Numerical simulation of streamflow process in a small headwater catchment in Hong Kong

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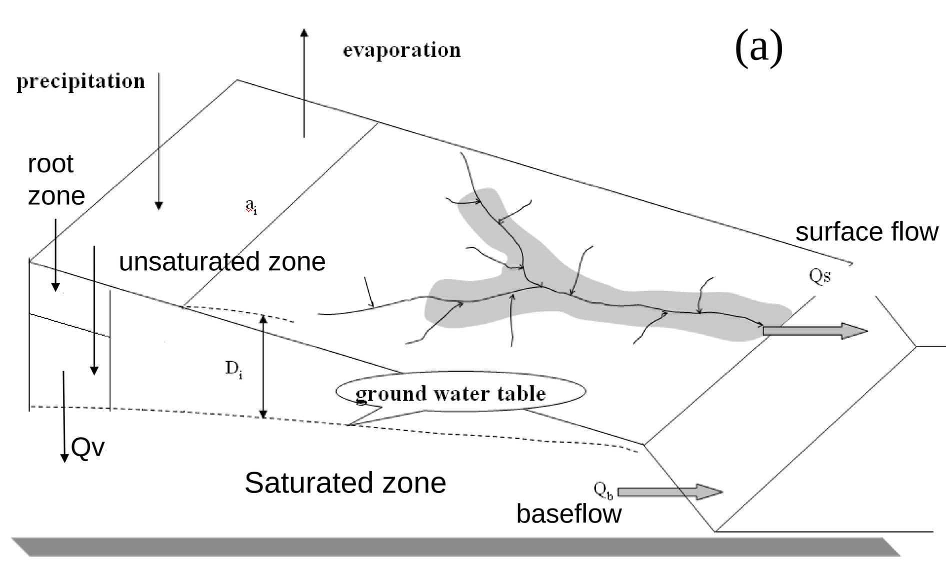
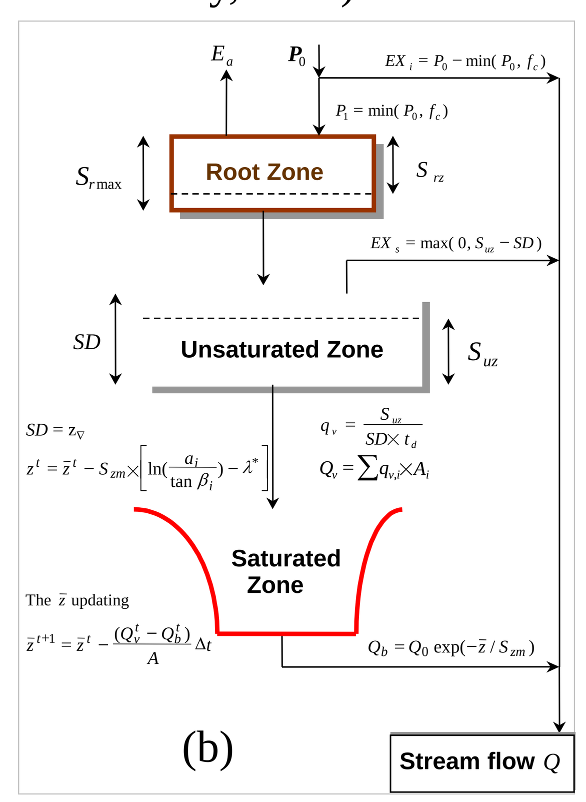
1. Introduction

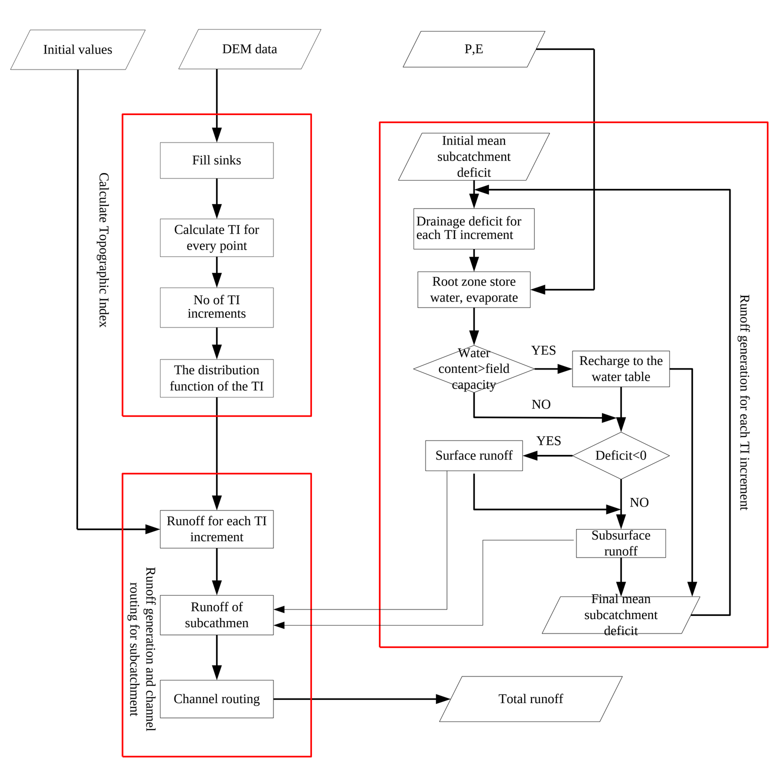
Hong Kong often suffers flash floods because of the frequently of heavy rainfall in the monsoon rainy season and steep slopes. The study of flash floods needs to simulated the hydrological processes with a fine temporal scale. It is general lacking in availability of fine resolution rainfall and streamflow records for detailed hydrological analysis to study flash flood. Therefore, this study contributes to this aspect of the understanding.

2. Model

In this study, TOPMODEL was applied to this small headwater catchment. TOPMODEL is a distributed or more specifically semi-distributed hydrological model, which was originally proposed by Beven and Kirkby in 1979 (Beven and Kirkby, 1979).







TOPMODEL Parameters:

SRMAX	root zone available water capacity (m)
M	exponential storage parameter (m)
T0	saturated lateral transmissivity ln(m²/h)
TD	unsaturated zone delay per unit storage deficit (h)
CHV	main channel routing velocity (m/h)
RV	internal subcatchment routing velocity (m/h)

SCE-UA (Shuffled Complex Evolution) method, which was developed at the University of Arizona in 1992 (*Duan et al.*) applied to optimize the model parameters.

Fig. 1 (a) Schematic representation of the TOPMODEL, (b) Flowchart with Equations and (c) Flowchart of the TOPMODEL

3. Study area

The study area (*Li*, 2009) is located on the slope of Kwun Yam Shan, the Kadoori Agricultural Research Center, the University of Hong Kong at Shek Kong of Yuen Long district, New Territories, Hong Kong.

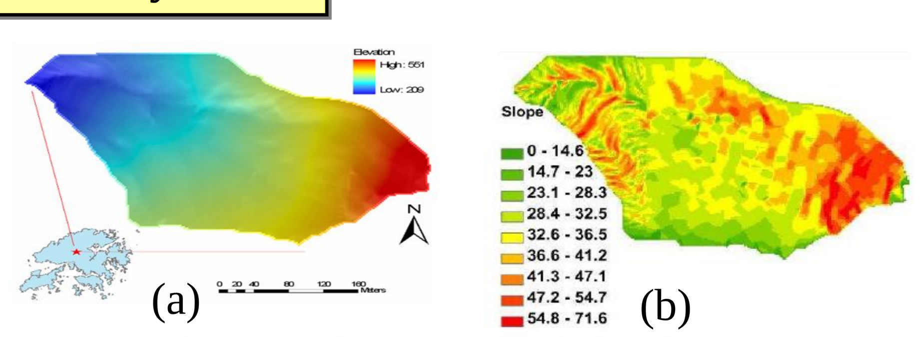


Fig. 2 (a) catchment elevation and (b) slope variation

4. Results

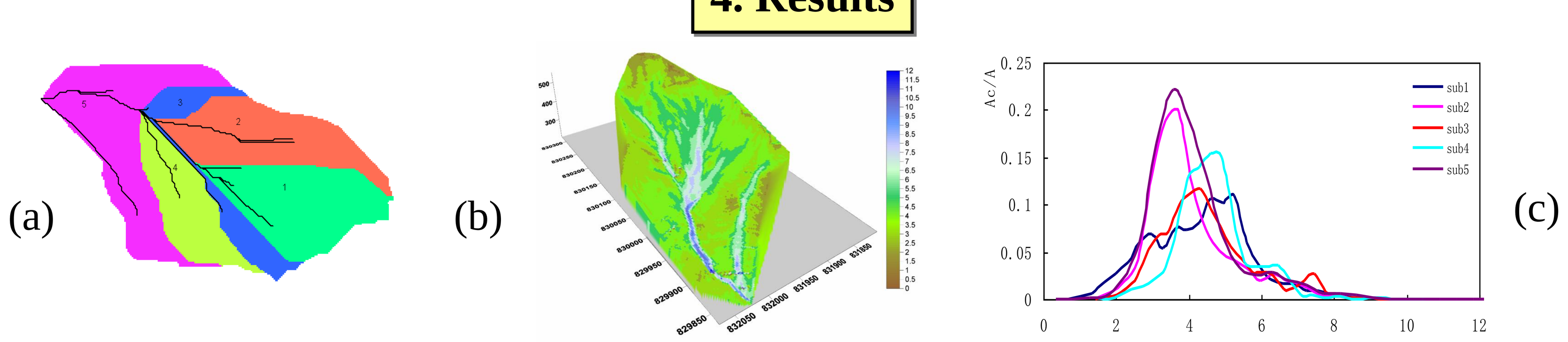


Fig. 3 (a) sub-catchments, (b) topographic index, and (c) distribution function of the ln(α/tanβ)

The model is run based at the 1-min time step. The basin was delineated into five sub-catchments (Fig. 3a) and Fig. 3b and c shows the distribution of the topographic index. The upper and lower limits of the parameter values used in the calibration are shown in the table 1.

Table 1 Parameter boundary values

Parameter	M(m)	LN(T0) (m²h⁻¹)	TD(h)	SRMAX (m)	RV(mh⁻¹)	CHV (mh⁻¹)
Lower Bound	0.001	-10	0	0.001	100	100
Upper Bound	0.1	10	10	0.1	5000	5000
Initial Value	0.01	1	1	0.01	100	100

The study demonstrates a parameter failed to search global optimum (Table 2) when model is in the ideal conditions .

Table 2 Calibrated values for the TOPMODEL parameters using SCE-UA

Parameter		M(m)	LN(T0) (m²h⁻¹)	TD(h)	SRMAX (m)	RV(mh⁻¹)	CHV(mh⁻¹)
#1	Global	0.09	1	1	0.06	1860	1900
	SCE-UA	0.089	1	6.742	0.06	1856	1905
#2	Global	0.06	3	1	0.01	660	900
	SCE-UA	0.059	3.052	3.901	0.01	595	884
#3	Global	0.032	9	3	0.07	2500	3000
	SCE-UA	0.032	9.643	6.673	0.07	2545	2923

Ten trials have been carried out for one flow series with different starting search positions.

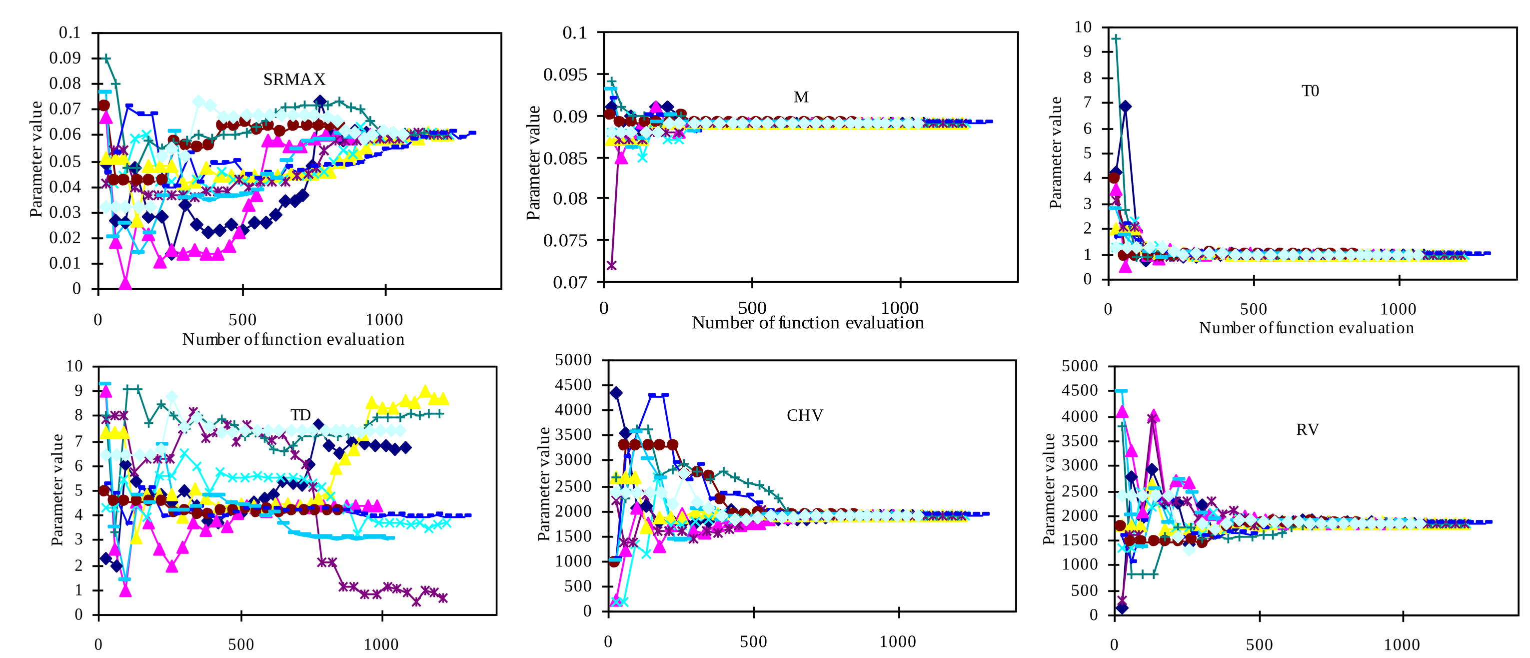


Fig. 4 Convergence behaviors of six parameters for 10 trials

Table 3 **Calibrated values for the TOPMODEL parameters using SCE-UA method**

Parameter	M	T0	CHV	RV	SRMAX
SCE-UA	0.089	1	1905.3	1857.5	0.06

Table 4 **Calibration results from the TOPMODEL**

	Periods	Peak flow Observed (m³/min)	Peak flow Simulated (m³/min)	Peak flow Relative error (%)	Peak time Observed (min)	Peak time Simulated (min)	Error	E
Calibration	12-19 6.2007	3.5	2.8	20	20:48	20:46	2	0.85
	28-30 6.2007	4.3	4.0	7	09:29	09:27	2	0.84
Validation	6-14 6.2008	9.8	10.4	6	11:57	11:57	0	0.86
	10-13 6.2008	24.0	27.1	13	08:42	08:49	7	0.82

In the two calibrated flood events (Table 4), TOPMODEL behaves well in peak flow and the relative errors are controlled within 20%. For the E value, all results are over 0.8. TOPMODEL also gives acceptable results for the time lag. Fig. 5 and 6 shows the hydrographs of the simulation and observation.

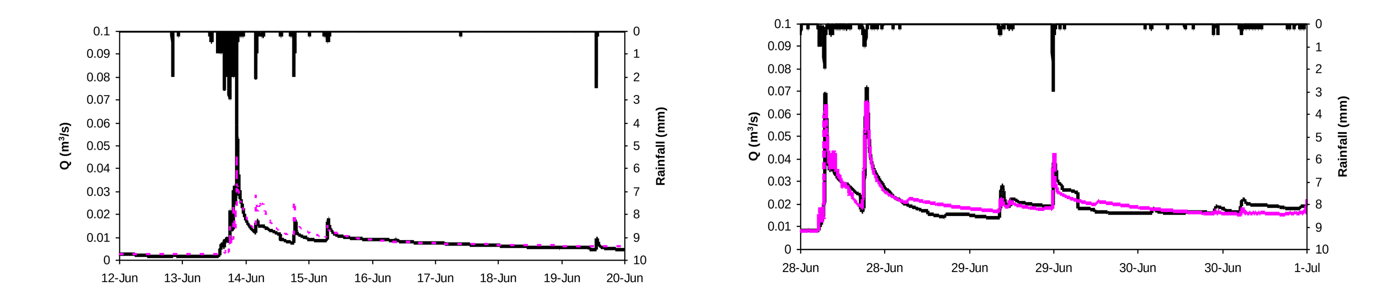


Fig. 5 TOPMODEL calibrations (a) 12-19 June 2007, and (b) 28-30 June 2007; black line represents observations; pink line represents simulations; and column represents rainfall.

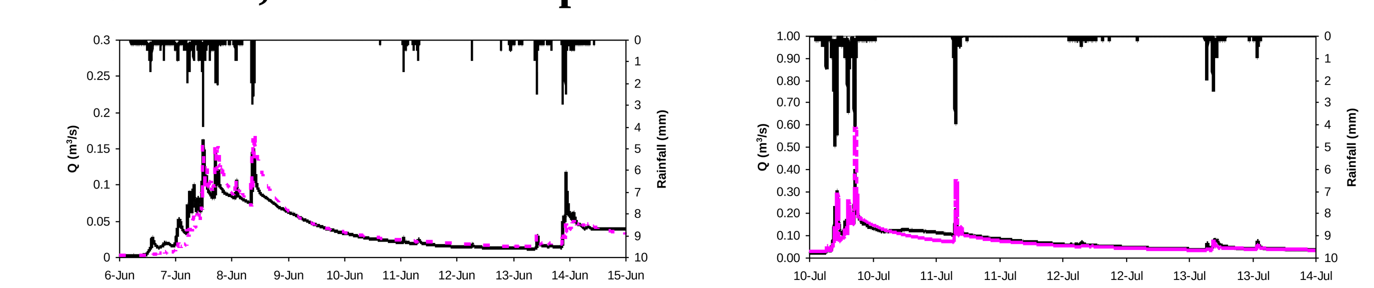


Fig. 6 Topmodel validations (a) 6-14 June 2008, and (b) 10-13 July 2008

Using the observation during the period of 6-14 June 2008, the flood event was simulated at different temporal steps, such as 5-min, 10-min, 30-min and 1-hour (Table 5).

Table 5 Peak observations in different time steps

Periods	Peak flow Observed (m³/min)	Peak flow Simulated (m³/min)	Peak flow Relative error (%)	Peak time Observed (min)	Peak time Simulated (min)	Error	E
1-min	9.8	10.4	6	11:57	11:57	0	0.86
5-min	9.5	9.7	2	12:00	12:00	0	0.83
10-min	9.1	12.3	35	12:00	12:00	0	0.82
30-min	7.9	10.0	27	12:30	12:00	30	0.82
60-min	7.8	9.6	23	13:00	13:00	0	0.80

5. Conclusions

1. The SCE-UA algorithm could locate the global optimum parameter set in the idea data study conducted using 1-min time step data. In the 10 SCE-UA trials, five parameters can converge, and one parameter fails to find the global optimum.
2. TOPMODEL can simulate the streamflow components, including total discharge, peak flow and peak time, at 1-min time step.
3. According to the time resolution analysis through comparison of simulations at the temporal steps 1-min, 5-min, 10-min, 30-min, and 1-hour, it is observed that 1-min time step rather than longer time step simulation is applicable to flash flood simulation whose duration is restricted within few hours.

References

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Acknowledgements

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