A Study on the Effects of Spatial and Temporal Scale of Rainfall Data Based on a Modified SWAT Model With Changeable Modeling Timesteps

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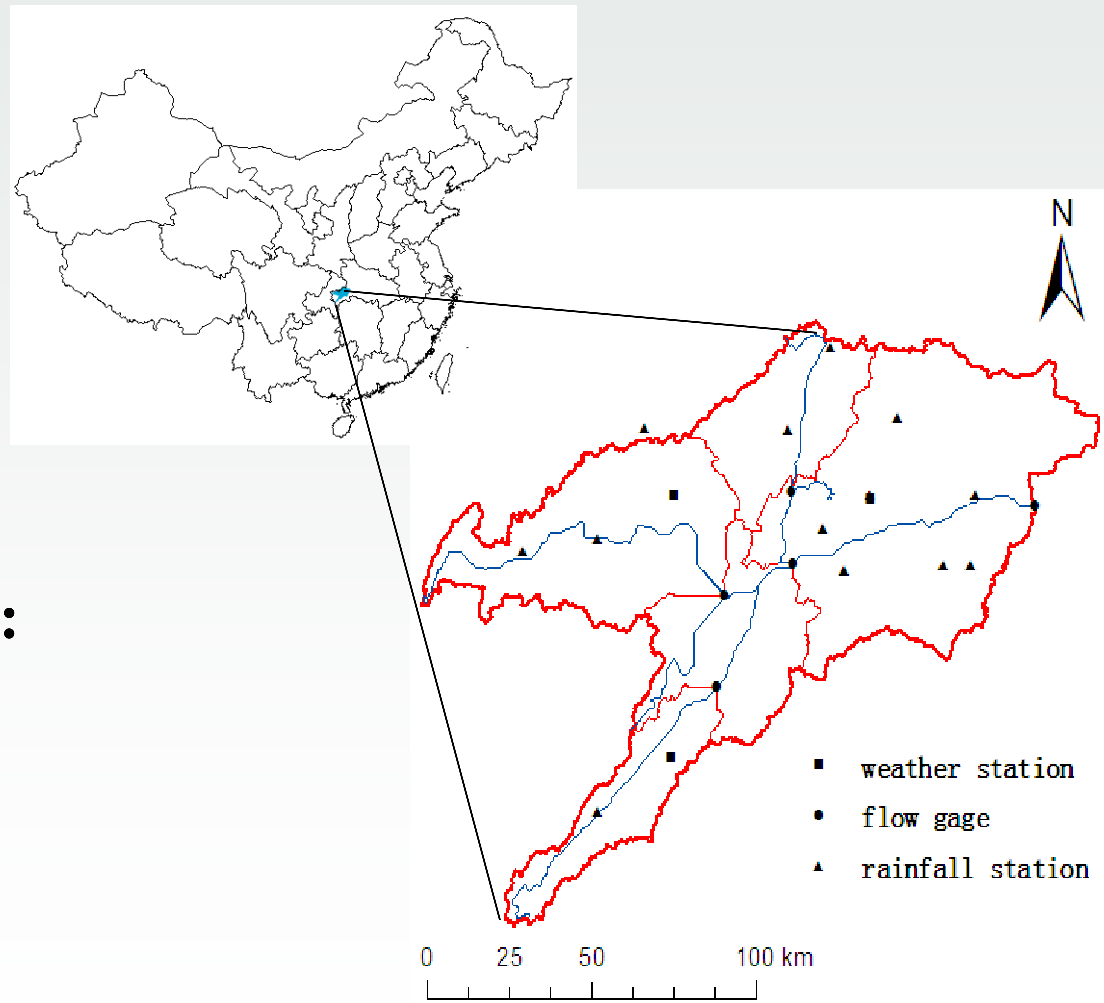
Qingjinag river basin

- **Location: 108° 35′-111° 35′, 29° 33′-30° 50′**
- **Area: 16700km², main channel length 423km, total water head: 1430m**
- **Average air temperature: 15℃-16℃ , humidity: 80%～84%, evaporation from open water body: 600～800mm, annual precipitation: 1460mm**



Data sets for SWAT

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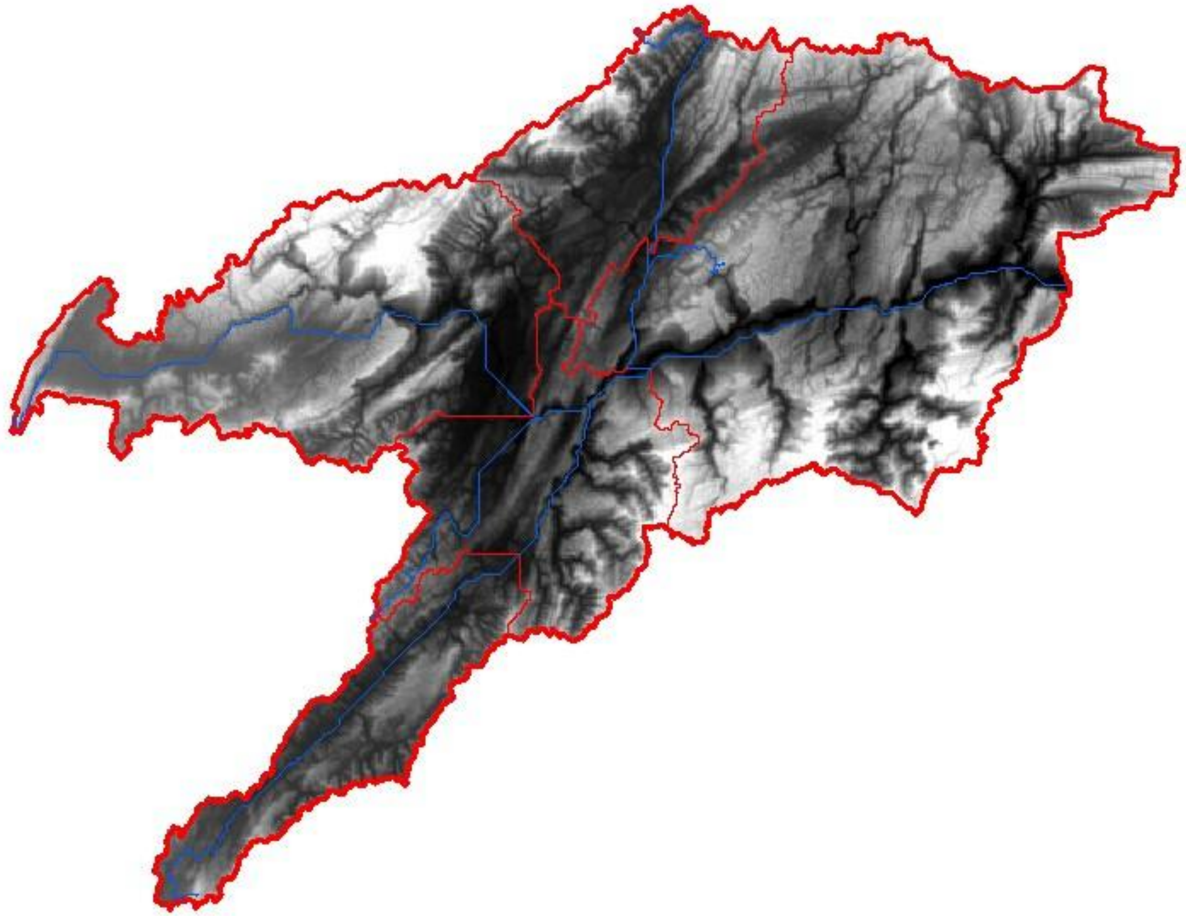
DEM	USGS（U.S. Geological Survey）， 90m*90m
soil	WSD(Harmonized World Soil Database)
Land use	USGS, year 2000 Global Landuse Data
Weather data	CFRS（Climate Forecast System Reanalysis）
rainfall	Year 1997-1999, 13 raingauges

Data sets for SWAT

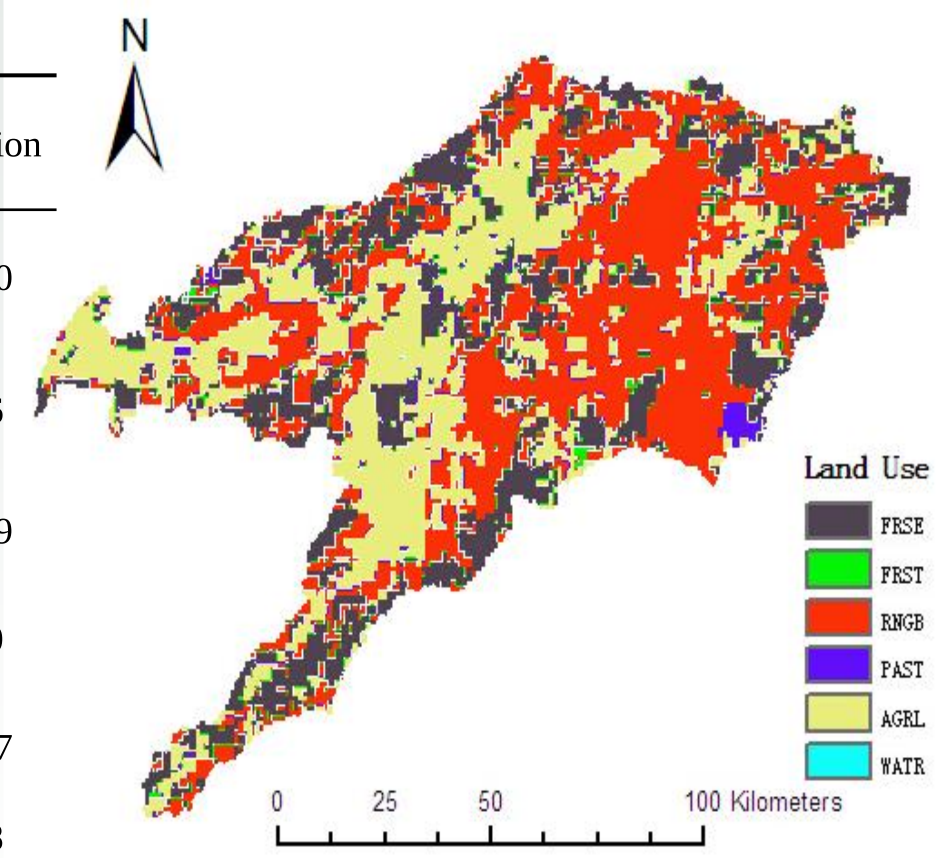
- DEM
- Basin boundary
- Channel network
- Subbasin boundaries



Data sets for SWAT

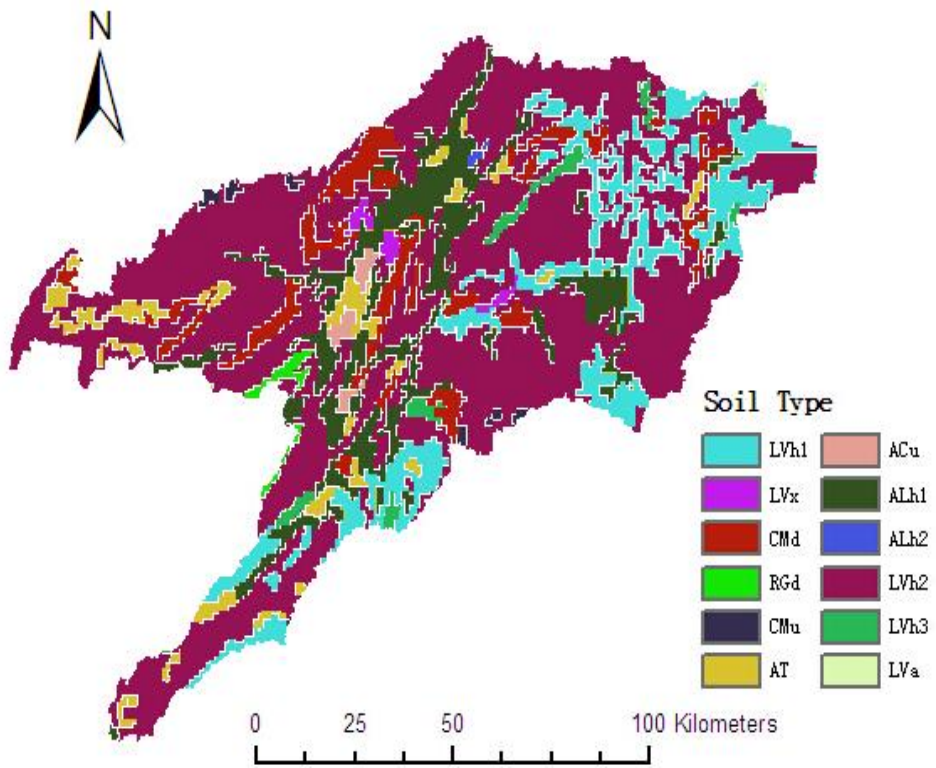
- **Land use**

CLC2000	Label	SWAT	Proportion (%)
1	Tree Cover, broadleaved, evergreen	FRSE	26.360
9	Mosaic: Tree Cover / Other natural vegetation	FRST	0.286
11	Shrub Cover, closed-open, evergreen	RNGB	42.329
13	Herbaceous Cover, closed-open	PAST	0.600
16	Cultivated and managed areas	AGRL	30.417
20	Water Bodies	WATR	0.008



Data sets for SWAT

- **Soil**



No.	Category I	Category II	Description	Proportion (%)
1		LVh1		12.52
2	LVh	LVh2	Haplic Luvisols	58.532
3		LVh3		1.646
4	ALh	ALh1	Haplic Alisols	12.963
5		ALh2		0.111
6	AT		Anthrosols	4.105
7	ACu		Humic Acrisols	0.725
8	CMu		Humic Cambisols	0.479
9	CMd		Dystric Cambisols	7.634
10	RGd		Dystric Regosols	0.536
11	Lva		Albic Luvsiols	0.052
12	Lvx		Chromic Luvisols	0.697

SWAT modification

Surface Runoff Volumn

Method	SCS curve number method	Green & Ampt infiltration method
Property	Empirical model	Physical model
Equation	$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)}$ $I_a = 0.2S \qquad S = 25.4(\frac{1000}{CN} - 10)$	$f_{\inf,t} = K_e(1 + \frac{\psi_{wf} \cdot \Delta\theta_v}{F_{\inf,t}})$
Principle	Estimating direct runoff using empirical relationships between the daily rainfall and watershed properties	Estimating surface runoff by comparing the infiltration rate and rainfall intensity

Surface Runoff Lag

- **SWAT2005: lag equation is based on daily time step, not suitable for sub-daily modelling.**

$$Q_{surf} = (Q'_{surf} + Q_{stor})[1 - \exp(\frac{-surlag}{t_{conc}})]$$

$$Q_{surf,i} = (Q'_{surf,i} + Q_{stor,i-1}) \cdot \alpha\_\Delta t$$

$$\alpha\_\Delta t = [1 - \exp(\frac{-surlag}{t_{conc} / \Delta t})]$$

slope concentration

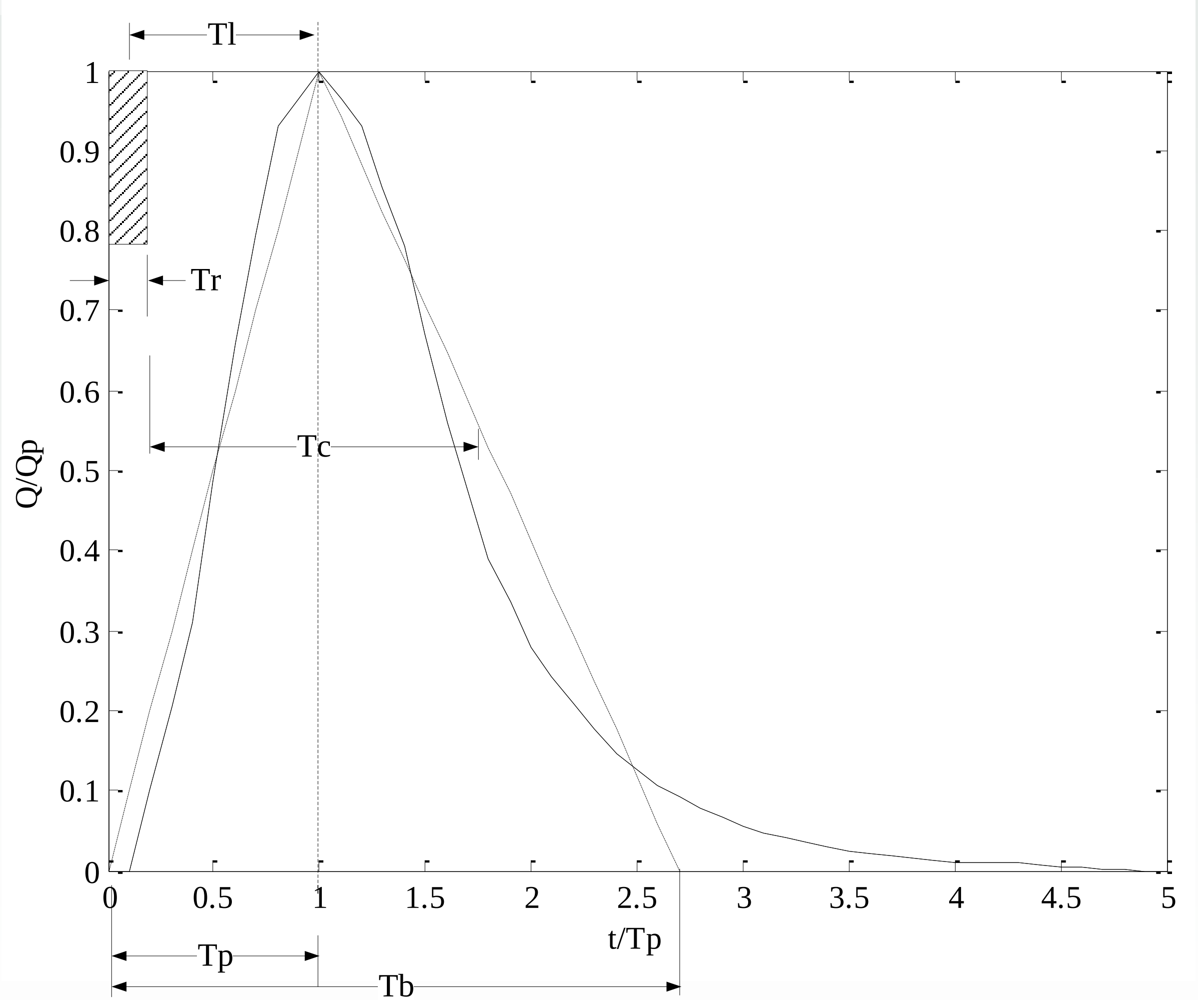
- **SCS unit hydrigraph**

$$\begin{cases} Q/Q_p = t/T_p & \text{当} t \le T_p \\ Q/Q_p = \dfrac{T_b - t}{T_b - t_p} & \text{当} t > T_p \end{cases}$$

$$T_p = 0.5T_r + 0.6T_c$$

$$T_b = \frac{8}{3}T_p$$

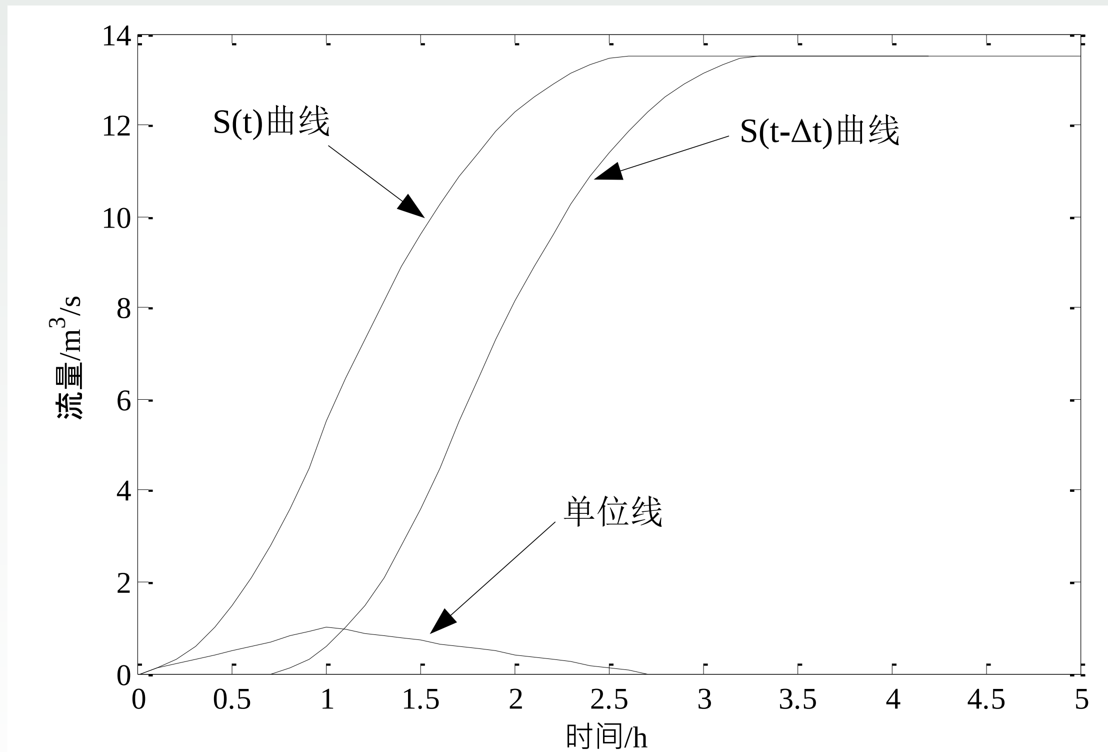
$$Q_p = \frac{2.08 A}{T_p}$$



slope cencentration

$$Q(\Delta t,t)=\frac{\Delta t}{1}[S(t)-S(t-\Delta t)]$$

- unit hydrograph: from 1 hour to T-hours



chennel routine

- **Characteristic river length**

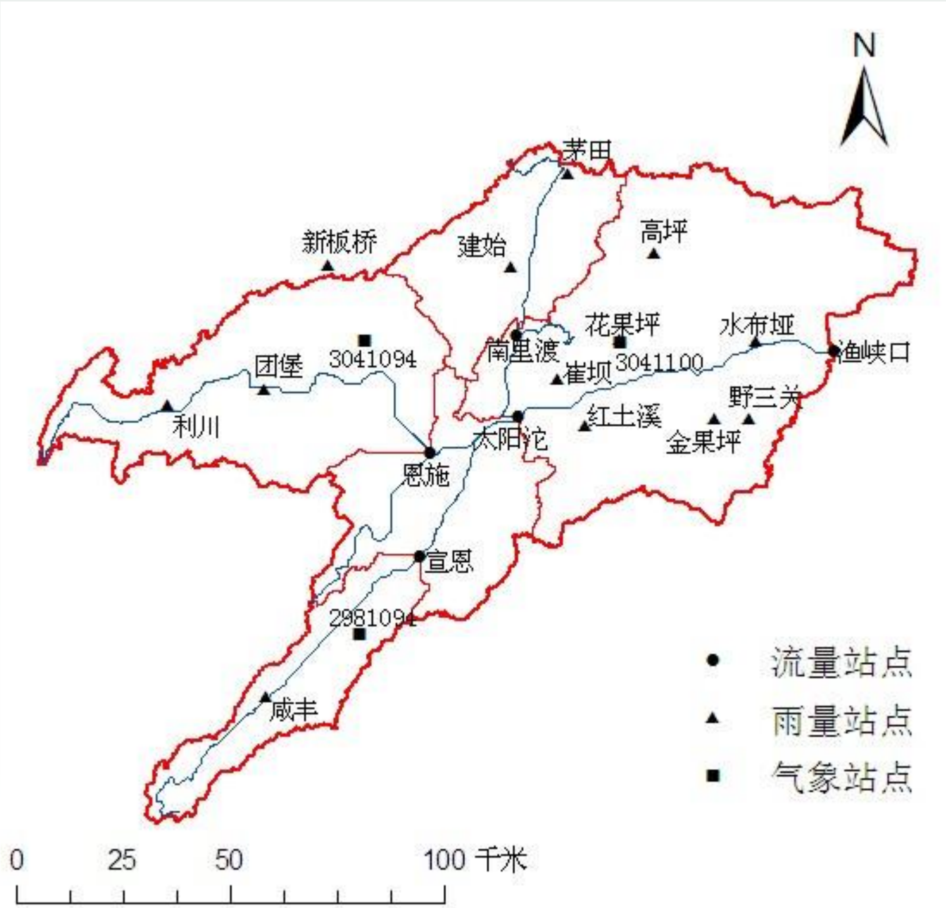
$$q_{out} = \frac{A_{ch} \cdot R_{ch}^{2/3} \cdot slp_{ch}^{1/2}}{n} \qquad TT = \frac{V_{stored}}{q_{out}} \qquad SC = \frac{2\Delta t}{2TT + \Delta t}$$

$$V_{out,2} = SC \cdot (V_{in} + V_{stored,1})$$

- **DeltT: from fixed 1 hour to flexible time steps.**

Applying modified SWAT in Qingjiang basin

- **13 raingauges with hourly data available, from 2002 to 2003**



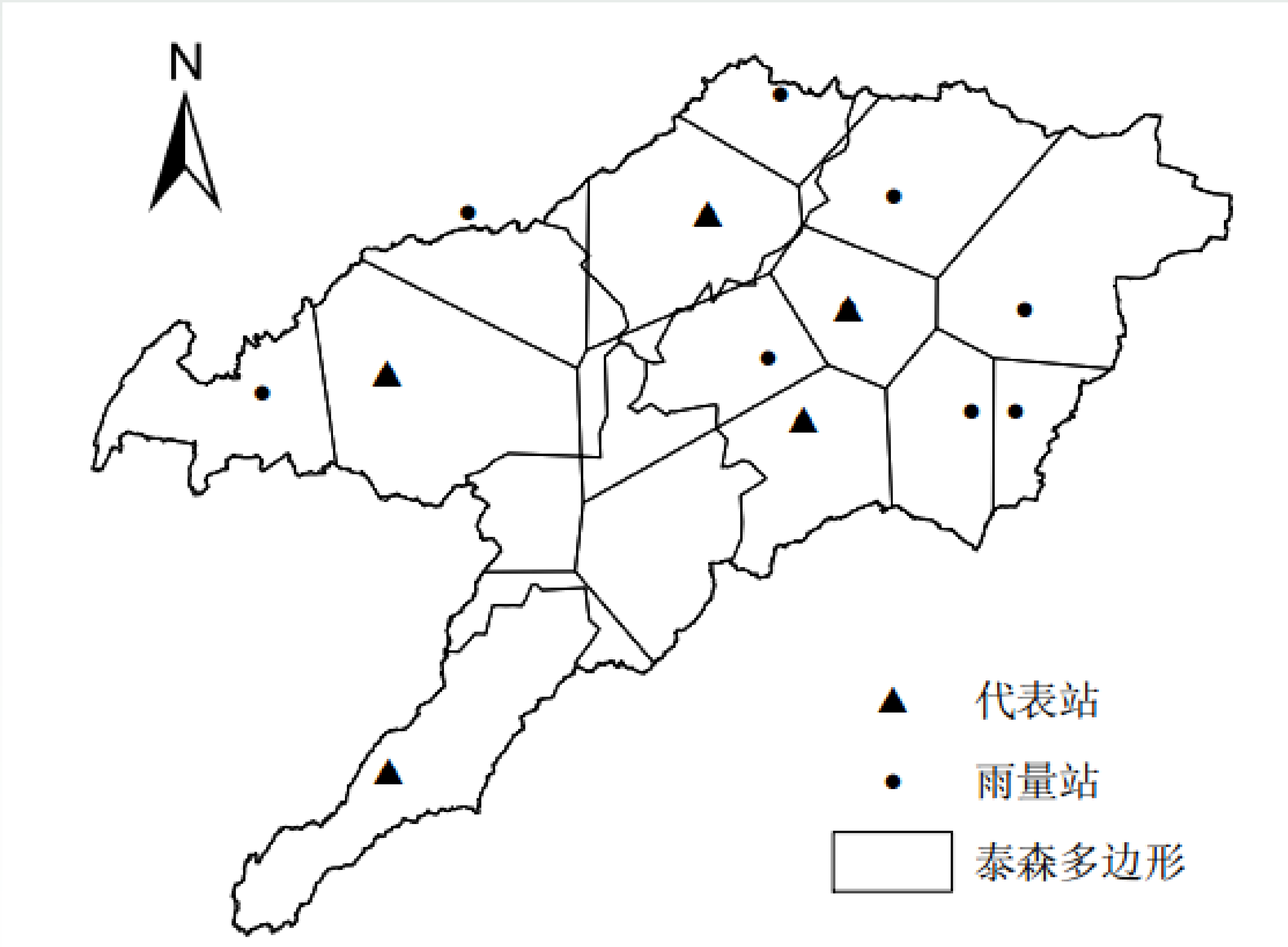
Sensitivity analysis of parameters

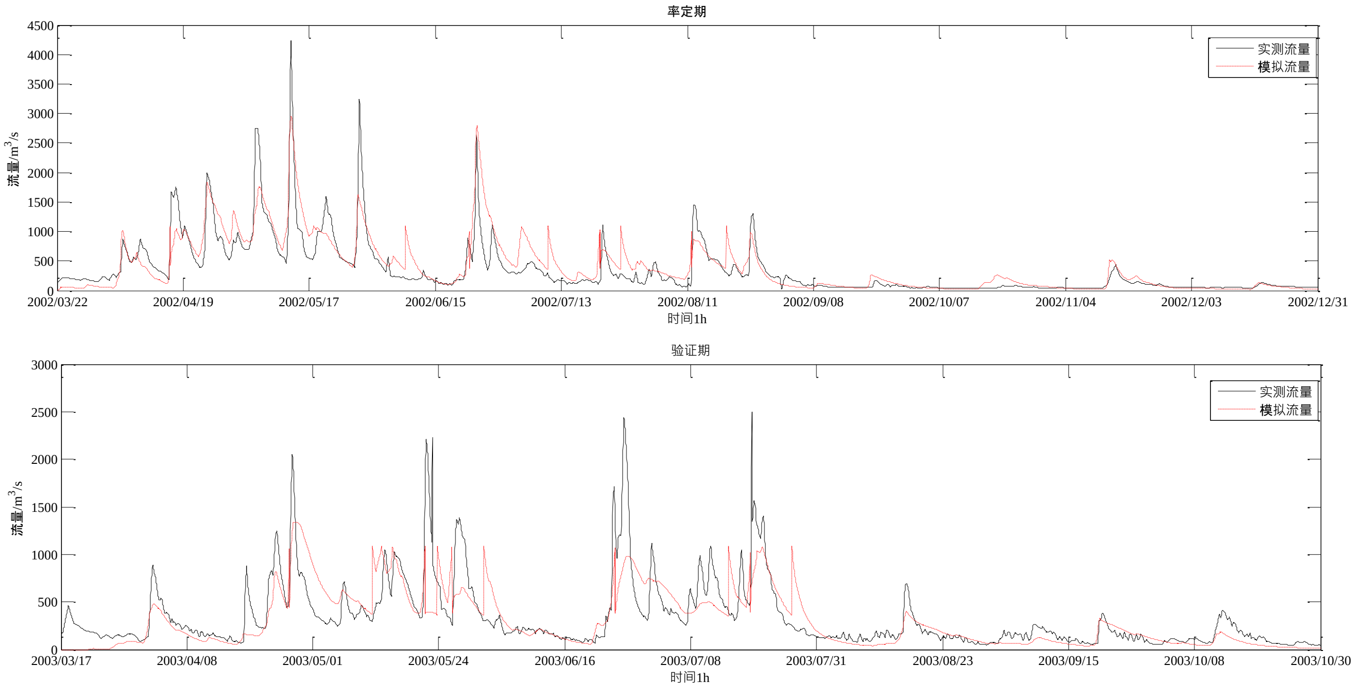
- **LH-OAT：a combination of LH（Latin-Hypercube） sampling method with OAT（One-factor-At-a-Time）experimental method, Embeded in SWAT 2005 model**
- **To identify the most sensitive parameters.**

Calibration of parameters

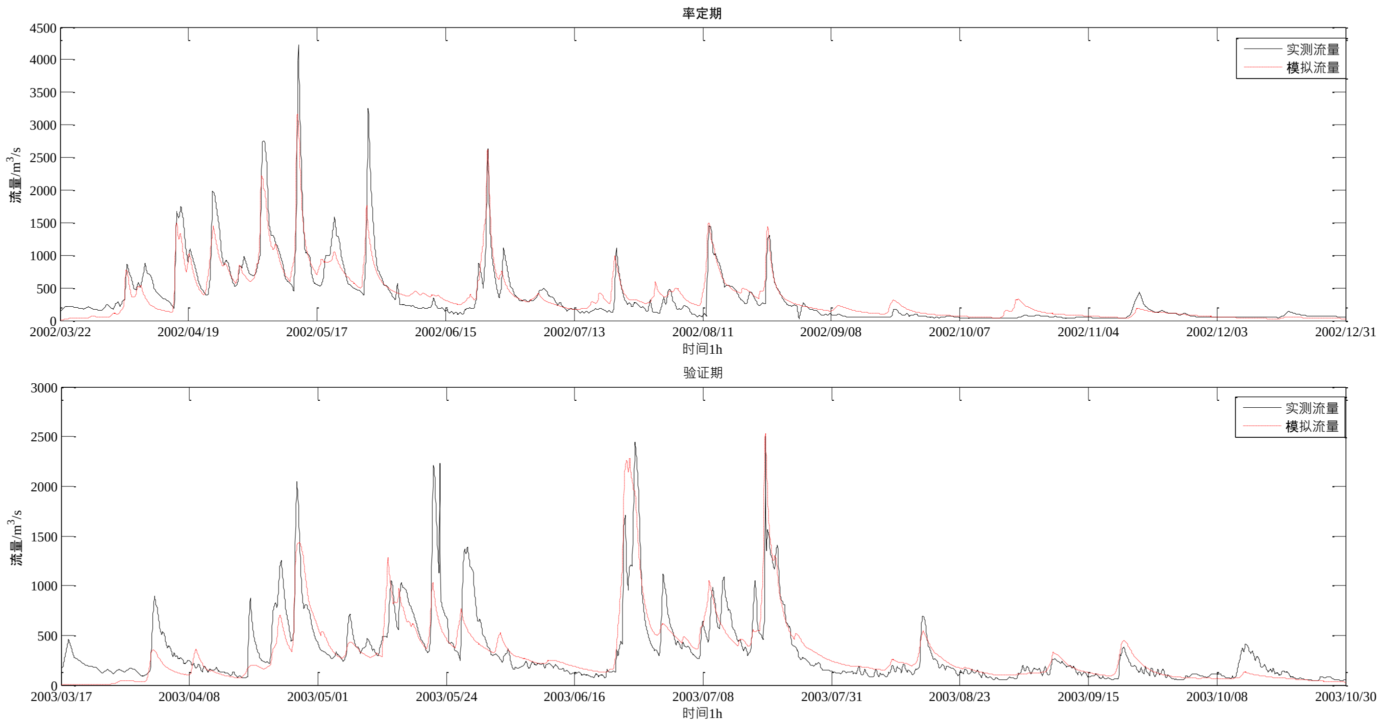
- SEC-UA algorithms embeded in SWAT 2005 model

Thiessen polygon vs. representative gauge





representative gauge

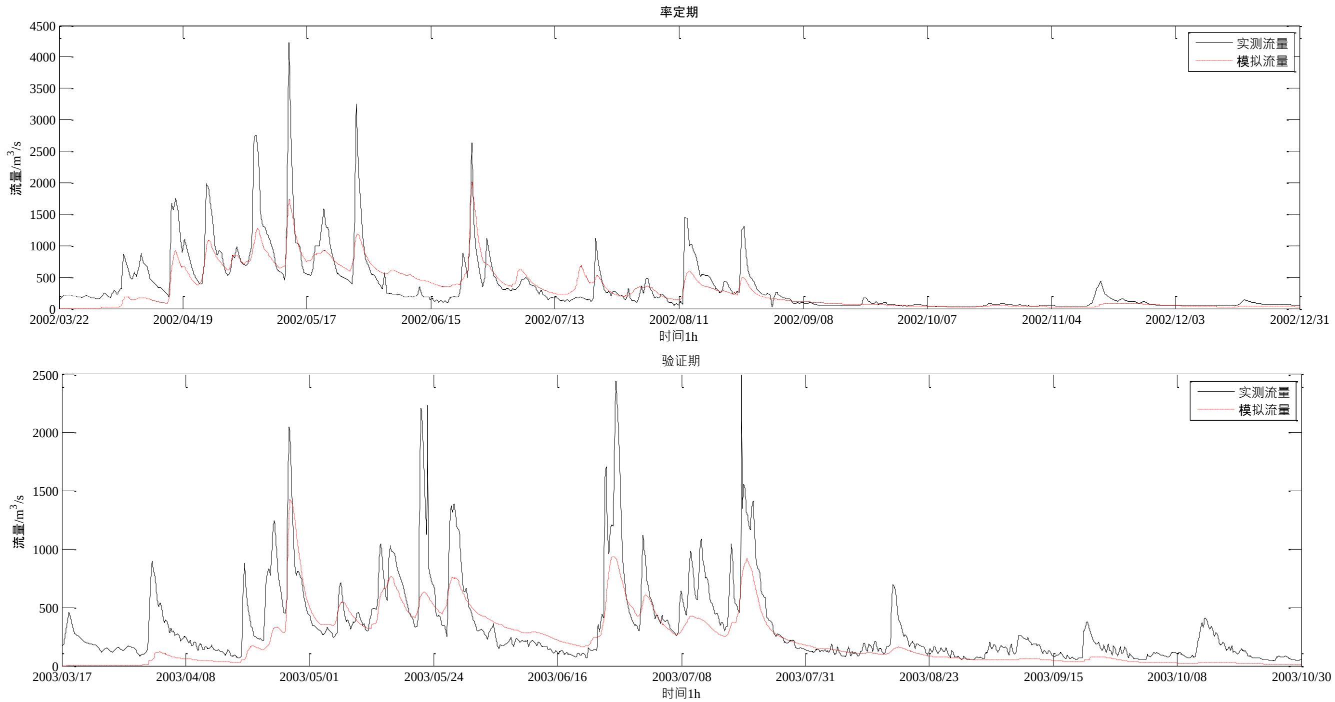


Thiessen polygon

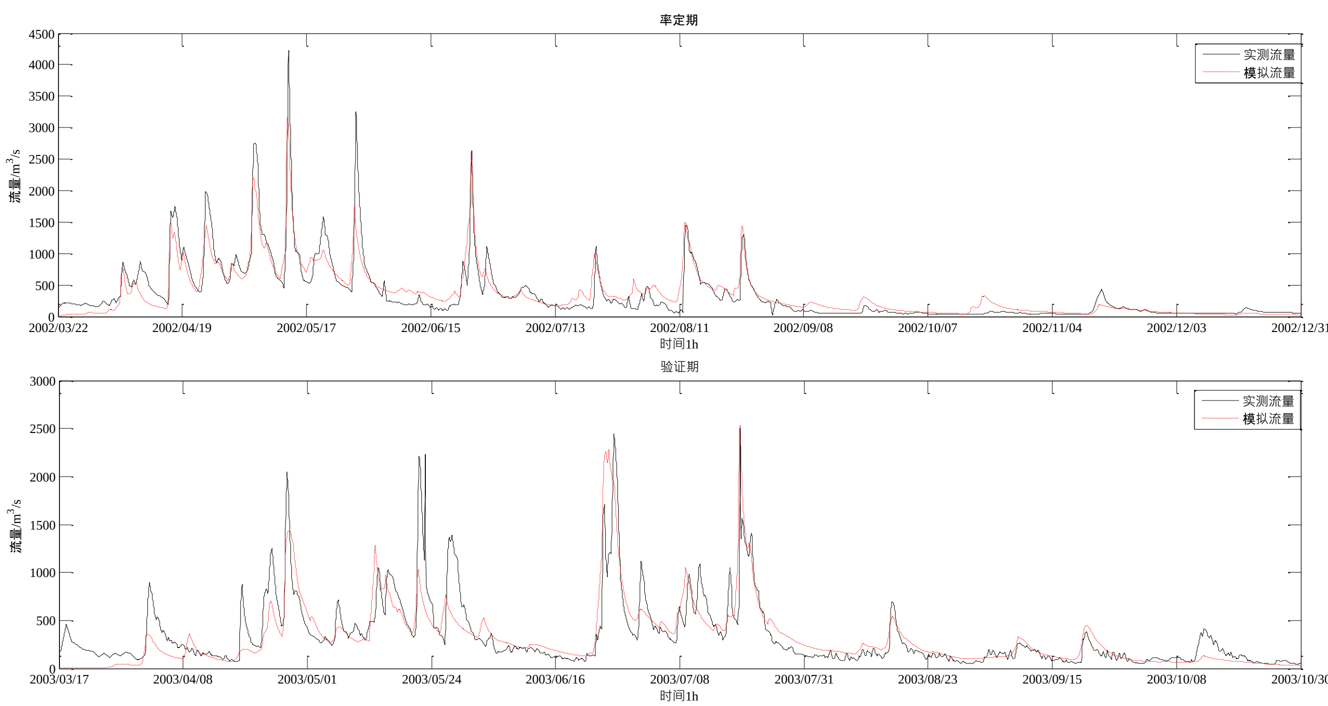
Thiessen polygon vs. representative gauge

	representative gauge		Thiessen	
	calibration	validation	calibration	validation
E_{ns}	0.73	0.51	0.84	0.69
R^2	0.86	0.72	0.92	0.82
RMSE	246.13	226.07	186.79	208.09

Modified vs. original SWAT model



original SWAT model



modified SWAT model

Modified vs. original SWAT model

	modified SWAT		original SWAT	
	calibration	validation	calibration	validation
E_{ns}	0.84	0.69	0.68	0.61
R^2	0.92	0.82	0.83	0.80
RMSE	186.79	208.09	265.05	243.22

Spatio-temporal scale effect of rainfall on flow simulation results

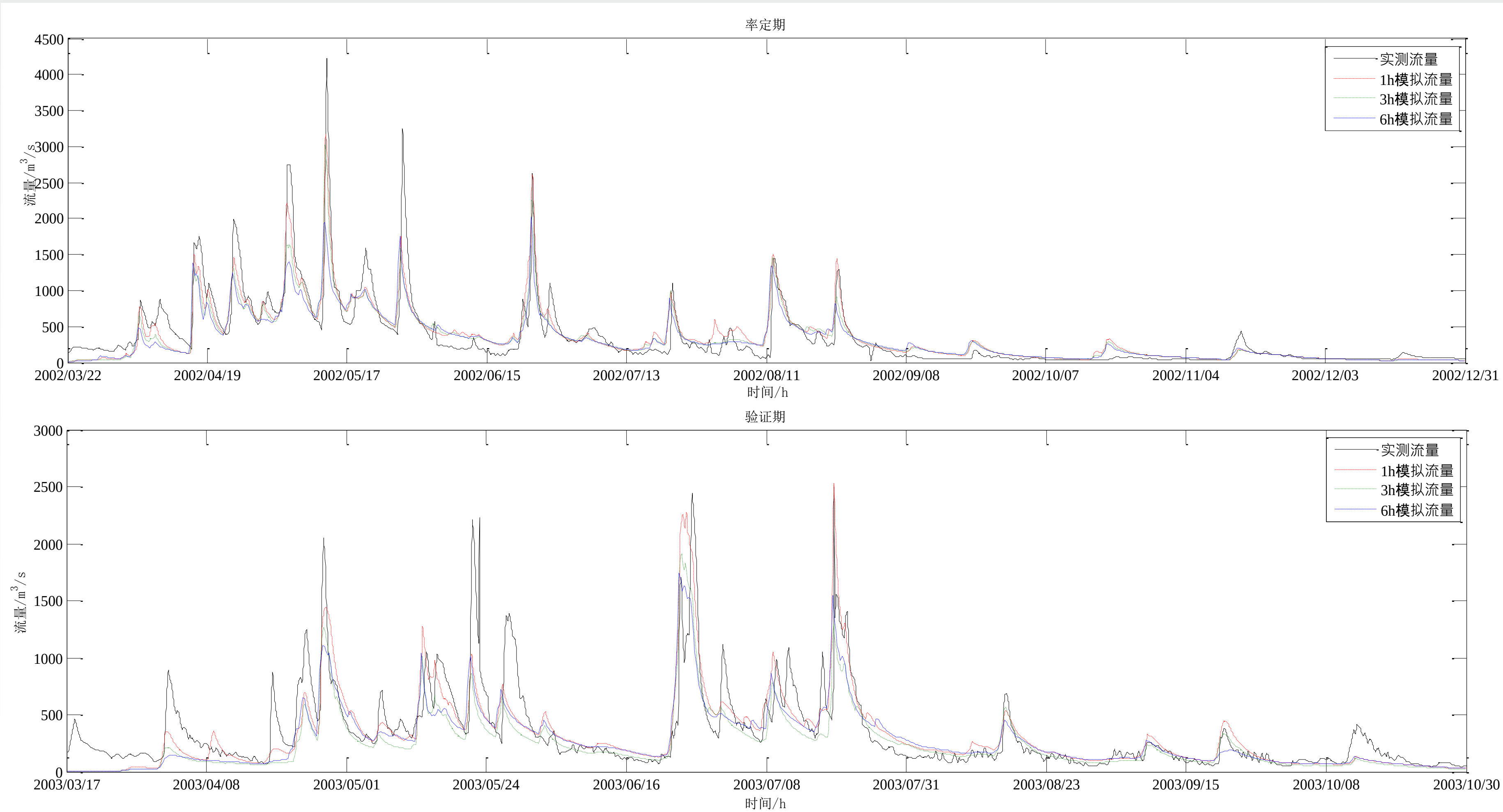
- Temporal scale: time step of rainfall samping;
- Spatial scale: density of rain gauges.

Temporal scale effect of rainfall on flow simulation

- Rainfall data with timesteps of 1h, 3h and 6h were imported into the modified SWAT model.

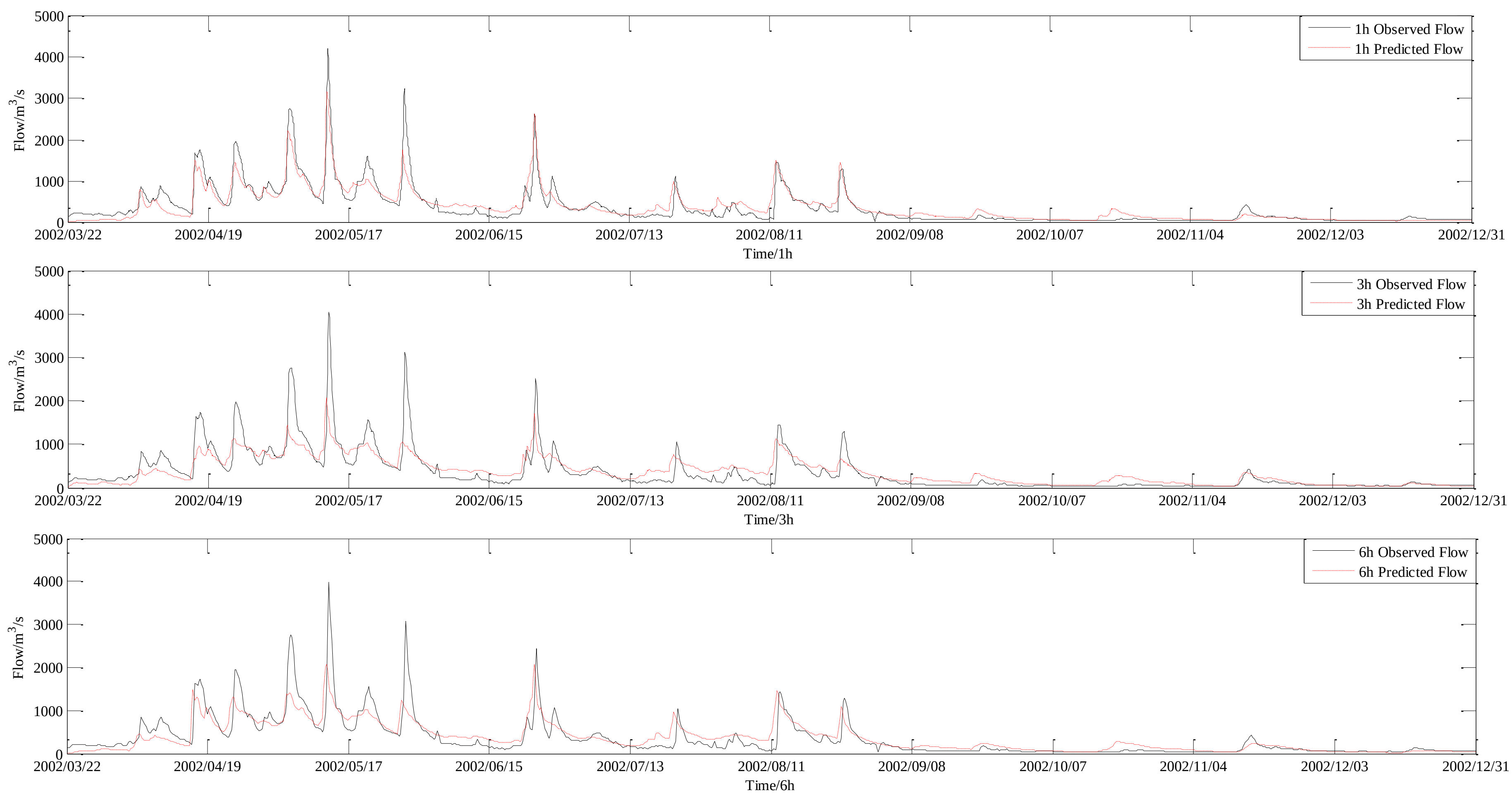
Temporal scale effect of rainfall on flow simulation

- Static parameter method



Temporal scale effect of rainfall on flow simulation

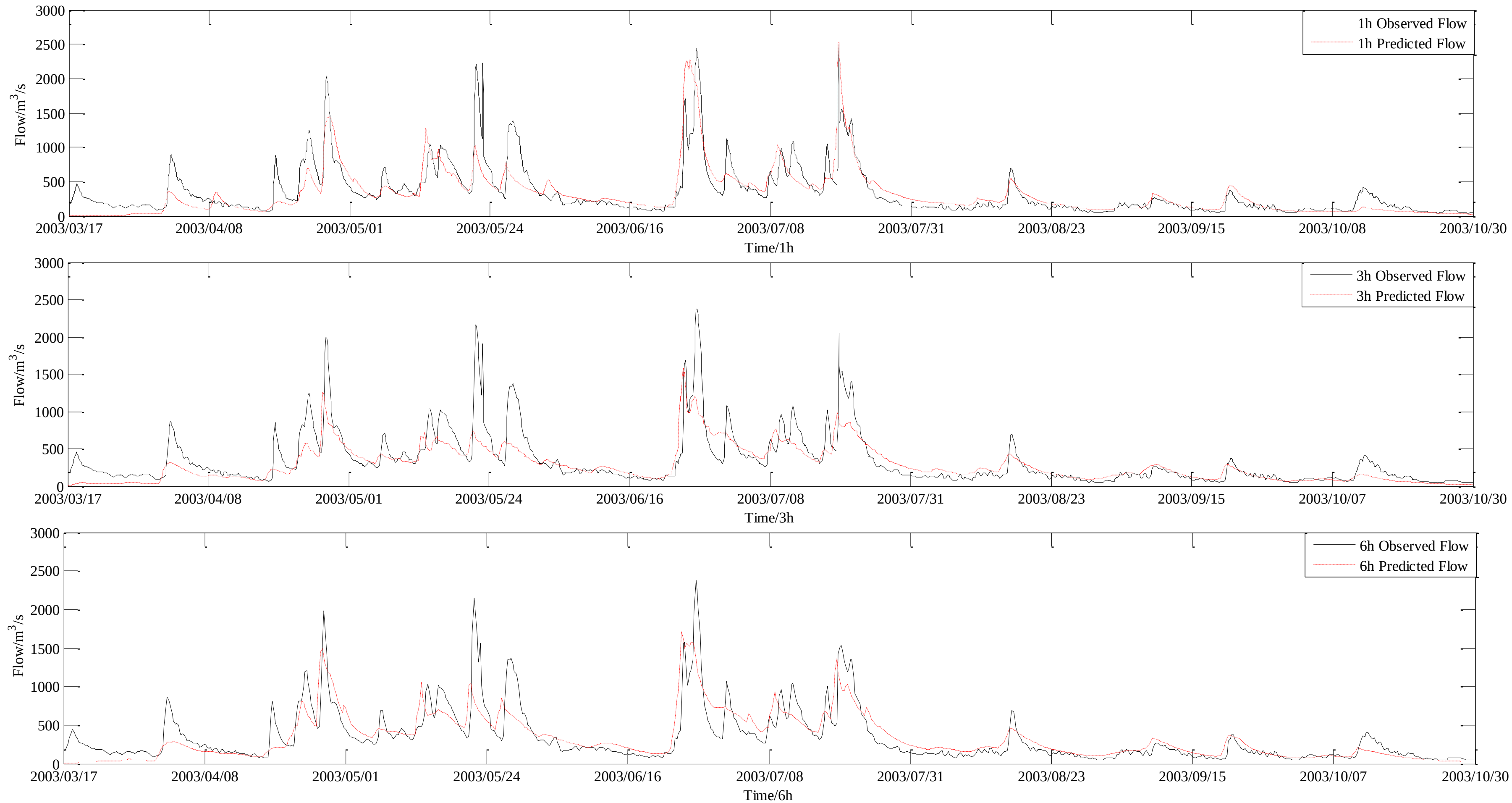
- Dynamic parameter method



Hydrographs with different temporal scales for calibration (2002)

Temporal scale effect of rainfall on flow simulation

- Dynamic parameter method



Hydrographs with different temporal scales for validation (2003)

Temporal scale effect Of rainfall on flow simulation

	1h		3h		6h	
	calibration	validation	calibration	validation	calibration	validation
E_{ns}	0.84	0.69	0.66	0.62	0.68	0.65
R^2	0.92	0.82	0.83	0.8	0.83	0.81
RMSE	186.79	208.09	268	221.17	259.25	205.62

- 1h rainfall data results in most accurate flow simulation results in general;
- Reasonable by the consideration that Qingjiang river basin is a mountaineous one, with rapid water concentration time.

Spatial scale effect of rainfall on flow simulation

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- Raingauge density
- Cross co-relation co-efficient between areal averaged rainfall (***R***) & runoff
- R_k - k (number of raingauges)

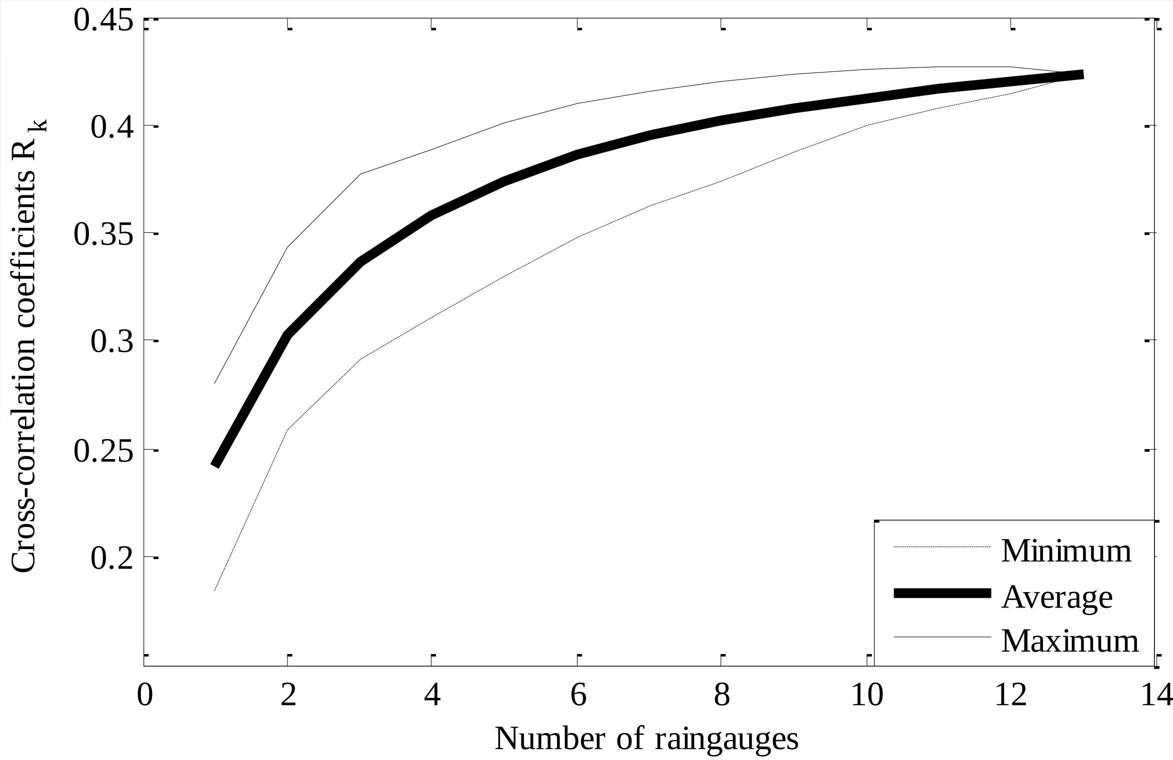
$$R_k = \frac{\mathrm{cov}(x_i, y_{i+k})}{(\mathrm{var}\, x_i, \mathrm{var}\, y_{i+k})^{1/2}}$$

$$= \frac{\sum_{i=1}^{N-k}(x_i - \frac{1}{N-k}\sum_{i=1}^{N-k} x_i)(y_{i+k} - \frac{1}{N-k}\sum_{i=1}^{N-k} y_{i+k})}{[(N-k)s_x^2]^{1/2}[(N-k)s_y^2]^{1/2}}$$

$$= \frac{\sum_{i=1}^{N-k}(y_{i+k} - \bar{y})\, x_i - \bar{x}\sum_{i=1}^{N-k}(y_{i+k} - \bar{y})}{[(N-k)s_x^2]^{1/2}[(N-k)s_y^2]^{1/2}}$$

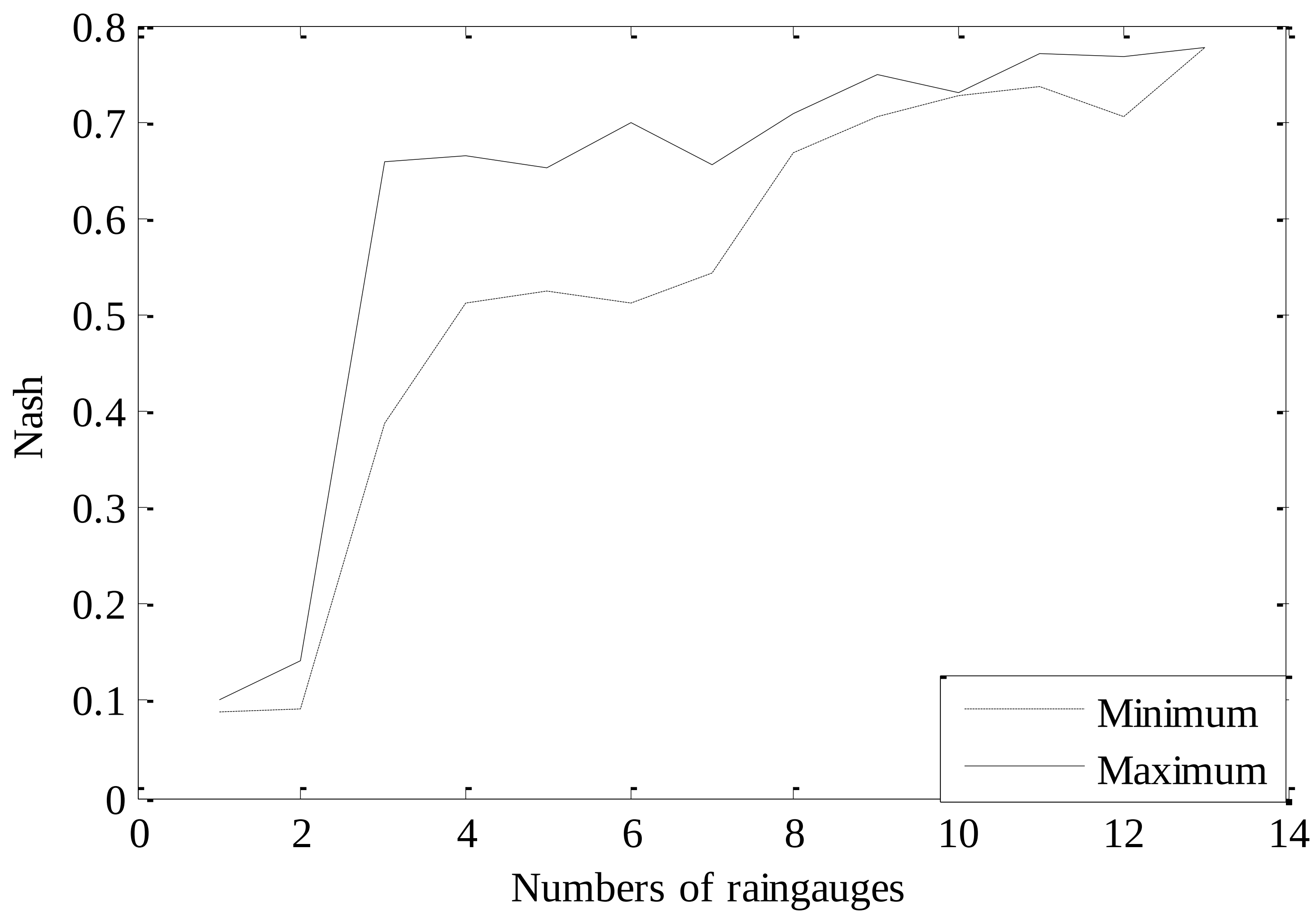
Spatial scale effect of rainfall on flow simulation

- ***R_k*** **increases hyperbolically with increasing k,**
- **could level off after 9 gauges, more gauges are needed to find out. .**

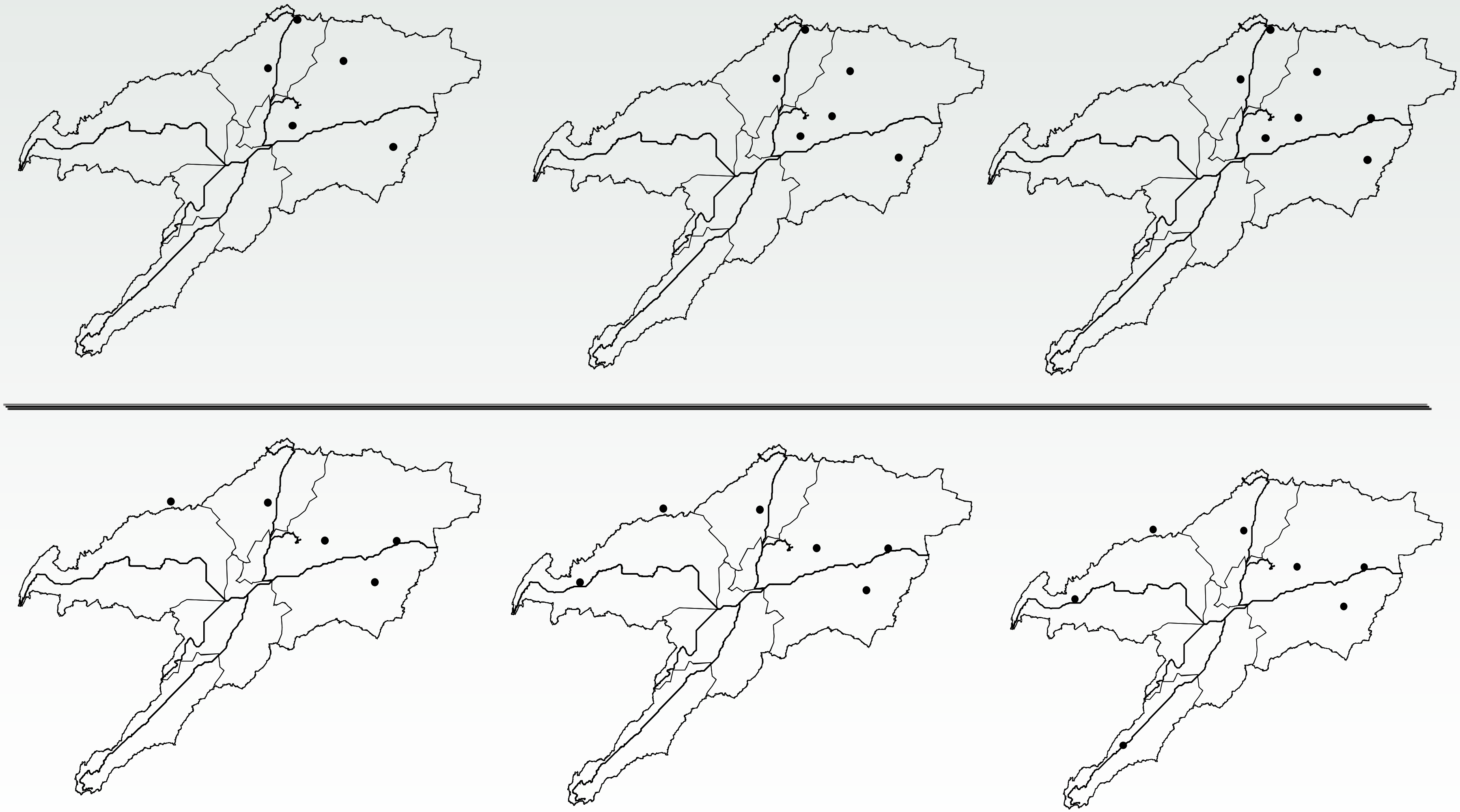


Spatial scale effect of rainfall on flow simulation

- **Verification by running SWAT model**



Spatial scale effect of rainfall on flow simulation



Worst combination

Best combination

5 gauges | 6 gauges | 7 gauges

Spatial scale effect of rainfall on flow simulation

Worst combination

Best combination

8 gauges

9 gauges

Rusults

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- Modified hourly SWAT model performs better than original daily model.
- Decreasing the time scale of rainfall data (from 6 to 1 hour) will increase the flow simulation accuracies from 0.65 to 0.69 (NS) for validation period (yr 2003).
- Increasing number of rain gauges will increase the flow simulation accuracies hyperbolically. More gauges need to be added to identify a threshold, greater than which the increase will level off.

Thank you for your attention!