Ⅱ－58 Comparison of water balance model taking account of water storage distribution

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1 Introduction

This paper presents a comparison of the performance of Xinanjiang rainfall-runoff model [1] with that of its simplified form, and also with the performances of those rainfall-runoff models which are based on the same philosophy as that of Xinanjiang model, but with differing tension water storage distribution patterns, viz., triangular and bucket distributions. These two later models are called herein as triangular model and bucket model respectively. These models are applied for rainfall-runoff modelling of a sub-basin (525 km) of Yodo River basin, using the AMeDAS data.

2 Methodology

The Xinanjiang model is a distributed basin model applicable to humid and semi-humid regions and it is being used for design and operations of water resources systems in China (Fig.1). The simplified Xinanjiang model, the triangle and the bucket models have been developed and studied to assess their utility in comparison with that of the Xinanjiang model. These models incorporate in them Energy Balance Method for computation of evapotranspiration process, different from that followed in the Xinanjiang model.

The comparison of these models is done based on the best fit criterion as used in the Xinanjiang model in simulating the observed discharge hydrograph.

3 Simplified Xinanjiang Model

While the original Xinanjiang model uses 15 parameters, the proposed simplified version of it use only 3 parameters viz., B, W_c and K_g respectively, the distribution parameter, the areal maximum tension water storage and the water storage coefficient with the following ranges: $0 < B \leq 2, 110 \leq W_c \leq 300$ and $0.01 \leq K_g \leq 0.05$. The computations are made for hourly and daily data of precipitation, P, evapotranspiration, E, and discharge, Q, for a period of one year. The excess rainfall is computed after satisfying the soil water storage defined by the following criteria:

$$i = i_m[1-(1-A(i))^{1/B}] \quad 0 \leq A(i) \leq 1 \tag{1}$$

where, i_m is the point maximum tension water capacity, $A(i)$ is the fraction of the basin area (Fig.2). The discharge is given by,

$$Q = \begin{cases} (P-E) - W_c + W & \text{if } i_m \leq i_o + P - E \\ (P-E) - W_c + W + W_c\left(1 - \dfrac{i_o + P - E}{i_m}\right)^{1+B} & \text{if } i_m \geq i_o + P - E \end{cases} \tag{2}$$

where W is the areal tension water storage, i_o is the present tension water capacity. Here $W_c = \frac{i_m}{1+B}$

4 Triangular Model

In this case (Fig.3), the density function which is the derivative of the distribution function of the tension water capacity is assumed to be triangular with its maximum occurring at i_p where $0 \leq i_p \leq i_m$. The discharge Q is given by:

$$Q = (P-E) - W_c + W + W' \tag{3}$$

where

$$W' = \begin{cases} \dfrac{i_m + i_p}{3} - \left(i - \dfrac{i^3}{3 i_m i_p}\right) & \text{if } 0 < i \leq i_p \\ i_m - \dfrac{2i_m^2/3 - i_m i_p}{i_m - i_p} - \left(i - \dfrac{-i^3/3 + i_m i^2 - i_m i_p i}{i_m(i_m - i_p)}\right) & \text{if } i_p < i \leq i_m \end{cases} \tag{4}$$

and

$$W_c = \frac{i_m + i_p}{3} \tag{5}$$

5 Bucket Model

In this case, the density function which is the derivative of a uniform distribution function defining the tension water capacity corresponds to the direct delta function (Fig.4). The discharge Q is given as:

$$Q = \begin{bmatrix} 0 & \text{if } i_m \geq i_o + P - E \\ (P - E) - W_c + W & \text{if } i_m < i_o + P - E \end{bmatrix} \tag{6}$$

and

$$W_c = i_m \tag{7}$$

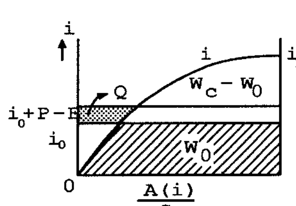

Fig1:Distribution of tension water capacity in basin(simplified Xinanjiang model)

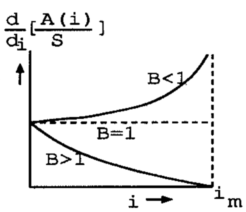

Fig2:Density function simplified Xinanjiang model

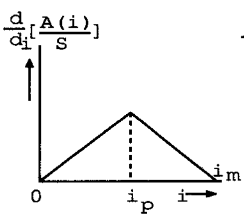

Fig3:Density function Triangle model

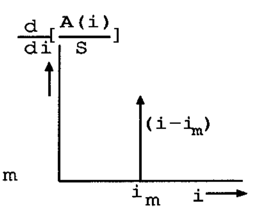

Fig4:Density function Bucket model

6 Results and Conclusion

Table 1 presents three goodness of fit criteria for the four models. Criteria 1 and 2 are best when Error = 0 , but criteria 3 is best when R^2 is 100. All vary between 0 and 100 (in %). Thus, it is clear that one particular criterion may not be able to suggest the actual best fit. Also the values show that the simplified models with 2–3 parameters only, perform equally well as that of the Xinanjiang model, suggesting that they are worth for further investigation. As expected the Bucket model is not able to take care of the various phenomenon in the simulation process so well.

Table1 Errors in simulated hydrograph (%)

Model Name	daily			daily(when hourly data is supplied)			hourly		
	Criterion1	Criterion2	Criterion3	Criterion1	Criterion2	Criterion3	Criterion1	Criterion2	Criterion3
Xinanjiang original	5.43	34.56	83.82	19.14	33.51	83.91	14.58	44.79	-91.06
Xinanjiang simplified	8.01	27.62	65.57	11.76	27.52	77.17	0.006	65.59	75.23
Triangular	8.05	29.12	66.79	14.68	32.02	77.45	0.003	65.42	75.36
Bucket	0.004	35.01	49.96	12.22	34.47	57.65	0.000	65.62	74.58

Criteria1:$Error = \frac{|\sum Q_i' - \sum Q_i|}{\sum Q_i}$, Criteria2:$Error = \sum \frac{|Q_i' - Q_i|}{Q_i}$, Criteria3:$R^2 = 1 - \frac{\sum (Q_i - Q_i')^2}{\sum (Q_i - Q)^2}$

Here Q_i is observed discharge, Q_i' is computed discharge, Q is year mean dischrge and R^2 is Nash and Sutcliffe coefficient.

References

[1] Zao Ren-Jun : The Xinanjiang model applied in China, J. of Hydro., Vol.135, pp.371-381, 1992.