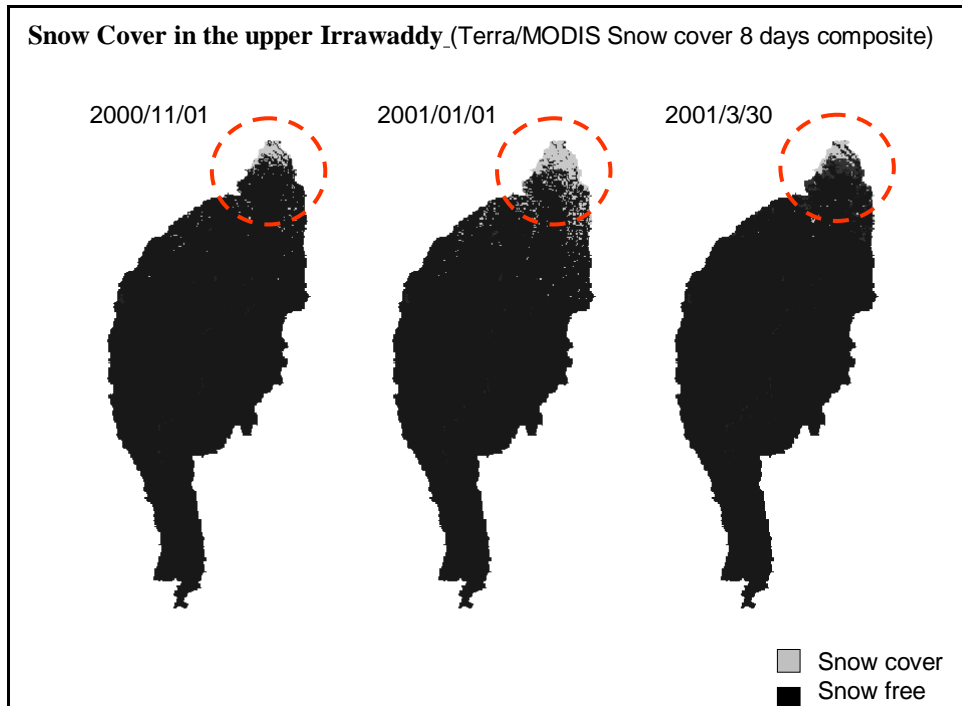


Figure 6. Snow Cover Area in the upstream of Ayeyarwady river basin

7. CONCLUSION

This study has presented utility of satellite-based data and application of proxy- basin for runoff prediction in large basin with lack of access to observed data. It is shown that how the transferred parameters from a similar basin can be used for modeling runoff generation using distributed hydrological modes in an ungauged basin. Satellite-based precipitation data (GPCP) is used along with other public domain available data such as global coverage topographic data land cover, and soil types. Similarity between different catchments is analyzed to identify proxy catchment for transferring parameters. A parsimonious version of BTOPMC was applied to blindly estimate river flow of Ayeyarwady River using Mekong basin as proxy. The main advantage of this study is to evaluate the utility of satellite-based precipitation for runoff generation in large basin. Despite of the underestimation of flow volume by satellite-based precipitation, the overall performance of application is encouraging for long term modeling in large basin. The result gives motivation for application of method in ungauged or poor data basins using proper proxy catchment.

8. REFERENCES

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