An improvement research of LCM----a rainstorm and flooding model

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1. Introduction

The essential theory of LCM model is LCM infiltration formula, which is based on water budget. The main description of this theory is shown as following:

$$f = R \cdot P^r \tag{1}$$

$$R = 0.8781 \cdot \ln(r) + 1.3422 \tag{2}$$

Where f is infiltration (mm), P is precipitation (mm), R and r is empirical coefficient, which can be determined by optimization selection method (Liu 2008).

LCM model developed for study of rainstorm and flooding which are very important hydrological processes of land surface. Short duration and strong rainfall intensity are significant characteristics of storms. The two characteristics lead to the result that underlying surface might be changed enormously during the process of rainstorm and flooding. Such natural phenomena are very common in the middle reach of the Yellow River (Shi 1990). However, traditional researches of rainstorm and flooding mostly focused on the description of rainfall and runoff in the whole watershed, with less consideration of spatial heterogeneity. It leaded two defects in such researches, firstly traditional rainstorm and flooding model could not show the spatial distribution of runoff which was caused by regional differences in precipitation, and secondly such method could not provide reasonable explanation for flood propagation in study area. In addition, distributed LCM model can be more appropriate for study of eco-hydrological research. So it is very important to develop traditional conceptual rainstorm and flooding model from lumped model to distributed hydrological model.

In this paper, the computing units of LCM conceptual model were divided to sub-catchment to achieve distributed computing of the model. Meanwhile a modified model which takes rainfall distribution into account during the simulation process was applied in the Gushanchuan basin and the simulation results were improved.

2. Study area

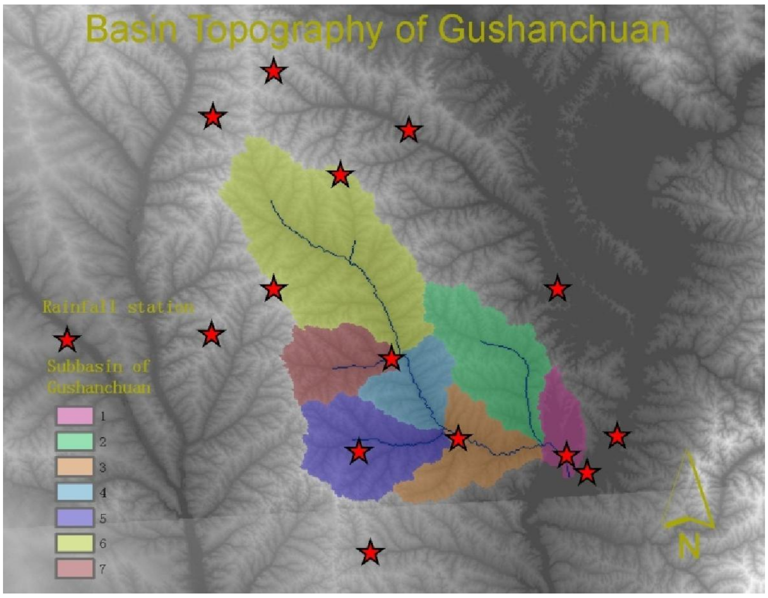

Figure.1 Basin topography of Gushanchaun

This study was conducted in the Gushanchuan watershed， which is an important branch of the midstream of the Yellow River. It originates from Zhungeer, Inner Mongolia autonomous regions, and feeds into the Yellow River in Fugu, Shanxi

Province. The length of the trunk stream is 79.4 km; the basin area is 1,263 km^2, for Gushanchuan, and the hydrological elements were measured at Gaoshiya gauging station. Geomorphic features in the basin are similar, and above 90% area has been covered by losses with deep soil, loosen texture, sparse vegetation, so Gushanchuan is a typical hilly and gully regions of the Loess plateau, which suffers serious soil erosion (Jiao 1992). The climate of catchment is arid and semi-arid, the annual average precipitation this area is 435.5mm, the maximum value is 849.6mm, and the minimum value is 227.7mm (Li 2012). Nearly 80 percent rainfall is concentrating in the summer by rainstorm (Wang 2002).

3. Data and methods

In this study, LCM model—a lumped conceptual rainstorm and flooding model developed by Academician Changming Liu—was adopted for distributed construction (Wang 2002). The core of the research was modification in input and routing: precipitation station data were interpolated to areal and outflow routing from 7 sub-basin. So data preparation is necessary, for taking precipitation data in LCM model to calculate runoff and outflow.

The data used in our study includes three sources: DEM with 30m resolution, event based rainfall data from 14 precipitation stations in or around study area, and runoff observation data of Gaoshiya gauging station.

The original precipitation data were recorded by different time interval, some of which were 3 hours', some were 42 minutes', and even 6 minutes'. But there was regularity that every record time is multiple of 6 minutes, so by equally dividing the precipitation to every 6 minutes and then summing the total parts belong to an hour, we got the regular precipitation data with one hour time-step. After sorting time series of rainfall data to one- hour format, we got the preliminary data of rainfall for spatial interpolation. We built up area rainfall database by implementing IDW（inverse distance weighted） interpolation in ARCGIS using python command. And DEM data were used to divide the watershed to 7 sub-basins for realizing distributed calculation. In addition, series flow concentration parameters such as slop, aspect, flow direction, flow accumulation, isochronal units and drainage had be calculated in ARCGIS with DEM.

The original LCM model describes the study area as a lumped system ， which was lack of consideration of inner flow concentration structure during the rainfall and runoff process. By calculating the 7 sub-basins runoff, slop concentration used isochronal method respectively and channel propagation by Muskingum method, we realized the distributed calculation of LCM model (Lin 2006). In addition, by redistributing the runoff calculated results to each isochronal unit's base on the spatial precipitation distribution, the calculation of flow concentration became more reasonable and detailed.

4. Result and discussion

The simulation results of improved model in two way is presented in Fig.2. We can see that outflows of considered rainfall distribution were more approximate to the observed value in 1988 than just divided to sub-basin model. As explain above, the peak values of simulation were elevated sharply by redistributing of runoff calculated results to each isochronal units base on precipitation distribution during the time 33 to 43 hour. And the maximum value during the simulate period raised from 612.463 m^3/s to 1079.13m^3/s. Meanwhile, the Nash efficiency coefficient has been improved from 0.721 to 0.809 with 14 % water balance. According to the graph we discovered that the inner spatial structure of rainfall and runoff basin is very significant, because the distributional calculation can represent effect of the flow of hydraulic accumulate. Therefore, distributed constructing of lumped conceptual hydrological model is very important to restore the spatial responding of runoff.

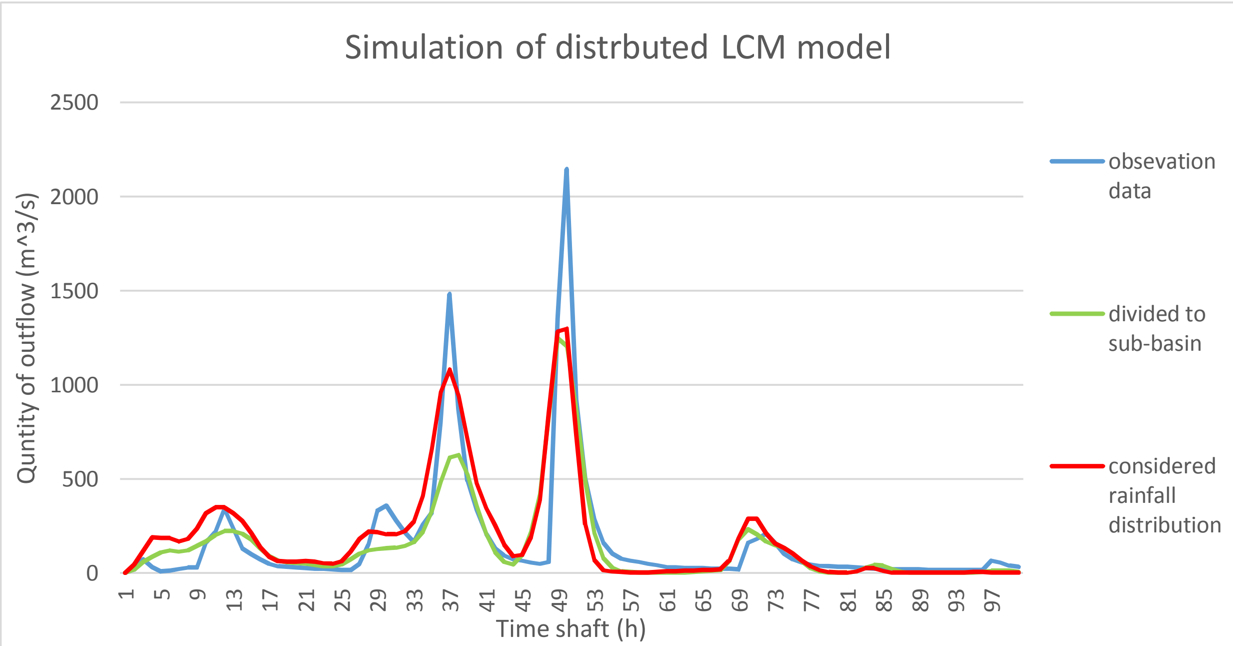

Figure.2 Continuous 100 hours outflow simulation in 1988, Gushanchuan

5. Conclusion

The outflow simulation with the improved LCM model shows strong spatial response, which can calculate rainstorm and flooding process more reasonable, and elevates the peak value in simulation. In addition, the runoff simulation by the improved LCM model can be displayed as sub-basin even isochronal unit inner sub-basin. All the improvements realized spatial distributed calculating in some extent.

But there still are several aspects that need to be improved in the following studies. The first is how to reflect the responding to underlying surface in the model. This will make the conceptual LCM model more theoretical, and calculating rainfall and runoff more reasonable. Secondly, slop influence in simulating should be taken in account in the following research. After the two revises, LCM model will be more distributed and theoretical.

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