

Research Article

Integrated Combination of the Multi Hydrological Models by Applying the Least Square Method

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Abstract: Different hydrological models show different outputs for specific catchment, thus combining all the models in suitable way is very important to improve the forecast. To solve the issue, researchers have applied different techniques which ranges from simple inter-comparison of different hydrological models to extended combination of hydrological models. The aim of this research is to find a suitable and applicable combination technique, by applying least square method to get more valuable flood forecasting results for the Jinshajiang River basin. The combination forecast has been compared with the results of the three models individually, based on the comparison of the simulation outputs and the Nash-Sutcliffe efficiency and Correlation coefficient. The result showed that the performance of combine system of three conceptual hydrological models including Xin'anjiang model, Antecedent Precipitation Index (API) model and Tank model is much more reliable as compared to their individual performance.

Keywords: Combination, flood forecasting, hydrological model, least square method

INTRODUCTION

For precise evaluation or prediction of floods, numerous hydrological models have been developed by different researchers and scientists according to need. These models includes empirical Black-box models, which are generally based on hydrograph theory of Sherman (1932), to further complex, sophisticated conceptual models, like the Stand ford watershed model (Crawford and Linsley, 1966) and the Sacramento model (Burnash *et al.*, 1973) etc. and also extra physically based models like, the "SHE" model (Abbott *et al.*, 1986a, b). Even though a verity of hydrological rainfall-runoff models exists, yet no one can claim any of them as an "Ideal model" which has all properties to perform well then other models in all conditions, regarding data need, catchment area and all other circumstances. To overcome these problems researchers has found another very useful but inadequate way by inter-comparison studies of models. World Meteorological Organization (1975, 1992) has carried out these comparisons for both simulation and observed time operating modes, which had not displayed strong strategies for model choice. In flood forecasting systems, hydrological models are typically used as mechanisms. Model selection depends upon the user's familiarity with a model among all the existing models, the type of the river basin and the facts availability. Under these circumstances, the investigator

or researcher could be contingent totally on the predictions of the selected applicable hydrological model, while a further advanced secondary model could also be used at the similar situation to provide self-governing standby forecast in the event of experimental temporary failure of the appropriate model. In its place of trusting on one distinct hydrological model, or changing model one from another, a substitute methodology could be applied to produce discharges all together from a numeral of changed hydrological models and to chain the predictions in a best mode (Shamseldin *et al.*, 1997).

Numerous researchers Newbold and Granger (1974) and Dickinson (1975), have done a lot of work on concept of joining different models to get more suitable results, firstly this method was introduced by Bates and Granger in (1969), regarding weather forecasting, combination of model has done by Thompson (1977). Previous work shows that, the Xin'anjiang model is selected as the optimal and practical conceptual hydrological model for the Jinshajiang River basin as compared to API and Tank model. Observing the results of Xin'anjiang model, we can relies that there is much difference in observed and simulated values, although these results are better than the API and Tank model but it needs more correction. The aim of present study is to combine the outputs of all three conceptual rainfall-runoff models (Xin'anjiang model, Antecedent Precipitation Index (API) model and

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Tank model) by applying Least Square Method (LSM) individually.

METHODOLOGY

Conceptual rainfall-runoff models have become elementary out fits for flood predicting and for river basin managing (Franchini and Galeati, 1997). The Xin'anjiang model was firstly developed in 1973 and available in 1980 (Zhao *et al.*, 1980) the Xin'anjiang rainfall-runoff model, is one of the rainfall-runoff models, which has been extensively used in humid, semi humid and semiarid areas of china in flood predicting and water assets valuation in decent reproduction exactness. Tank model is used for examining the features of stream flow. It was firstly proposed by Sugawara in 1950s. It gives statistics of water accessibility and be used to forecast flood existences. Numerous efforts to study vibrant water equilibrium in a watershed have typically been showed and few have brought about in good hydrological models. Like others, there is a tank model that splits the watershed into numerous chambers and water flow systems (Sugawara *et al.*, 1984). We can catch a set of tank models assembled in many diverse methods demanding to approach the field circumstances (Elhassan *et al.*, 2001). API was firstly presented by Kohler and Linsley (1951). At that time it was hard to understand the soil properties by using infiltration theory and more difficult to apply on large basin (Benkhaled *et al.*, 2004). The API is typically used for the assessment of over flow produces from precipitation actions on those turning points whose backup data are partial, or not accessible. The rising usage of API as an alternative of the Artificial Neural Network (ANN) model (Descroix *et al.*, 2002) proposes the participation of partiality in purpose of API to denote physical circumstances, then demands better and more expressive API model. Least Square Method (LSM) was firstly proposed by Gauss, famous German mathematician, published in 1805 by Legendre. The use of LSM in a current statistical outline can be sketched to Galton (1886) who used it in his study on the heritability of size which laid down the foundations of correlation and (also gave the name to) regression analysis. The two great researcher of statistics Pearson and Fisher, who did so much in the basics of statistics, used and developed it in different contexts (factor analysis for Pearson and experimental design for Fisher). Some recent form of LSM is Alternative Least Square (ALS) and Partial Least Square (PLS). The process is broadly used to catch or evaluate the mathematical codes of the parameters to adequate a function to a set of data and to describe the statistical goods of approximations. The least squares method is a procedure to guess the finest suitable line to data, the proof uses basic mathematics or algebra. Inappropriately, it is very improbable that we will witness a faultless linear relationship. It has two explanations, first is investigational fault, other is the

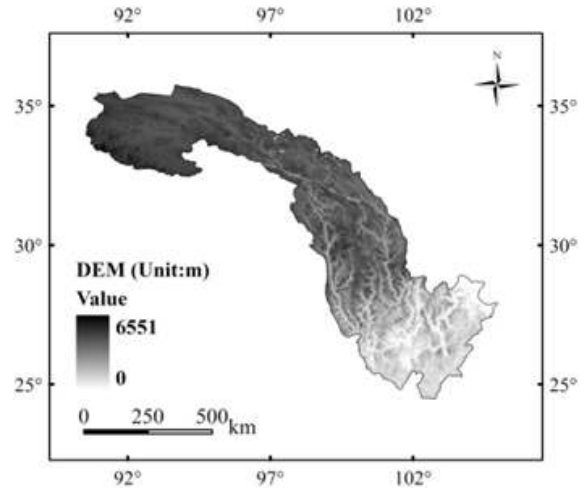


Fig. 1: The Jinshajiang river basin

fundamental association could not be precisely linear, but somewhat simply linear. The Least Squares method is a method, demanding just basic calculus and linear algebra, to determine what the “finest suitable” line is to the data.

Exactly, in first we need to understand what we mean by “finest suitable”, which will want a short evaluation of some probability and statistics. By applying the simple concept of least square method we can improve the results of three conceptual rainfall-runoff models used in previous and present study. Firstly we need to find out the finest suitable weight for each model separately, secondly after applying these weights to each output of each model, we can have more suitable result comparing to the result of each model individually. Thus, we can have the best forecasting result for the specific research area.

Study area and data: The Jinshajiang river basin Fig. 1, considered as the upper reaches of Yangtze River. Hydrological cycle of this region is of great importance to some national projects such as the Three-Gorges-Dam and South-to North Water Diversion program. The area of whole catchment is about 4.7×10^5 km², the extension of Jinshajiang River basin is about 3400 km and annual runoff volume of basin is 1.52×10^{10} m³. The river channel for present study is from Panzhihua section to Xiangjiaba section and the forecast station is Xiangjiaba station. Hydrological data is hourly observation at the main stations including Panzhihua, Sanduizi, Longjie, Wudongde, Huatan, Baihetan, Xiluodu, Xiangjiaba. The data period is from 2004 to 2013. The outflow hydrograph from each sub-area is finally routed down the channels to the main basin outlet by the Muskingum method.

Calibration and verification: The aim of the historic study is to deliver the whole information for calibration and verification of the hydrological model as well as to estimate the aquifer features and the boundary conditions which were used. The process of correcting

the model parameter still a best fit with ancient measurements reached is known as calibration. Sustained work on these methods will result in better models and model use in the future. During this period of calibration and verification, it is beneficial to have the researchers who develop the data assist with the verification process. Once the model has been verified to the modelers' satisfaction and within the significance of the data and the ultimate use of the model, it is ready to be used to forecast the performance of the basin under substitute plans for basin management.

Two sub-basin, Niulan river basin and Xining River basin have been selected for the calibration and verification of three hydrological models (Xin'anjiang model, API model and Tank model). Niulan river basin has an area of 12977 km², 13 years continuous daily stream flow recorded for Niulan sub-basin. Earlier six years (2000-2006) data was used for calibration and later 6 years (2007-2012) data was used for verification process. Xining River basin has an area of 971 km², continuous daily stream flow data was available for eight years (2006-2013) for calibration and verification. Earlier data of five years (2006-2010) were used for calibration and later data of later three years (2011-2013) data were used for verification. The features and competences of these three models were calculated at both sub-basins by using the Nash-Sutcliffe efficiency. Parameters for each model was fixed by referring literature (Zhao, 1992) or adjusted by using trial and error method.

RESULTS AND DISCUSSION

Two flood events started on 2013-07-18 and 2013-08-14 were selected out at Xiangjiaba station, after calibration and verification of three hydrological models. However all three hydrological models showed valuable correlation between observed and simulated values but still it requires more perfection to receive best forecasting results. By applying simple least square method to each model for each flood event, respectively, we can able to get weights for each model. By putting these weights to the previous outputs each model will able to have better forecasting results, but the goal of this study is get best forecasting results. To get best results, in next step we need to combine the outputs of each model for each flood event by using Eq. (1):

$$Q' = \alpha_0 + \alpha_1 Q_{Xinanjia} + \alpha_2 Q_{API} + \alpha_3 Q_{Tank} \quad (1)$$

In this equation, α_1 , α_2 , α_3 are the weights for Xin'anjiang model, API model and Tank model, respectively, $Q_{Xinanjia}$, Q_{API} , Q_{Tank} are discharge of each model, Q' is combined or net simulated discharge.

For flood event 2013-07-18, the calculated weights for Xin'anjiang model, API model and Tank model are

Table 1: Models performances for selected flood events

Flood event	Models	Nash-sutcliffe efficiency	Correlation coefficient
2013-07-18	Xin'anjiang	0.84	0.98
	API	0.59	0.98
	Tank	0.63	0.98
	Q'	0.98	0.99
2013-08-14	Xin'anjiang	0.86	0.98
	API	0.77	0.94
	Tank	0.70	0.97
	Q'	0.96	0.99

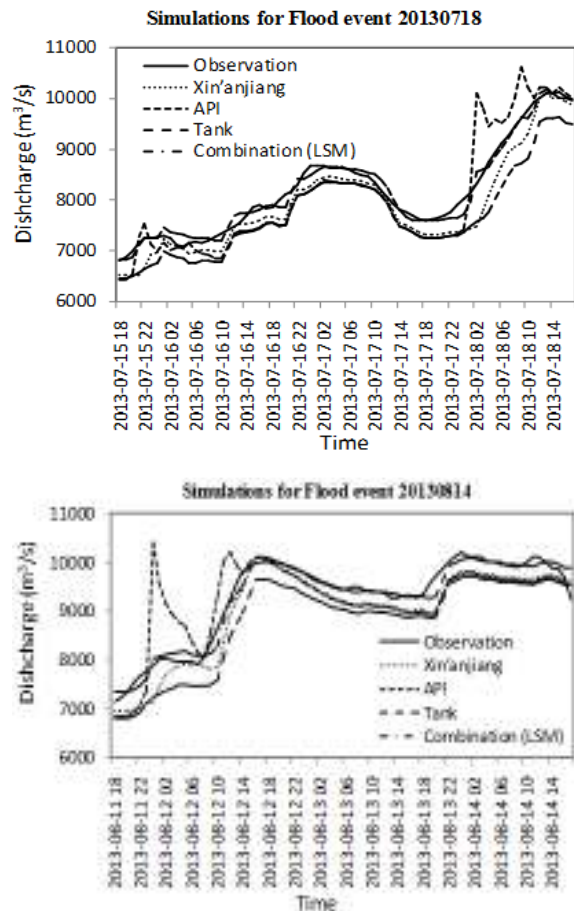


Fig. 2: Simulations and observations for flood event 2013-07-18 and 2013-08-14

0.358, 0.279, 0.314, respectively, 671.529 is the constant value for this flood event. Similarly, for flood event 2013-08-14, the calculated weights for Xin'anjiang model, API model and Tank model are 0.194, 0.110, 0.637, respectively, 906.246 is the constant value for this flood. By putting all these weight to their respective models for each flood event and by combining them, we can able to get the best fit results as compared to all individual results of each model. To assess the outcomes comparing of simulation outputs of three individual models and combined model with Nash-Sutcliffe efficiency and correlation coefficient index have been done. The performance and efficiency of three hydrological models and combined model (Q') for two typical flood events is shown in Table 1.

Flow hydrographs of both flood events 2013-07-18 and 2013-08-14 are verifying the results of both indices that, simulation which we have done by combining all three hydrological models outputs after applying Least Square Method are showing the best correlation between observed and simulated (LSM) outputs as compared to the three individual outputs of three hydrological models Xin'anjiang model, API model and Tank model. By deep analysis of flow hydrograph, of both events showed that, Xin'anjiang model has better results as compared to API and Tank model on individual basis, but the purpose of this study is get best fit results for forecasting at Jinshajiang river basin, by minimizing errors in three individual model simulation, by combining their outputs after applying least square method, we have received best combine system model. Flow hydrograph for both flood events in Fig. 2 shows that combine system is the system which has ability to give more reliable and more authentic simulations.

CONCLUSION

To obtained the best forecasting results at the Jinshajiang river basin, we have applied three hydrological models individually and the combine system of three hydrological model after applying least square method to it, by selecting two flood events at Xiangjiaba station. Results from Nash-Sutcliffe efficiency, correlation coefficient index and flow hydrograph has shown that the combine system of three hydrological models is more reliable as compared to the individual performance of Xin'anjiang model, API model and Tank model.

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