How to maximize the predictive value of available data in ungauged basins？

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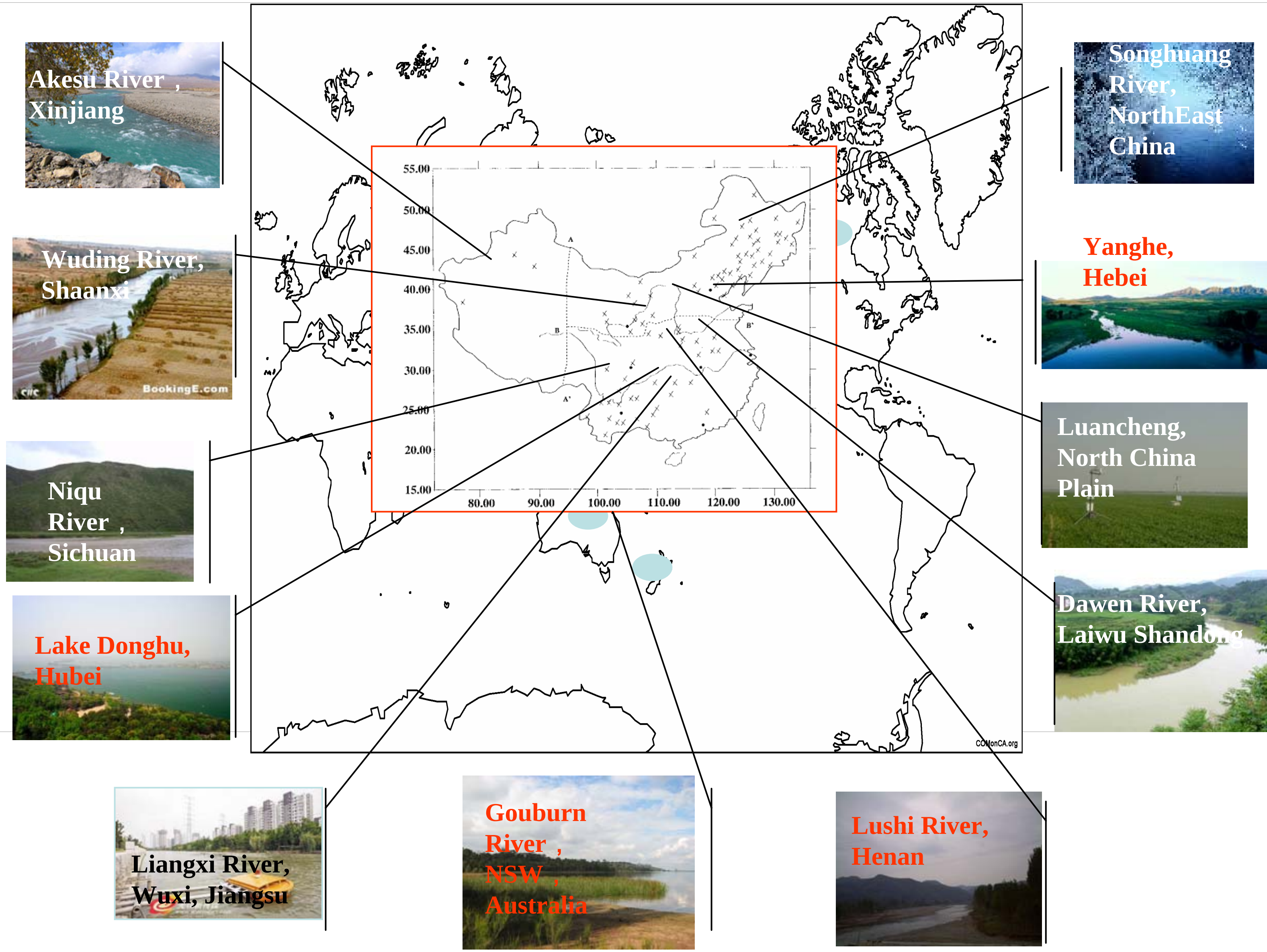
Suxia Liu



Akesu River，Xinjiang
Wuding River, Shaanxi
Niqu River，Sichuan
Lake Donghu, Hubei
Liangxi River, Wuxi, Jiangsu
Gouburn River，NSW，Australia
Lushi River, Henan
Songhuang River, NorthEast China
Yanghe, Hebei
Luancheng, North China Plain
Dawen River, Laiwu Shandong
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130.00

My research interests

- Interface Processes
- Spatial and Temporal Variation of Hydrological elements
- Hydrological Response to CC and LUCC
- Environmental Flow

- Strengthen the hydrological theory
- Extend the prediction of discharge to all the hydrological elements
- Not only on the predictions of elements, but also on the Responses and among others
- Not only hydrological, but also Interdisciplinary

China PUB Working Group

- Established in 2004
- Scientific Chair: Professor Academician Changming Liu
- Chair: Professor Jun Xia
- Vice Chair: Professor Dawen Yang, etc
- Secretary General: Professor Suxia Liu

IAHS-PUB-CHINA meeting2004

Activities of China PUB so far

PUB Seminar 2004

Activities of China PUB so far

IAHS-PUB-CHINA 2006

IAHS Publication No. 322 （RED book)

Activities of China PUB so far

IAHS-PUB-CHINA 2008

IAHS Publication No. 335（RED book)

Activities of China PUB so far

IAHS-PUB-CHINA 2010

Special issue……..

Activities of China PUB so far

How？to maximize the predictive value of available data in ungauged basins？

巧妇如何为无米之炊?

- If there is no food at home, how will a house wife maximize the nutrition value of available food under the no-rice situations?

Liu et al. Advances in Geographical Science, 2010

How？ to maximize the predictive value of available data in ungauged basins？

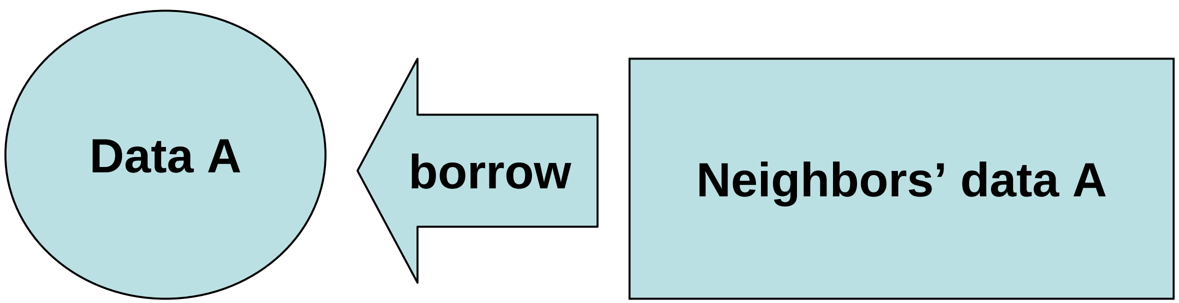
- She will
  - – Borrow (maps for interpolating&transplanting)
  - – Replace----to find some substitutes
    - **From the same region**, (by modeling, rational; innovation ideas)
    - **From other regions**, (comparative analysis, paired-catchment and upscaling)
  - – Generate (field and laboratory experiment)

Liu et al. Advances in Geographical Science, 2010

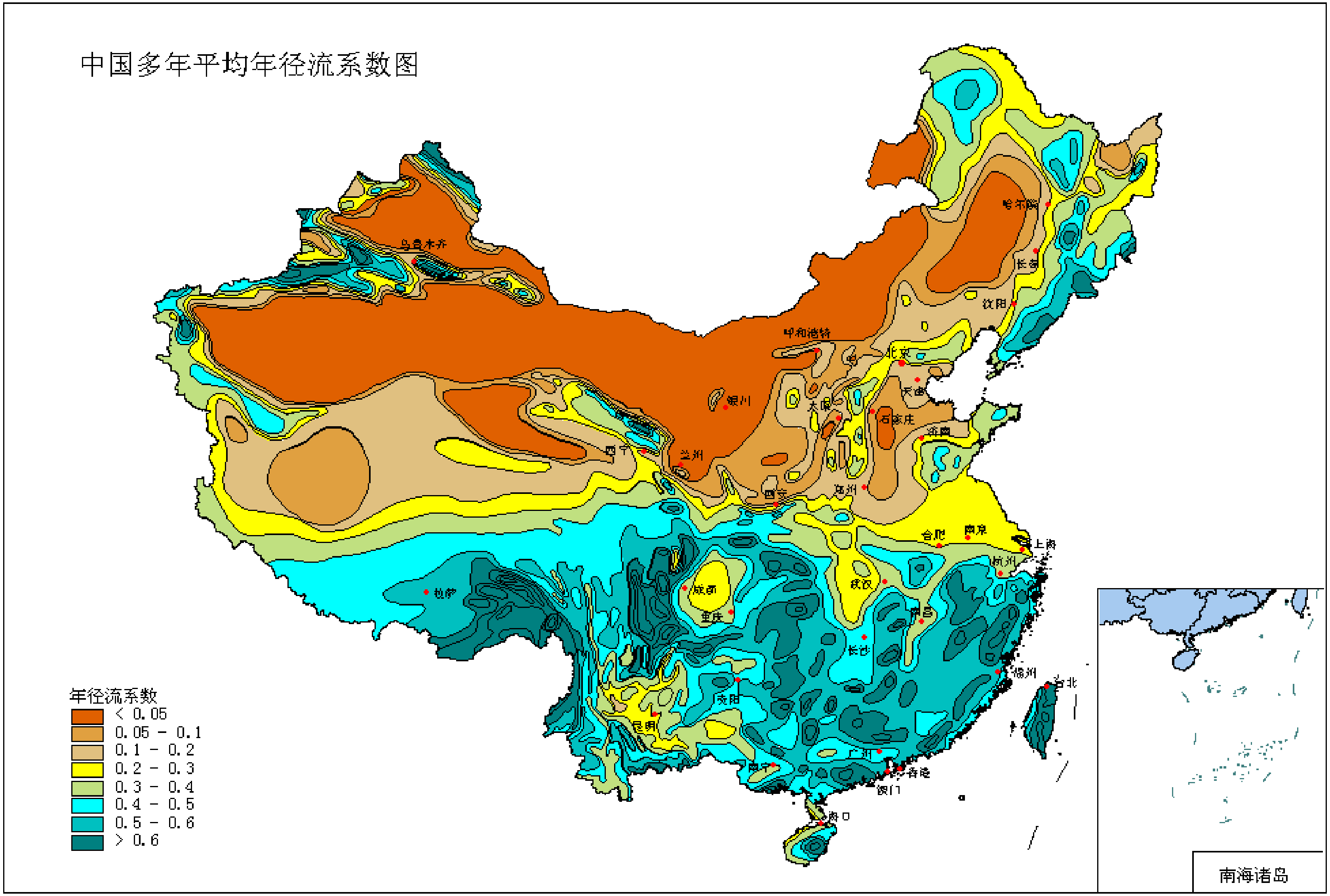
How？ to maximize the predictive value of available data in ungauged basins？

(1) By borrowing

- Maps, annals of hydrological elements for interpolating and transplanting data from known regions



How？to maximize the predictive value of available data in ungauged basins？



Regional map

sdinfo1.chinawater.net.cn/yytj/Wr_narco.htm

How？ to maximize the predictive value of available data in ungauged basins

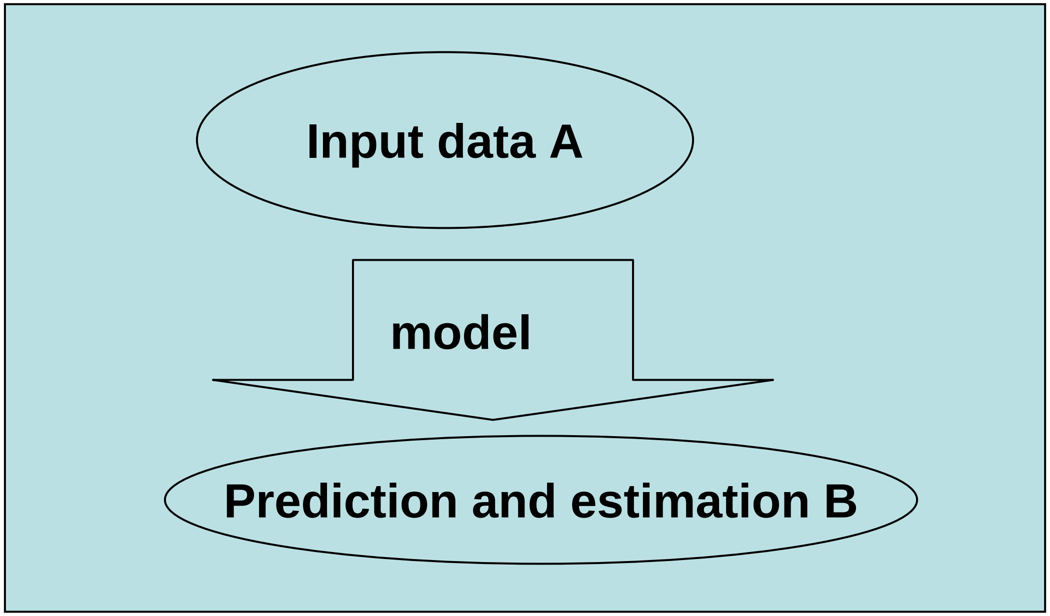
By borrowing

- Simple, but useful, usually for estimating annual runoff.
- Should and can be extended to all elements including evapotranspiration, soil moisture, etc.
- Hard to be sure in mountain areas,needs better interpolation method.
- GIS will enhance its applications

How？ to maximize the predictive value of available data in ungauged basins

（2.1）Replace _from the same region

- By using **hydrological models**



How ? to maximize the predictive value of available data in ungauged basins

By Replacing from the same region

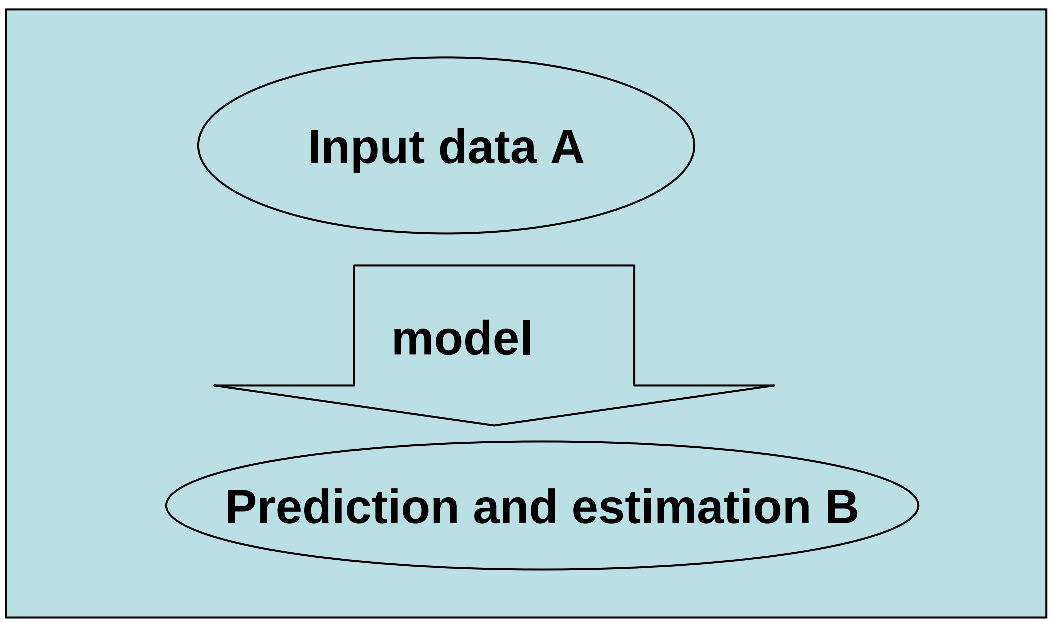
- Simple (conceptual model, rational formula , etc), or complex model (process-based model, eco-hydrological model, etc) ?

Both have pro and cons but each plays important roles in different ways for PUB

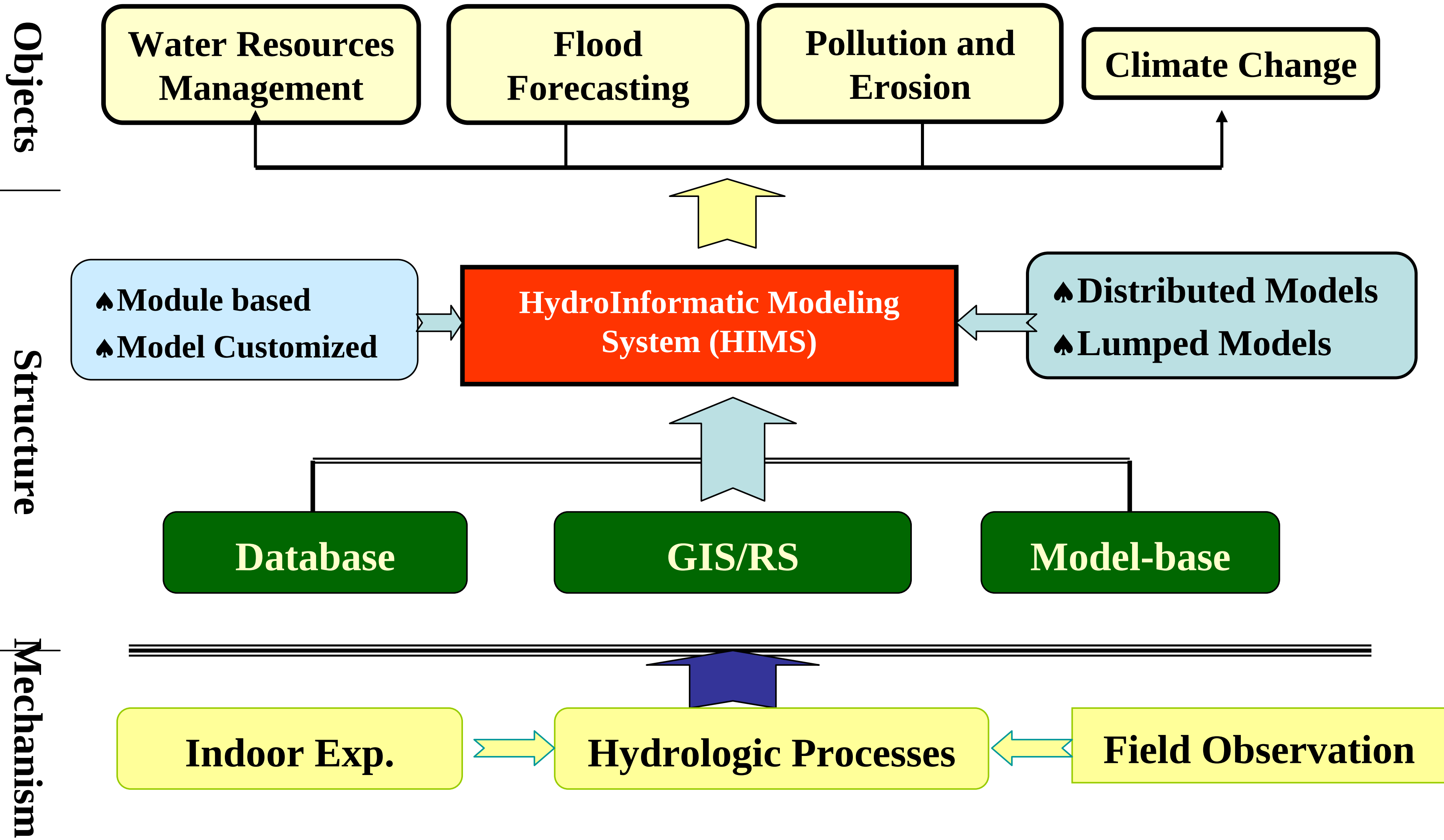
How？to maximize the predictive value of available data in ungauged basins

（2.1）Replace _from the same region

- Example By using HIMS model.



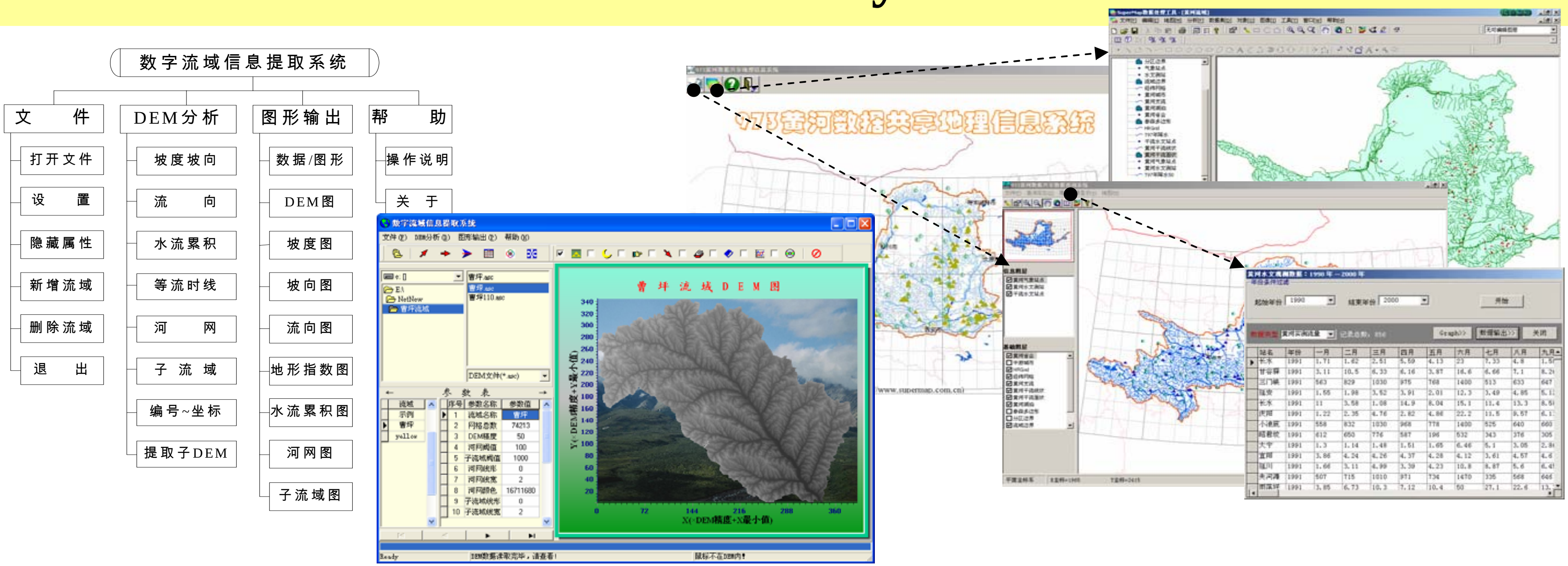
Framework of HIMS



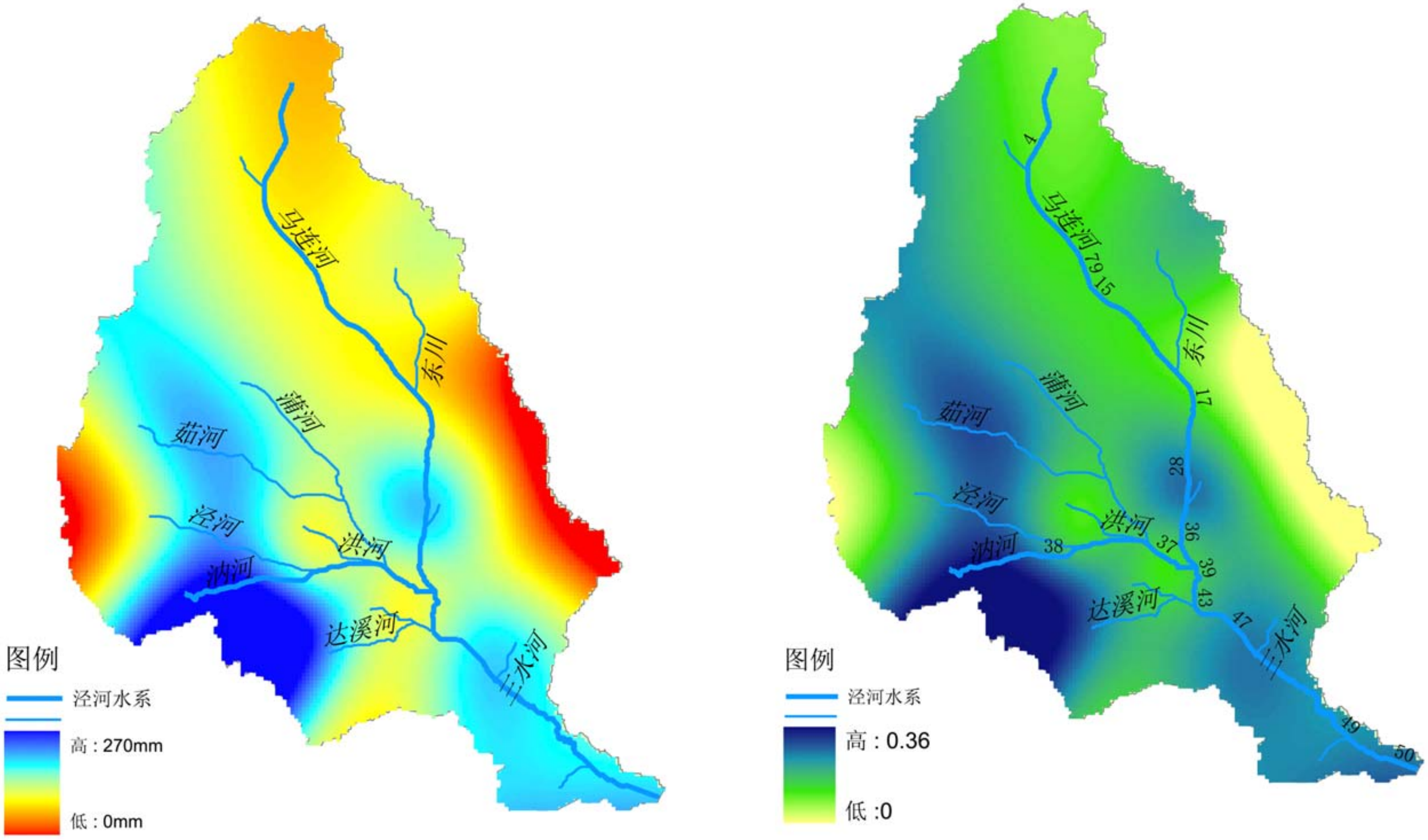
Components of HIMS:

HydroInformatic System Based on GIS

With the component-based GIS software (SuperMap), HIMS is able to manage the hydrologic database efficiently and derivate a watershed effectively.



Case study of the daily scale model in the Jinghe River Basin

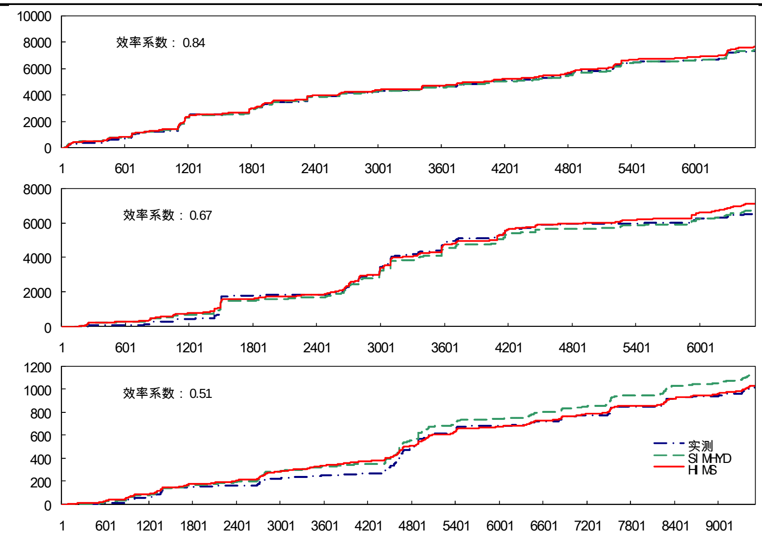


Spatial patterns of runoff and runoff coefficient

Case study of Daily model in 331 watersheds of Australia

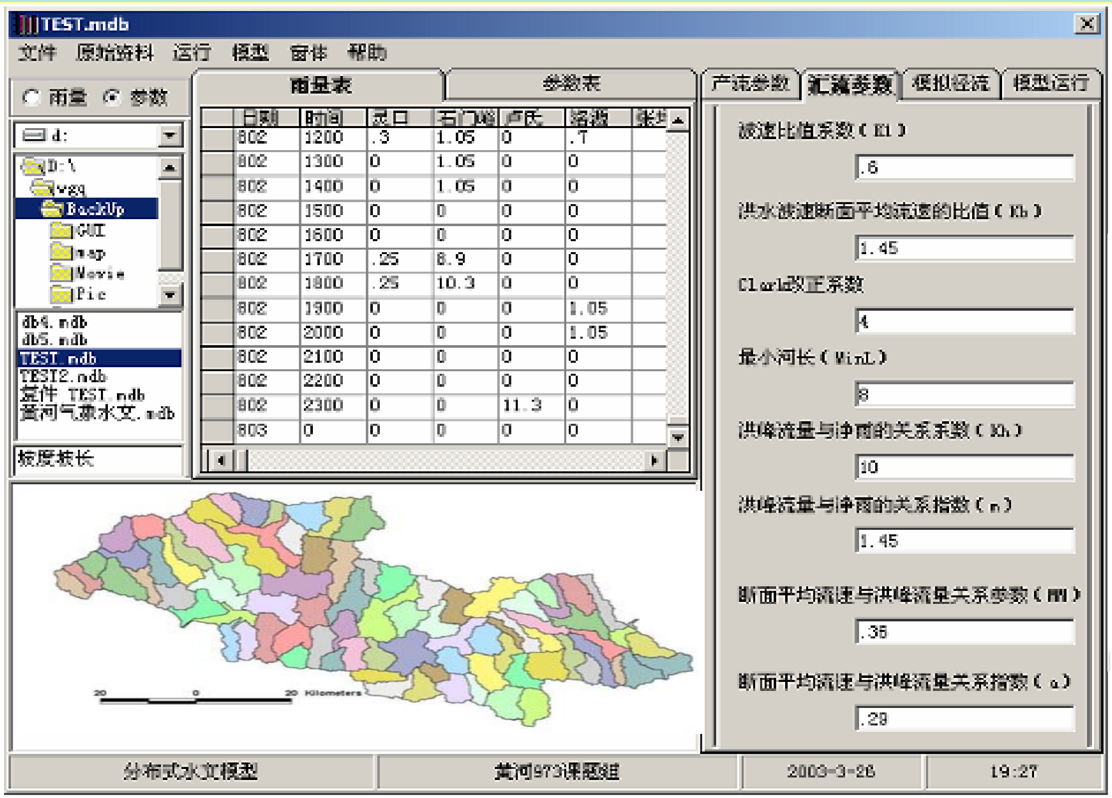
Precipitation	<400mm	400-600mm	600-800mm	800-1200mm	>1200mm	mean
Area< 100 km^2	-	0.60	0.60	0.67	0.79	0.66
100-500 km^2	0.56	0.51	0.78	0.78	0.84	0.73
500-1000 km^2	-	0.52	0.70	0.81	0.69	0.68
>1000 km^2	-	0.25	0.80	0.81	0.75	0.65
Mean	0.56	0.47	0.72	0.76	0.77	0.68

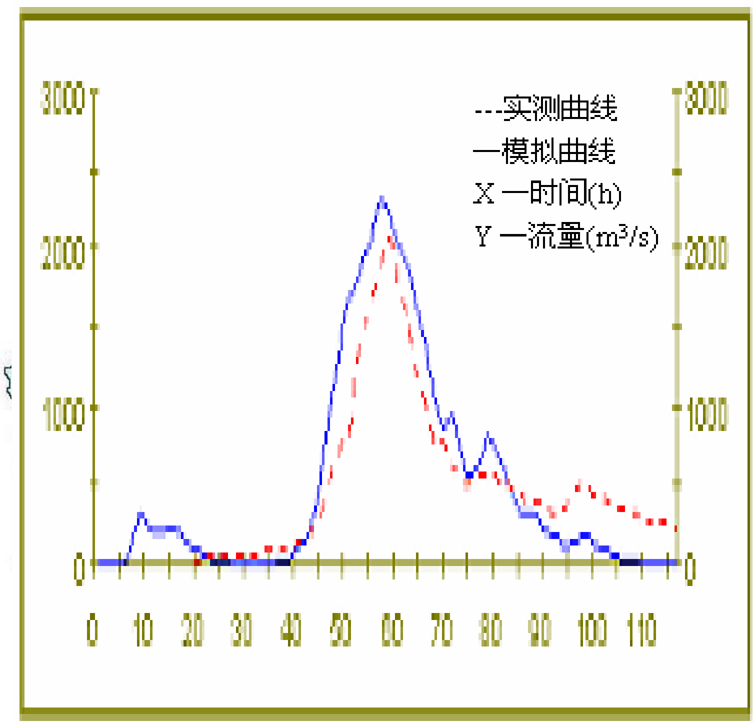
- **Dataset: 331 watersheds, 50 years daily precipitation and potential evaporation;**
- **Efficiency Coefficient: average to 0.68**



¬Flood events prediction

- DEM resolution:30-100m
- Temporal resolution: minutes to hours





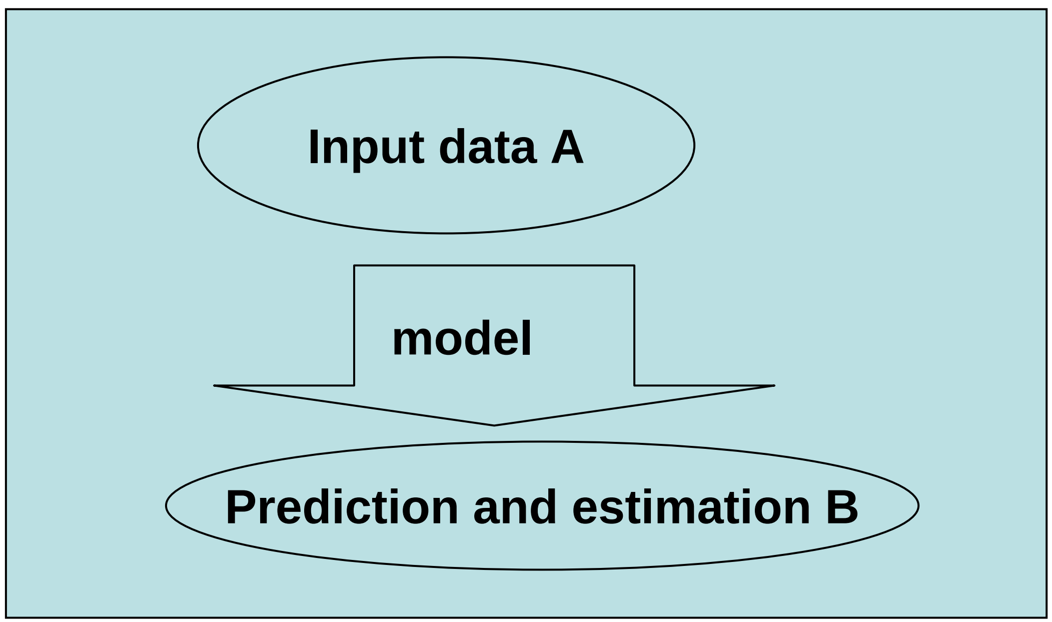
Efficiency Coefficient>0.8

The HIMS model, with good modeling behavior in different climate zone， shows high potential for regionalization，the potential to be used in ungauged basins.

How？ to maximize the predictive value of available data in ungauged basins

（2.1）Replace _from the same region

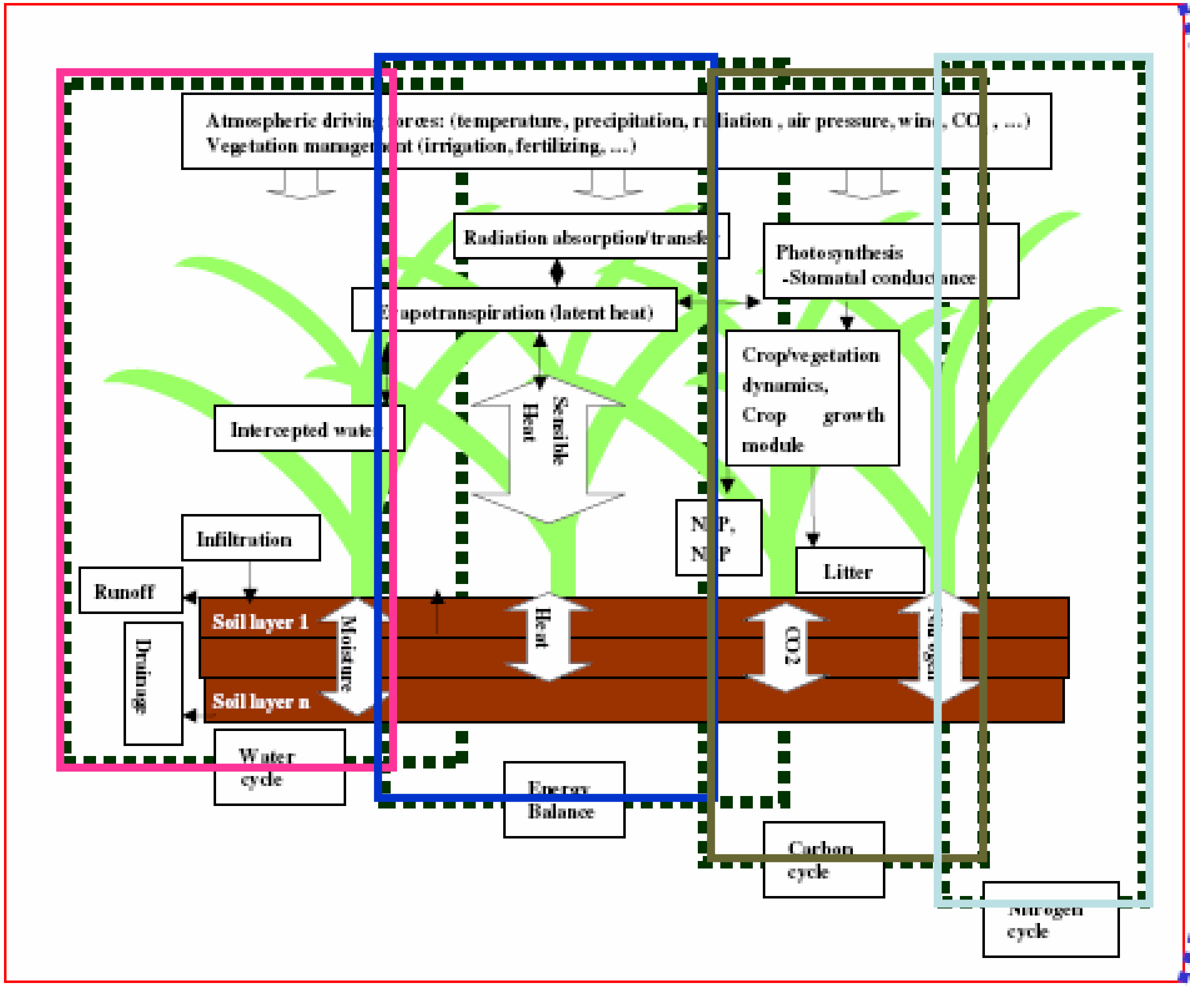
- Example by using VIP model.

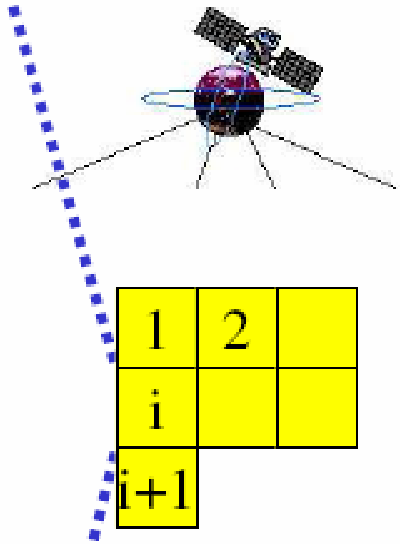


VIP model

Cell mass and energy fluxes

Land surface coverage





Mo et al. AEE, 2009

Features

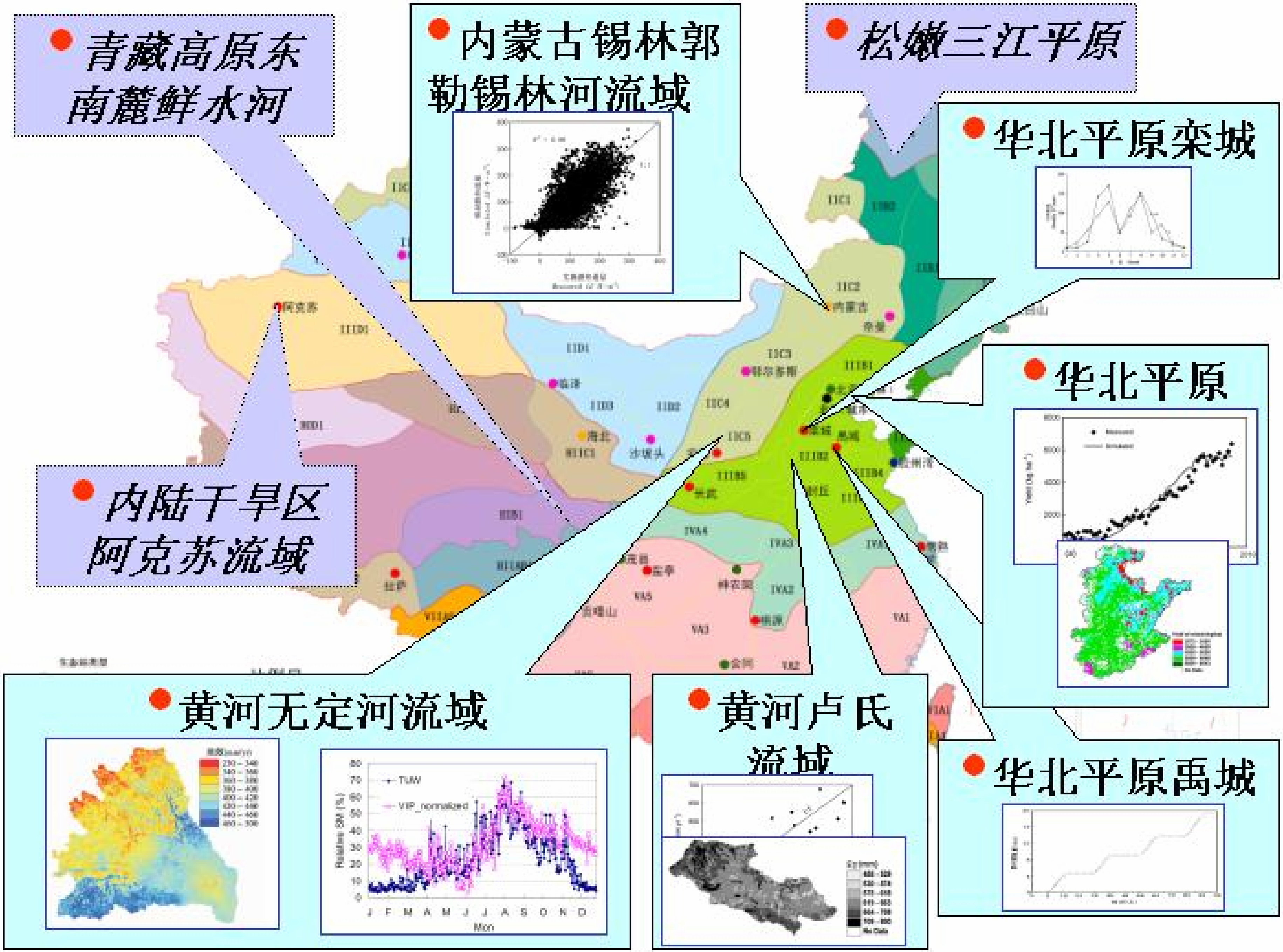
- Three sources (sunlit and shaded canopy and soil surface) energy balance
- Variable storage runoff formation curve
- Vegetation ecological dynamic parameterization

Mo et al, AFM,2001

Mo et al. MAP, 2004

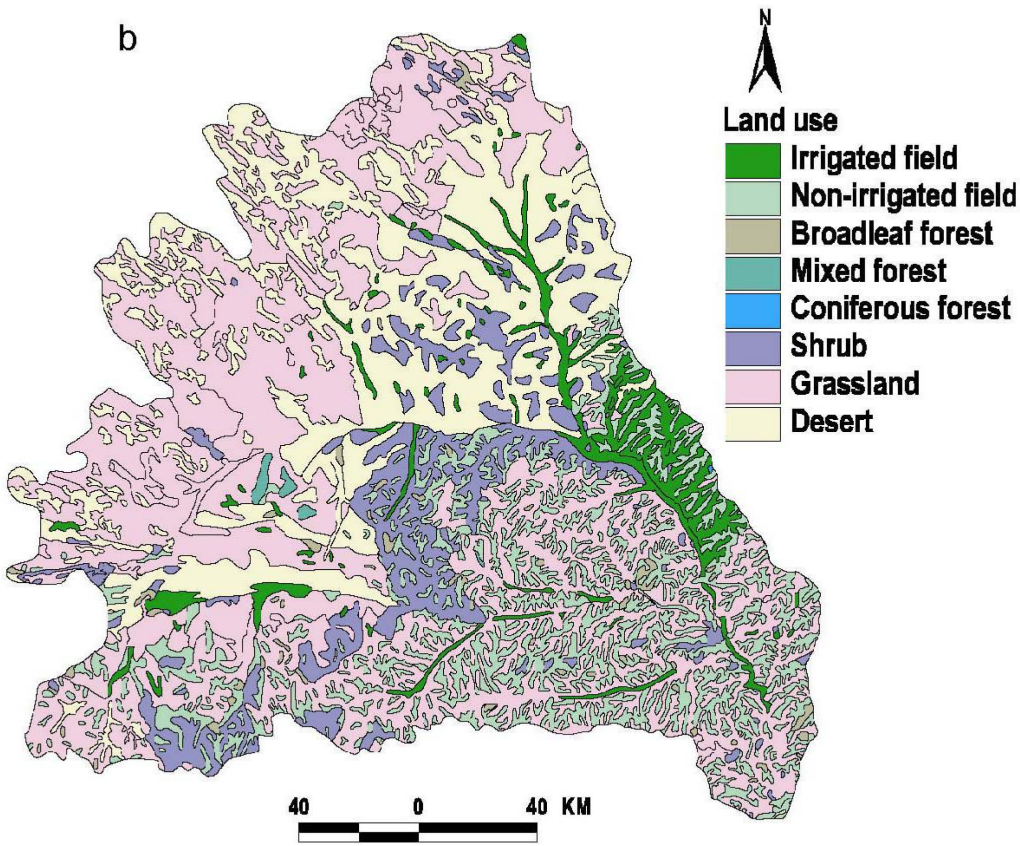
Mo et al. EM, 2005

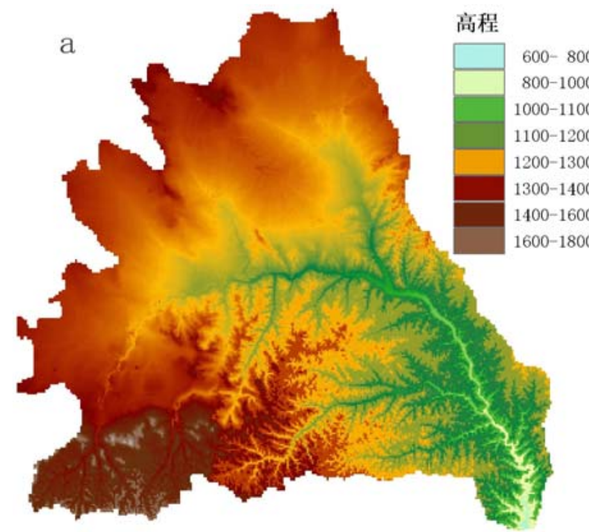
Mo et al. AEE, 2009

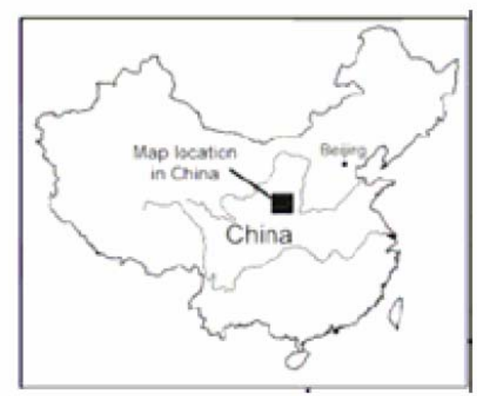


青藏高原东南麓鲜水河
内蒙古锡林郭勒锡林河流域
松嫩三江平原
华北平原栾城
华北平原
内陆干旱区阿克苏流域
黄河无定河流域
黄河卢氏流域
华北平原禹城

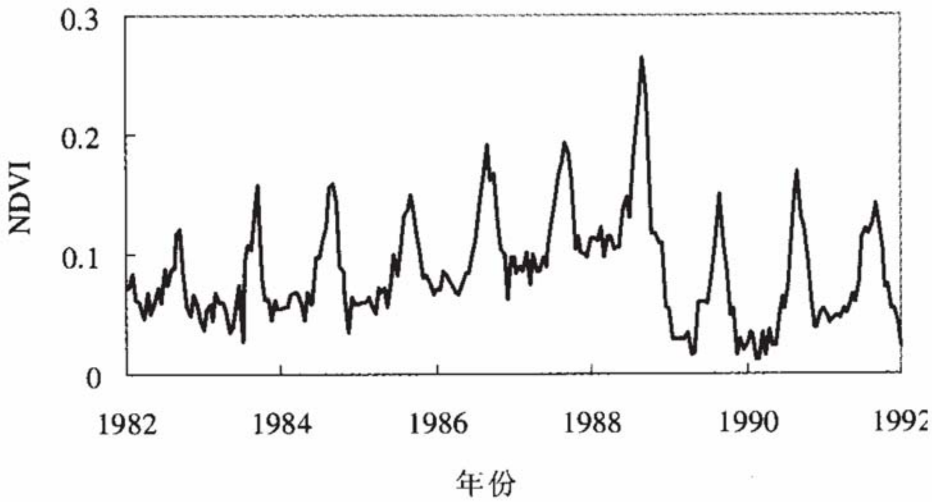
Wuding River

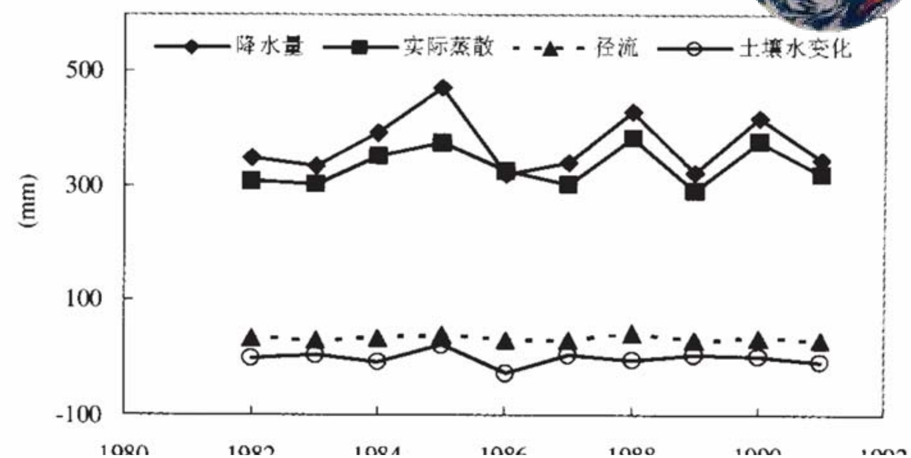


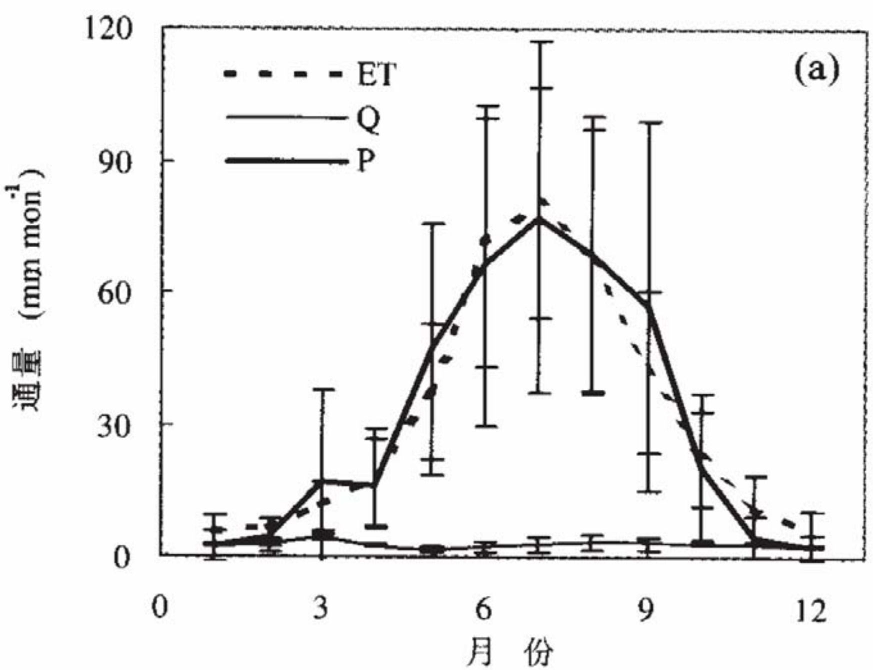


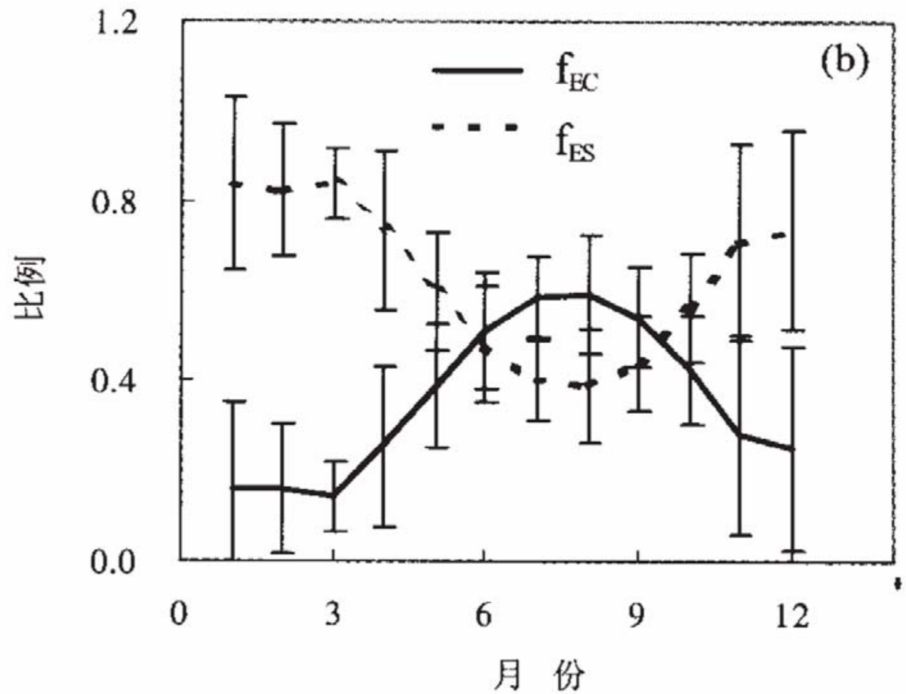


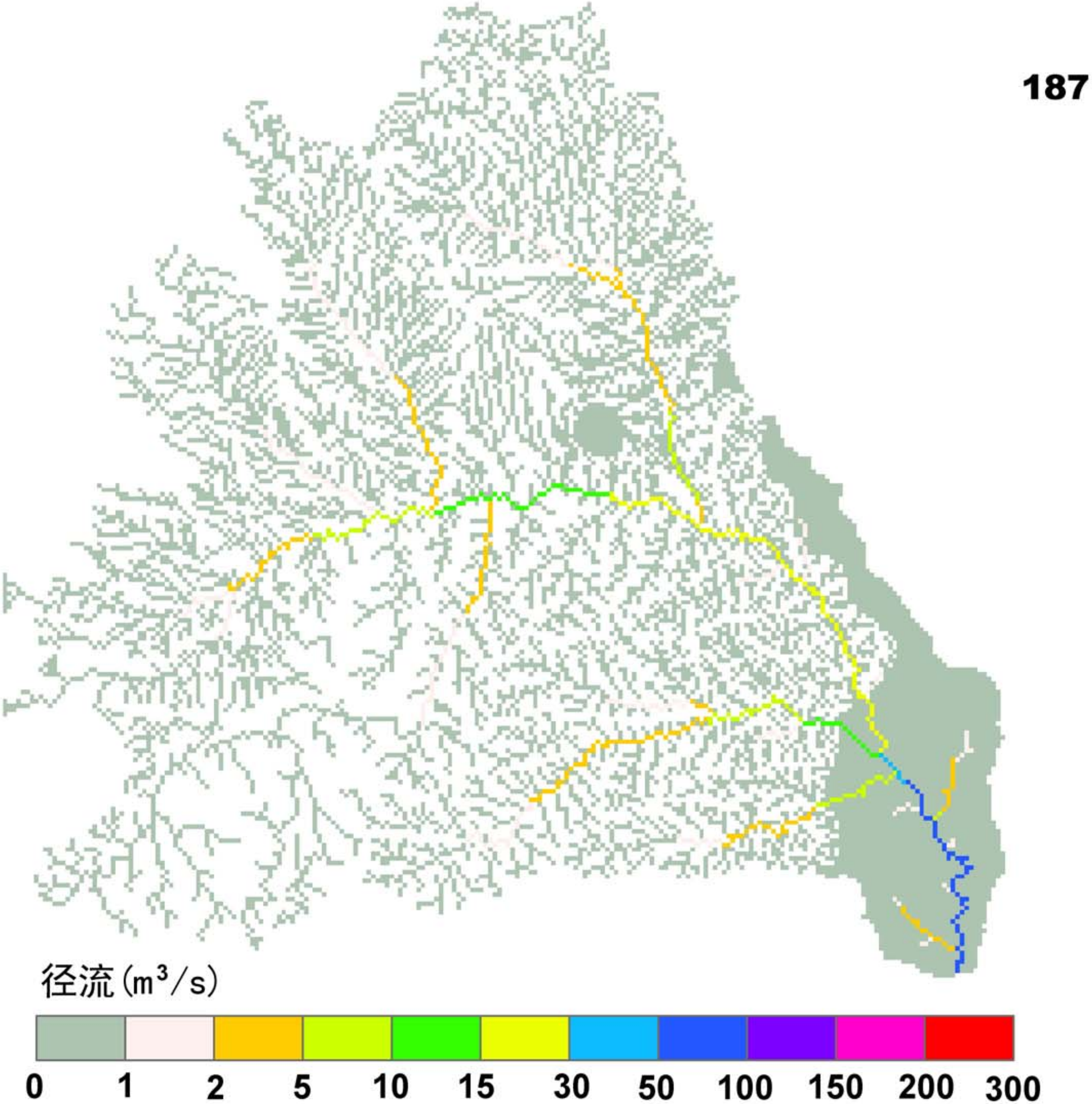
Model Output










187
径流(m³/s)
0
1
2
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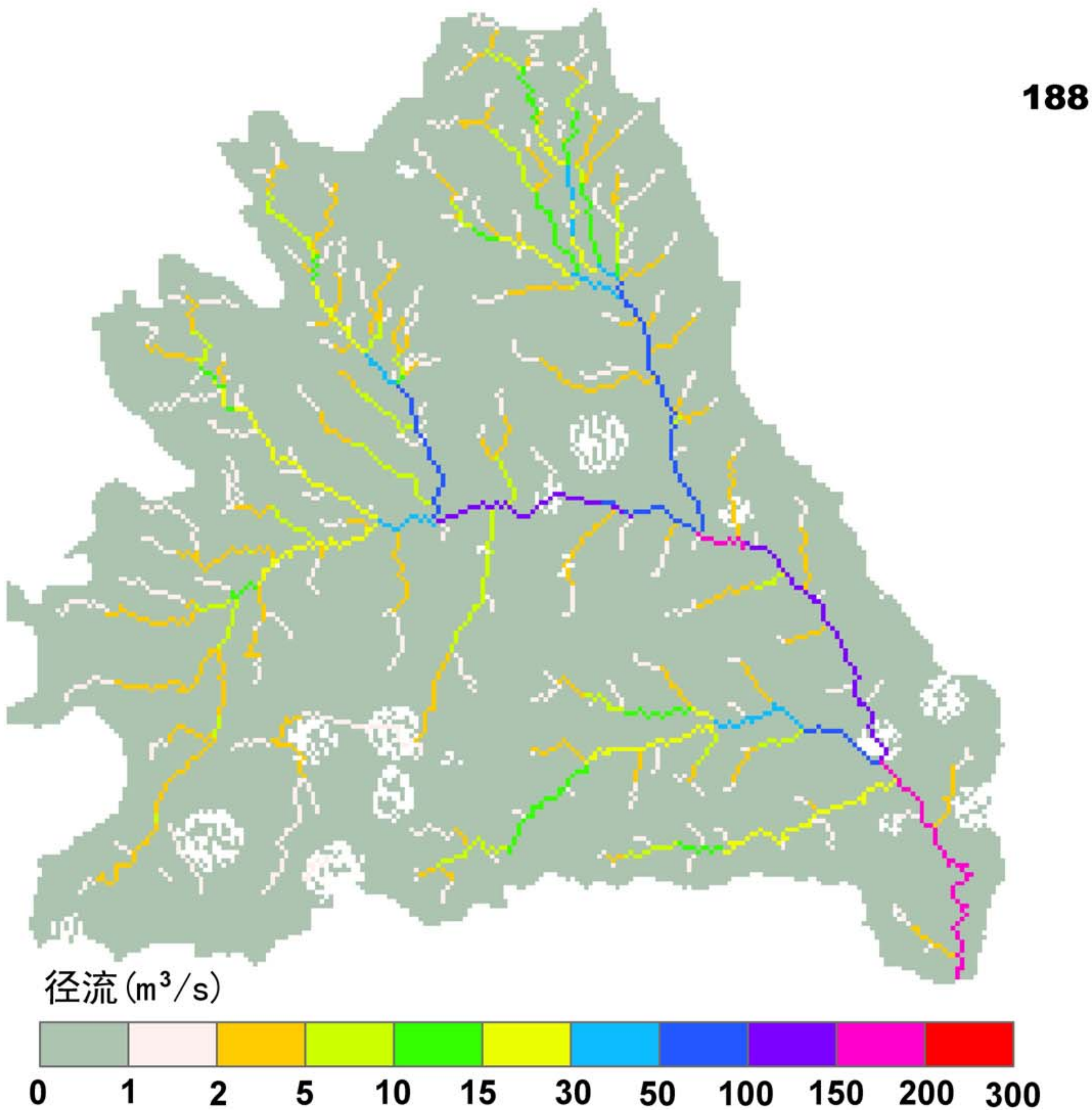
188
径流(m³/s)
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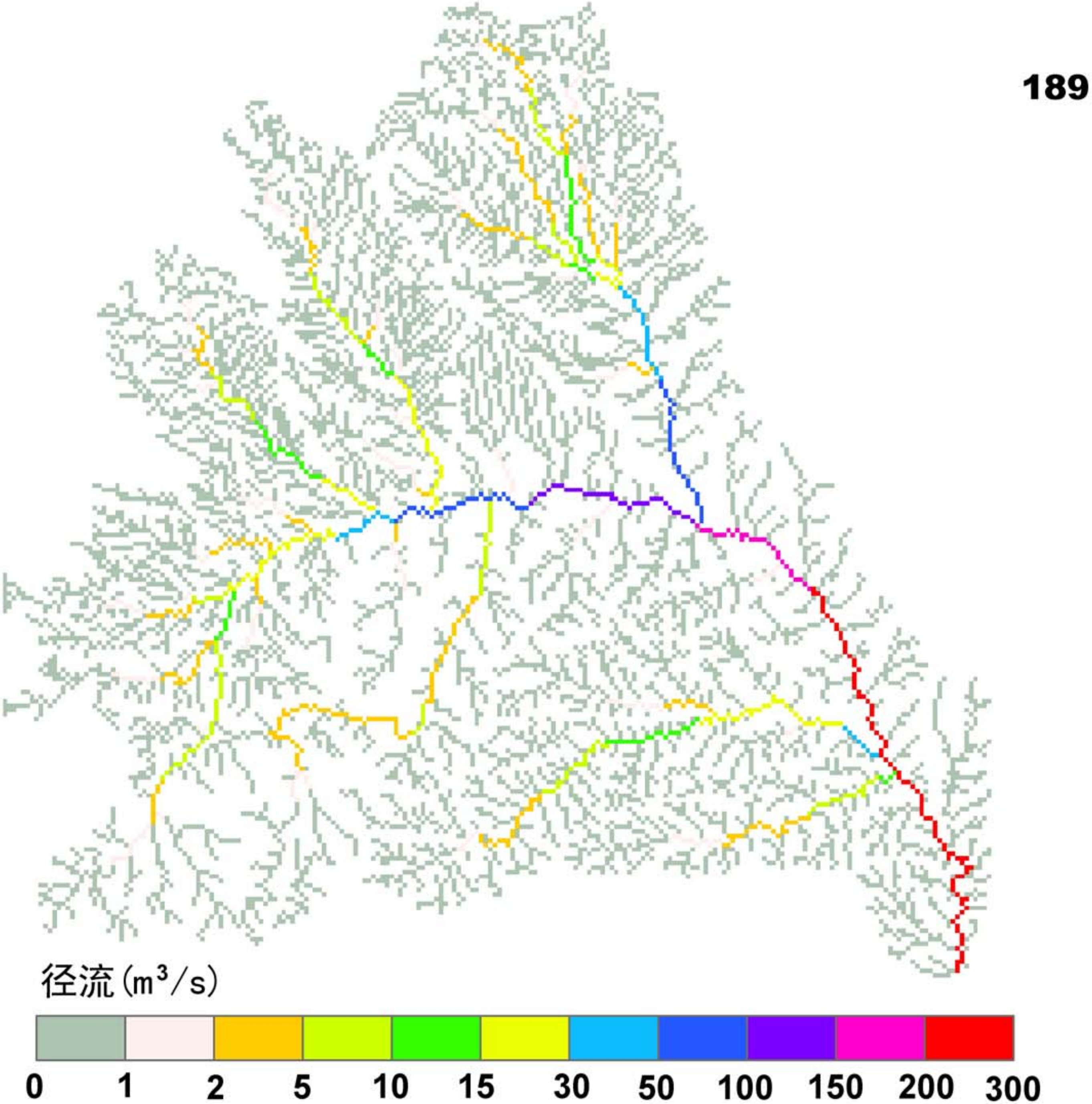
189
径流(m³/s)
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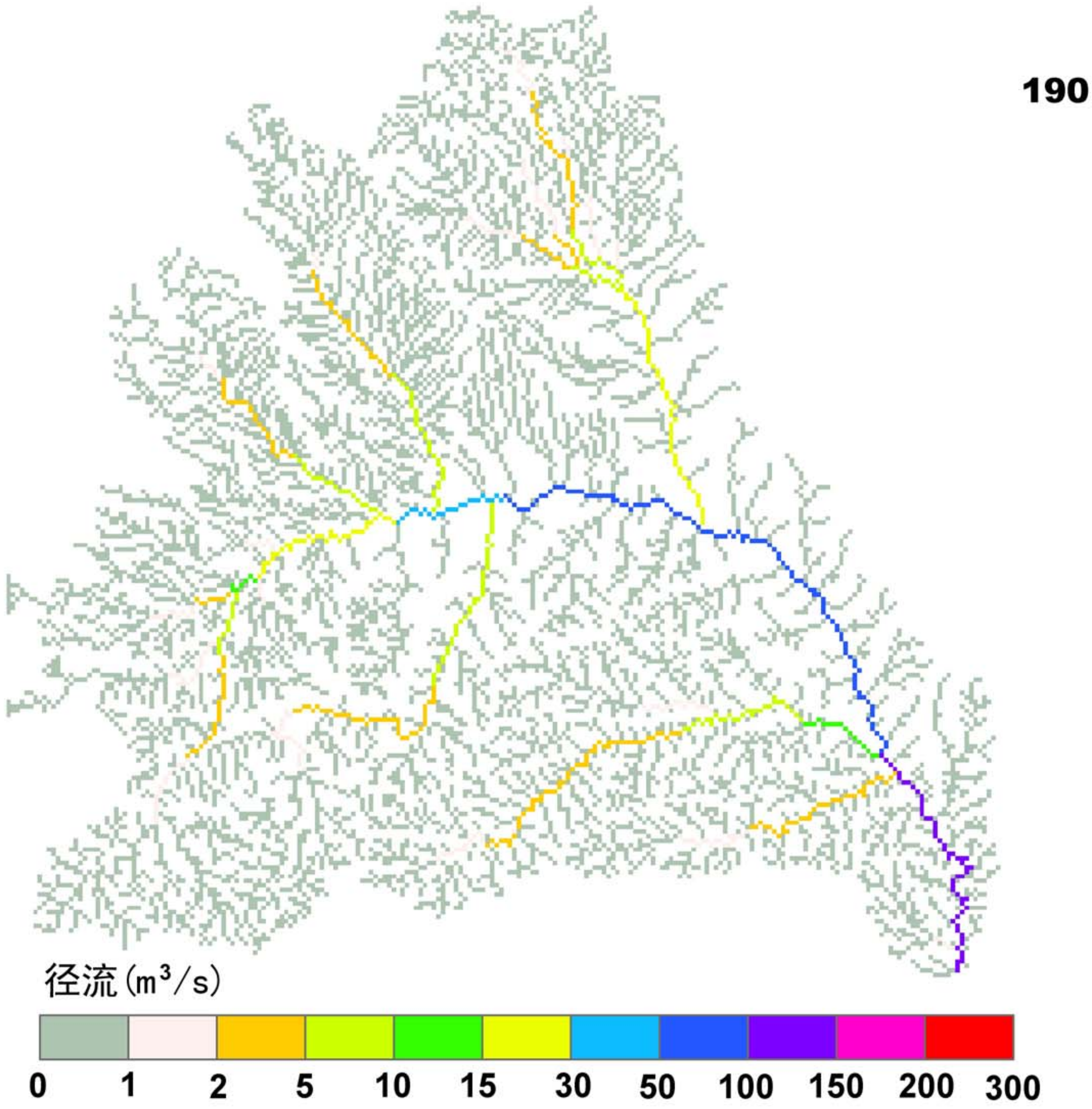
190
径流(m³/s)
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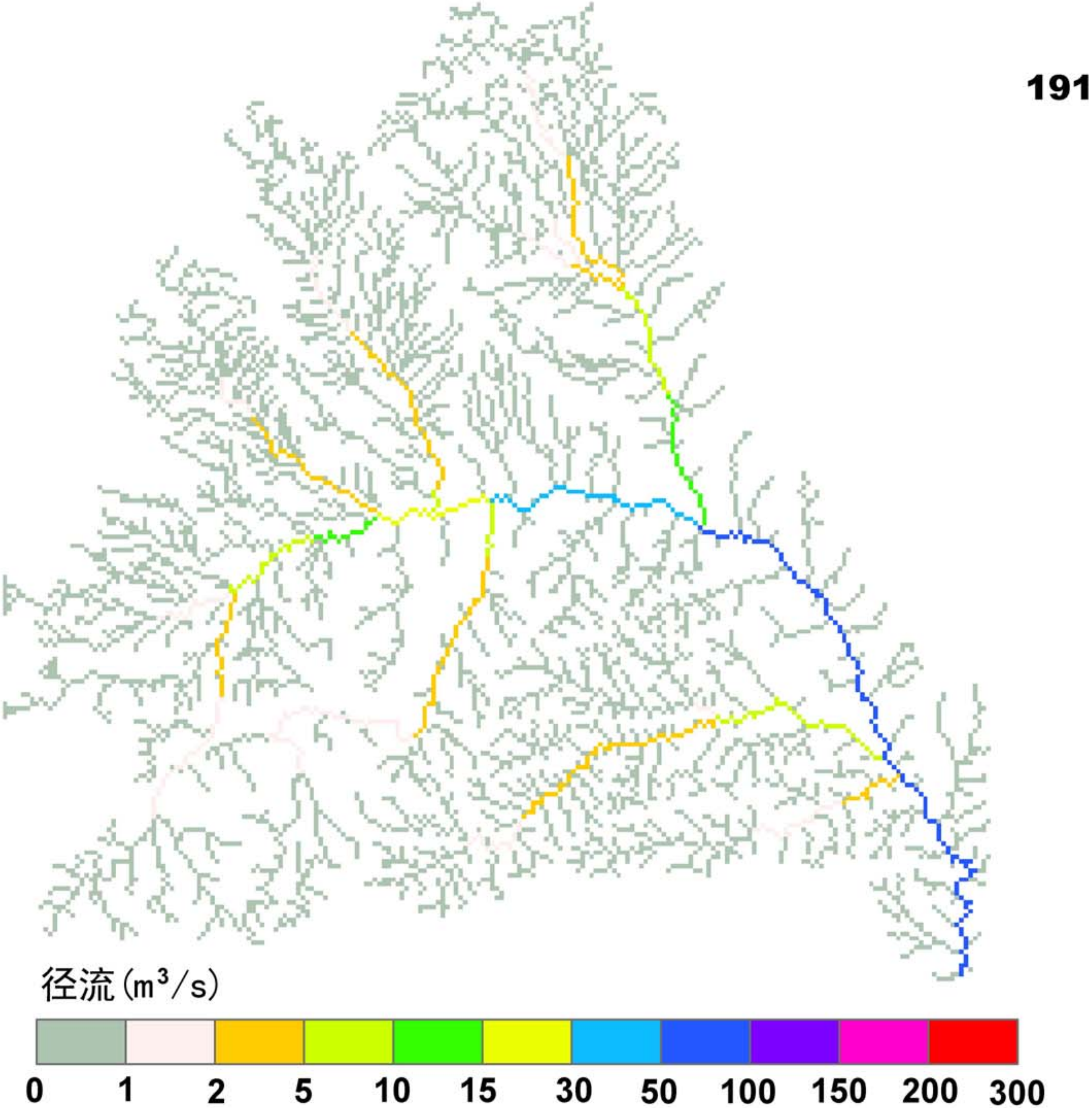
191
径流(m³/s)
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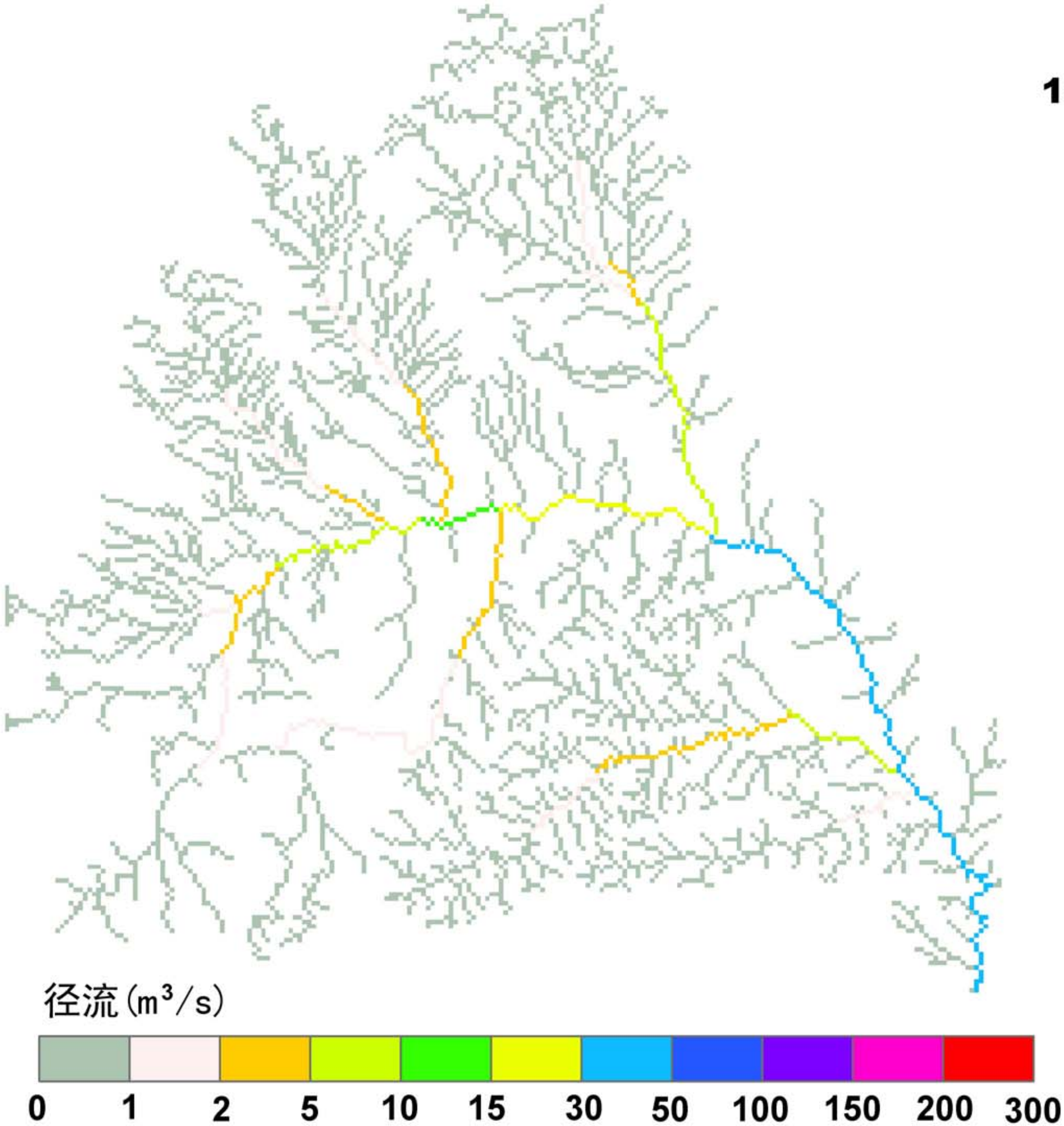
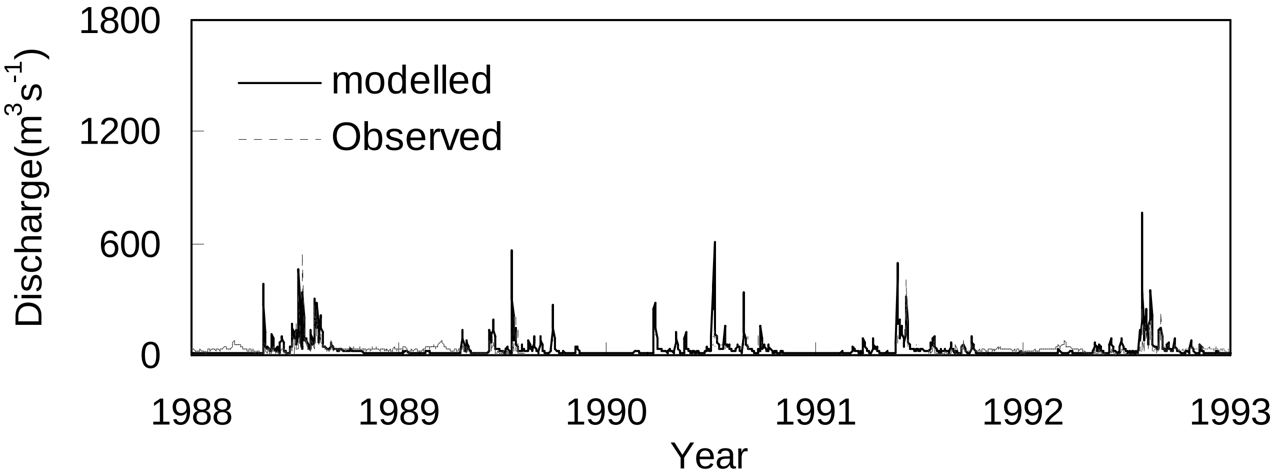
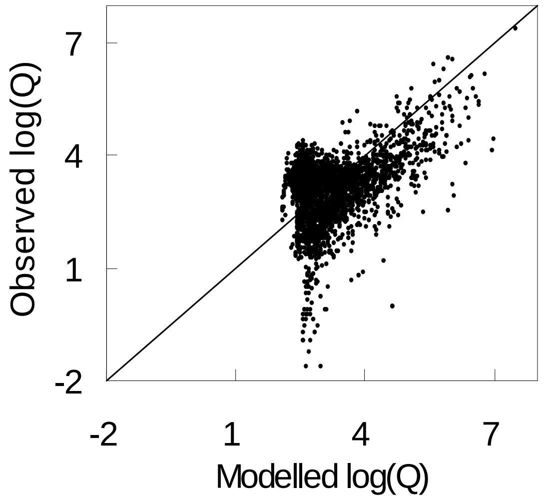
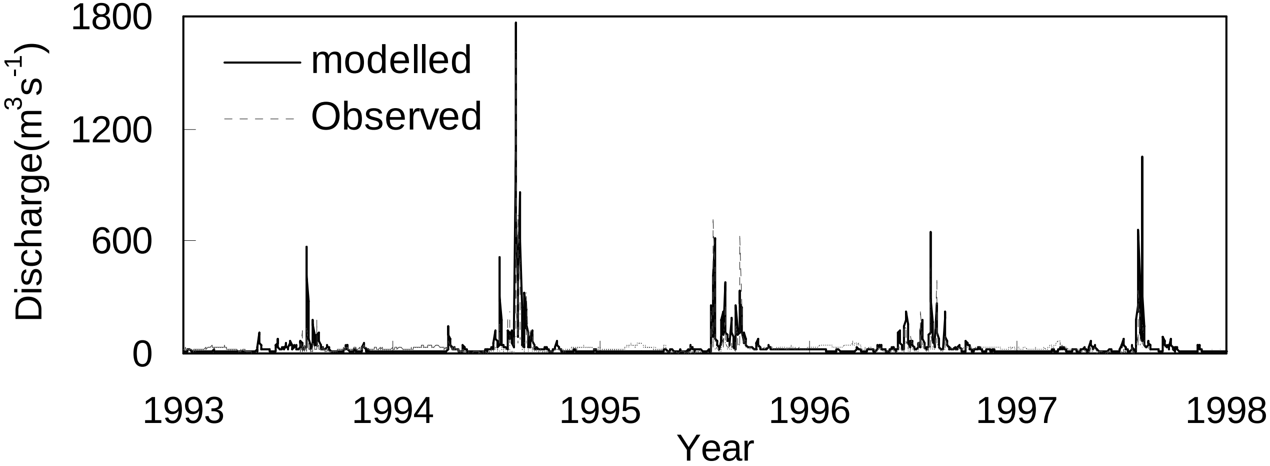
192



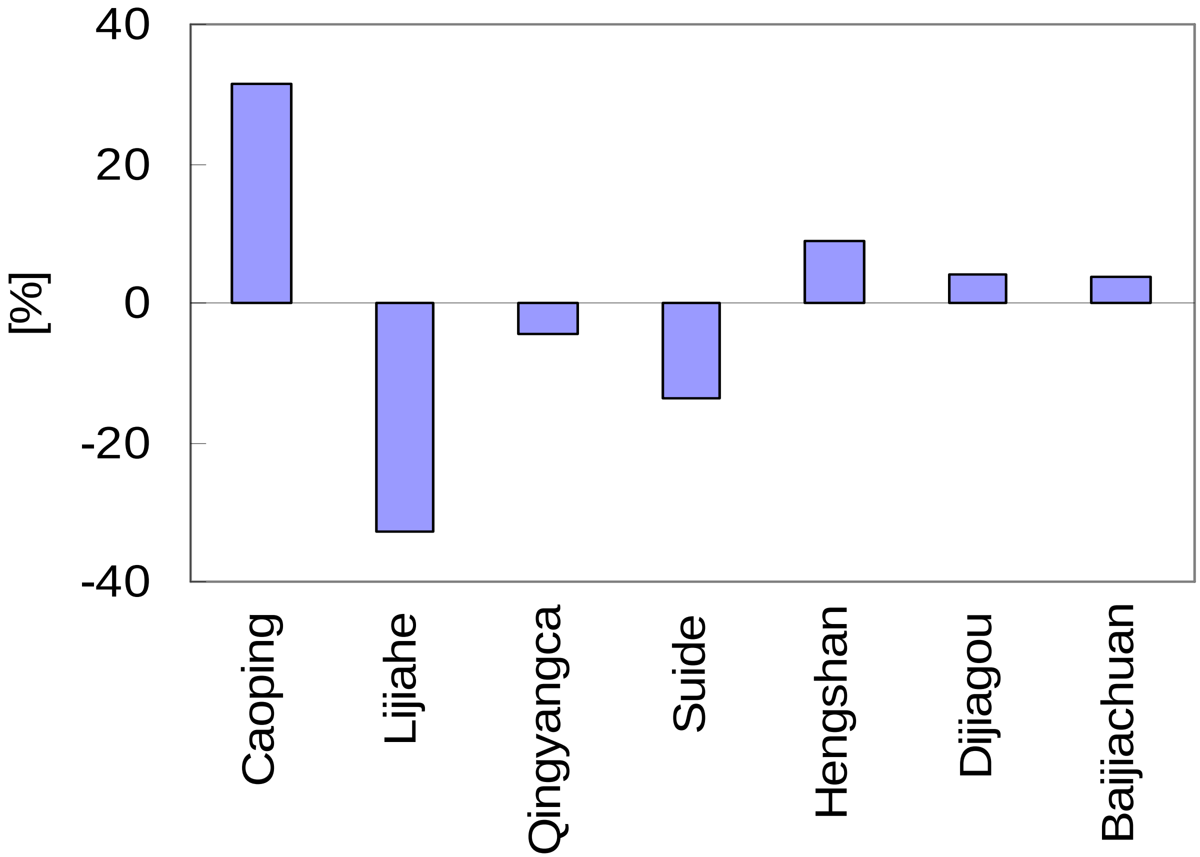
Model Validation





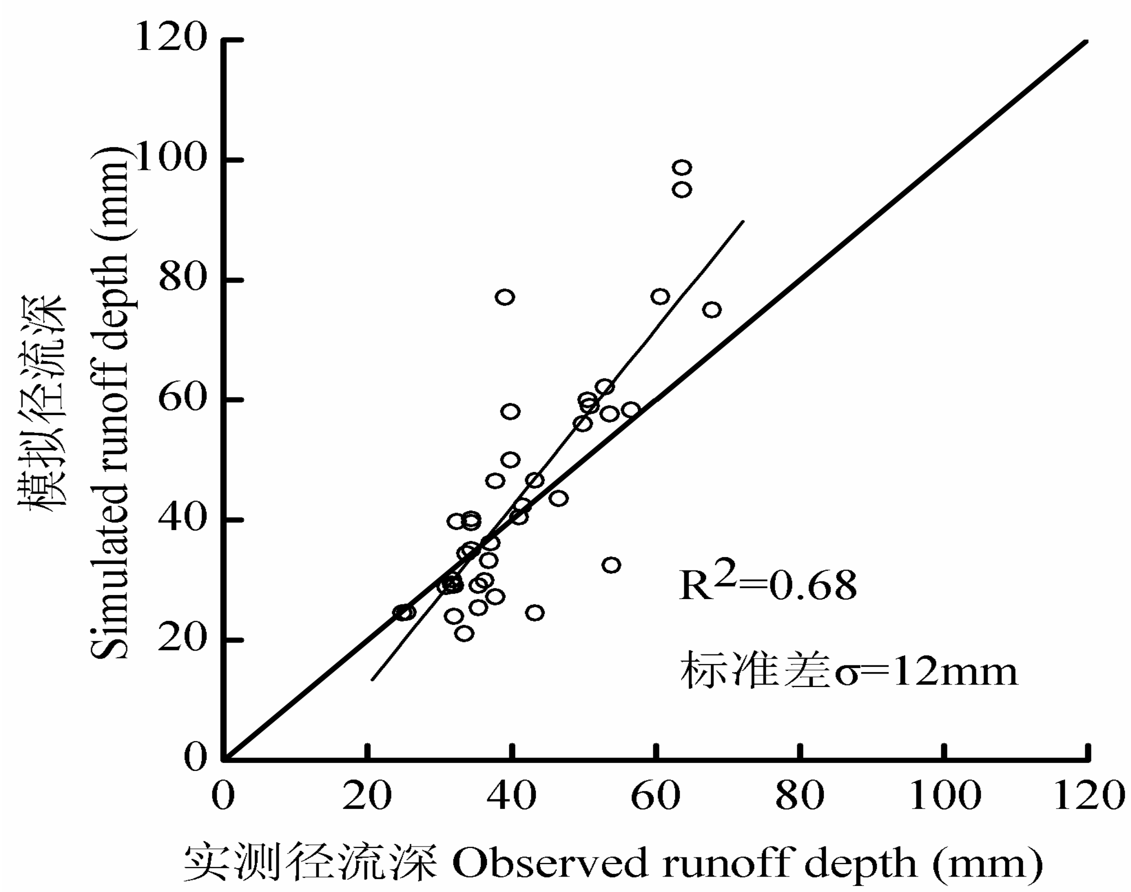


Model Validation



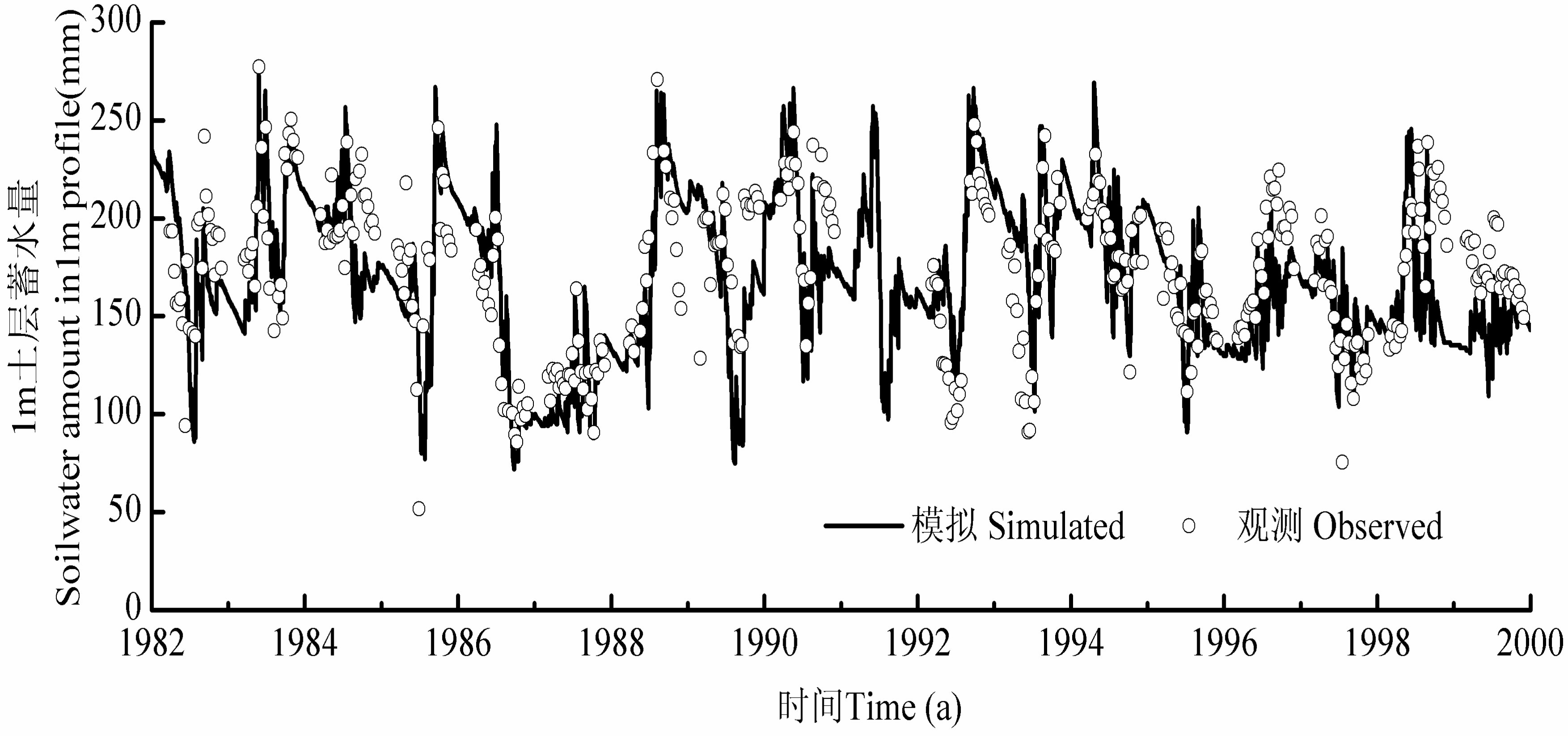
Y: (Q_Sim-Q_obs)/Q_obs

Model Validation

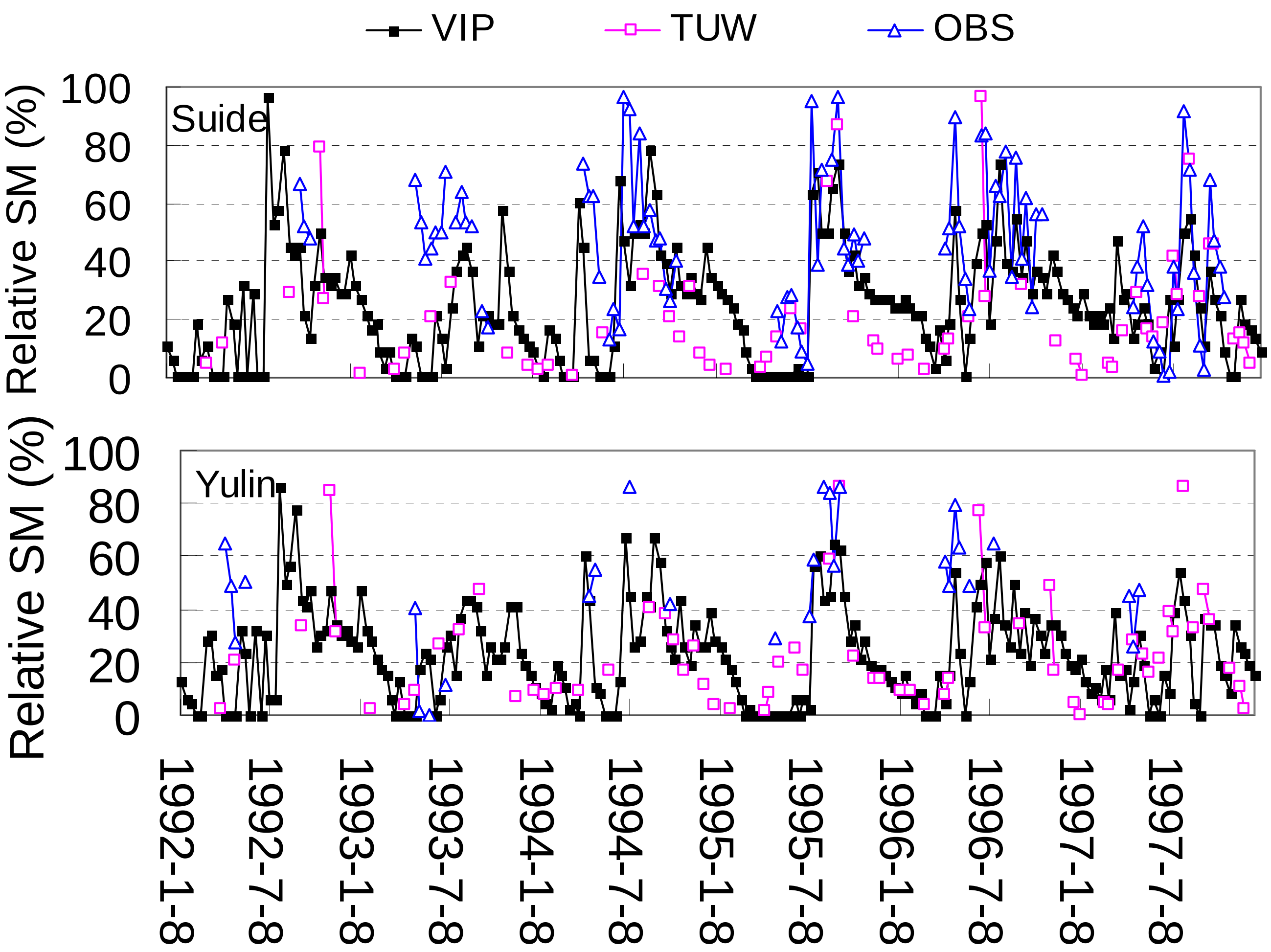


Annual scale

Model Validation



Model Validation



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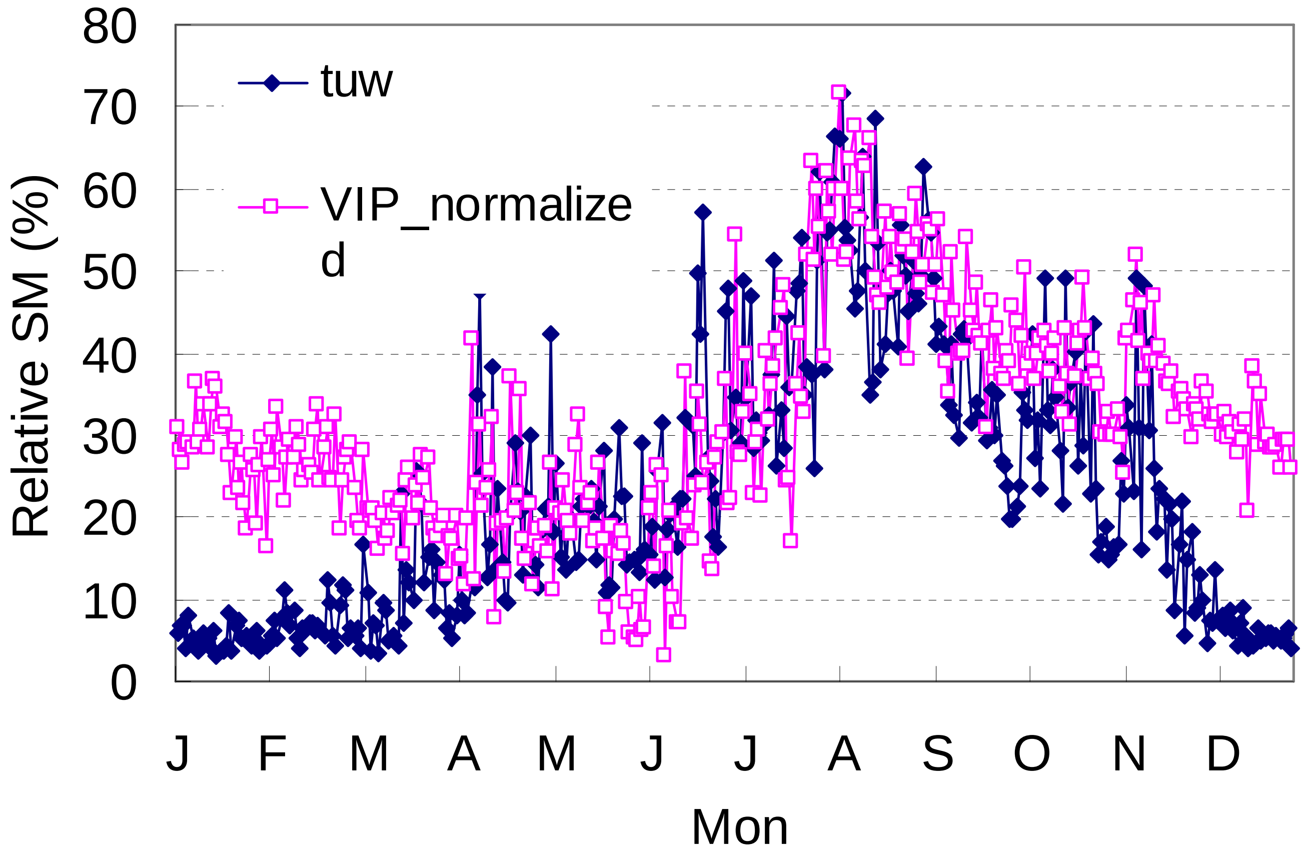
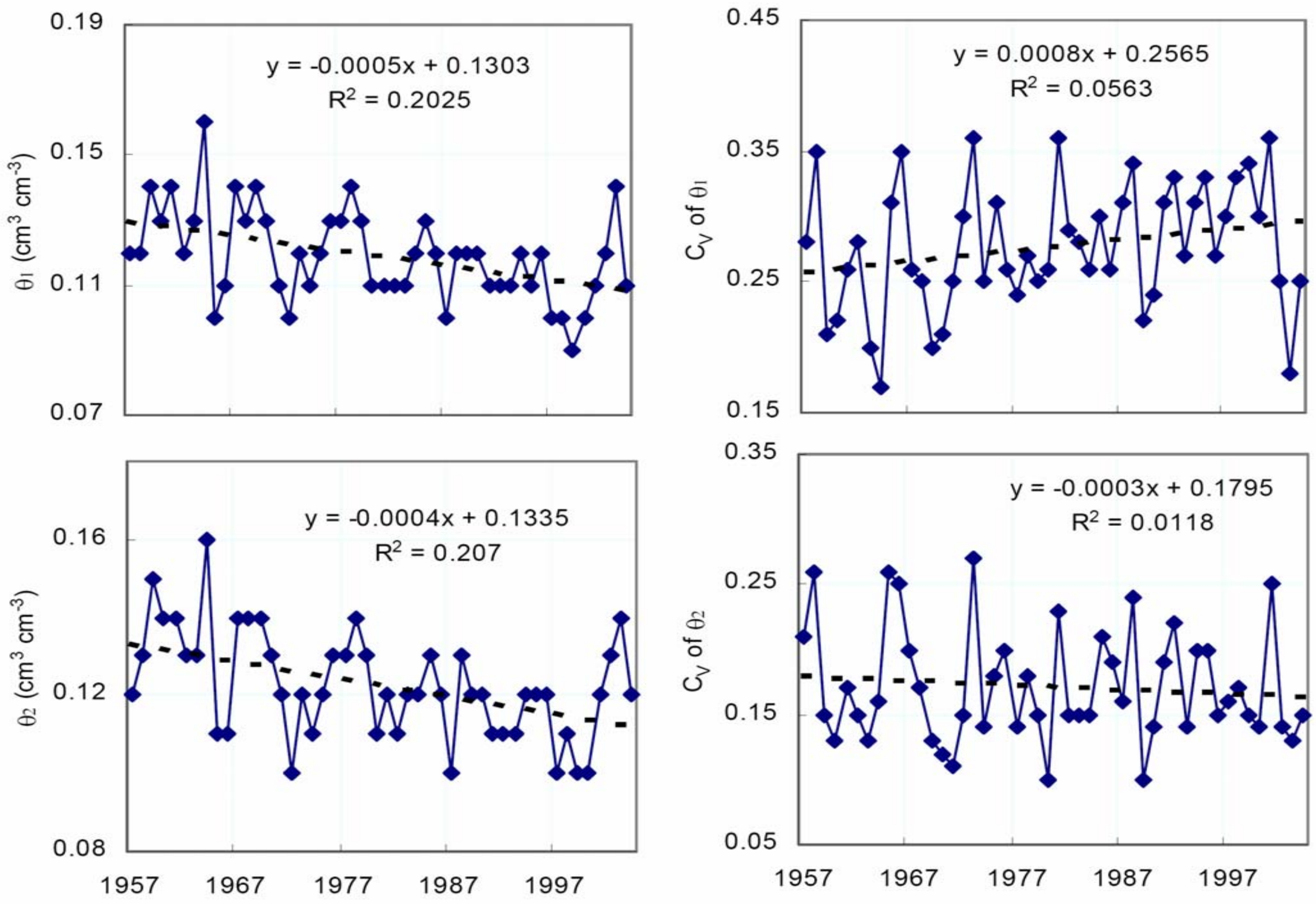


Model applications----generate long-term data series for future trend



North Drying,

Model applications----generate long-term data series for future trend

Var. (1)	Linear trend: Original time scale (2)	Linear trend: Standardized time scale (3)	Sig. (4)	Lag-1 cor: ρ_1 (5)	Lag-1 cor: Sig. (6)	The final estimate of trend: Z (7)	Sig (8)	μ (9)
P	−0.2886	−0.021	d	−0.15		−1.715	d	−0.020
R_n	−0.0972	−0.007		−0.06		−1.031		−0.011
E_T	−0.2378	−0.017		0.295	c	−1.027		−0.012
E_C	−0.0897	−0.006		0.124		−0.418		−0.006
E_S	−0.3462	−0.025	c	0.411	b	−2.219	c	−0.024
E_I	0.0072	0.0005		−0.41	b	0.367		0.003
GPP	0.4381	0.0313	b	0.074		3.102	b	0.034
NPP	0.0837	0.006		−0.23		0.649		0.009
Runoff	−0.4345	−0.031	b	0.076		−3.333	a	−0.019
θ_2	−0.3877	−0.028	c	0.204		−2.826	b	−0.031
T	0.546	0.039	a	0.423	b	3.081	b	0.037

[a] if trend/correlation at α=0.001 level of significance, for correlation coefficient,lower bound=-0.49, upper bound=0.45
[b] if trend/correlation at α=0.01 level of significance, for correlation coefficient,lower bound=-0.39, upper bound=0.35
[c] if trend/correlation at α=0.05 level of significance, for correlation coefficient,lower bound=-0.30, upper bound=0.26
[d] if trend/correlation at α=0.1 level of significance, for correlation coefficient,lower bound=-0.26, upper bound=0.22

SM decrease at 0.01;

Discharge decrease at 0.001;

P decrease at 0.1,

T increases at 0.01

Model applications----explore the response of hydrological elements to LUCC

表 2 以 1991 的土地利用和气候状况为参考值，不同土地利用/覆被情景下岔巴沟子流域的水文效应 （%）

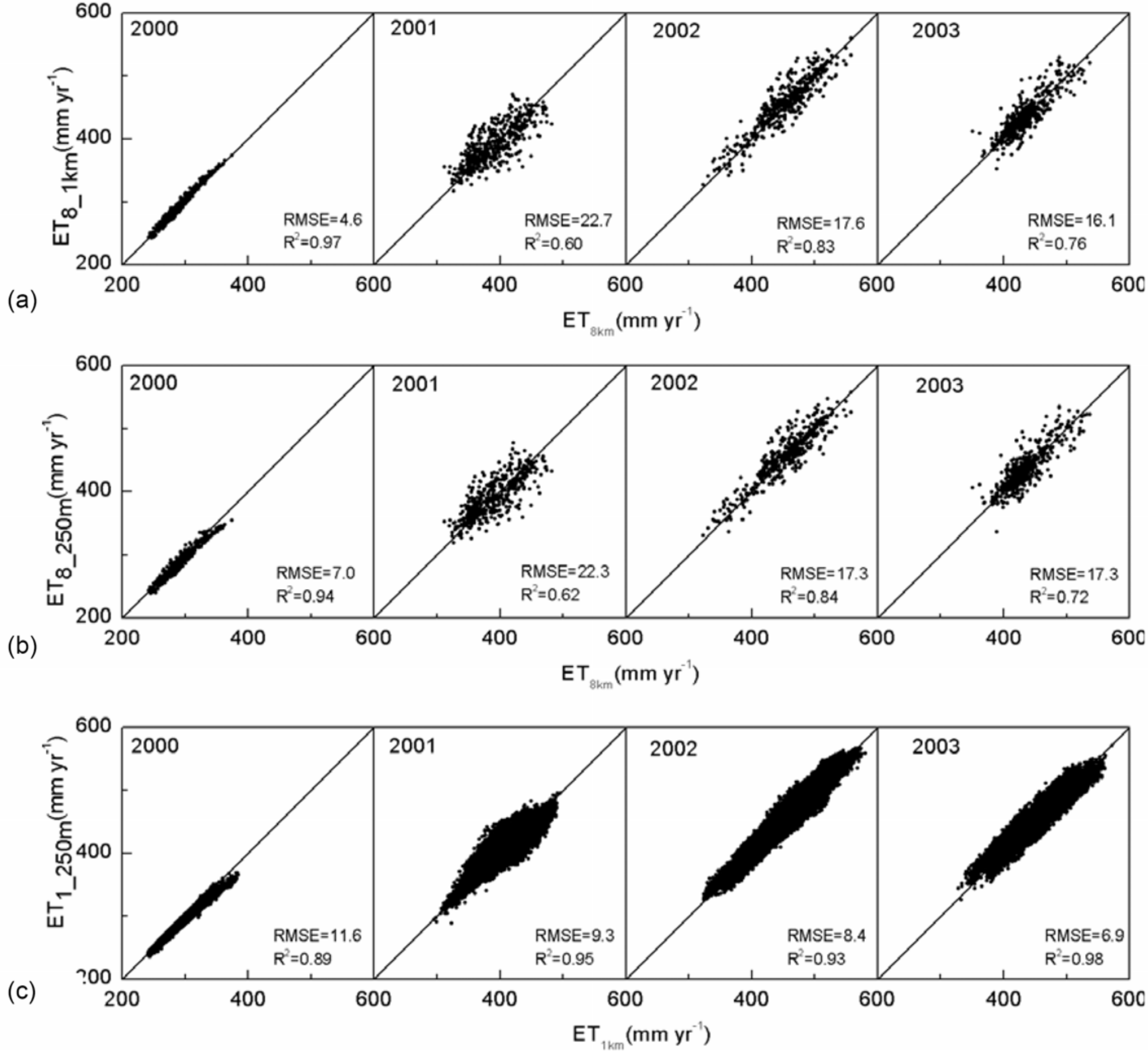
Tab. 2 The variation of net radiation and water balance components under different scenarios of land use (%)

	净辐射	蒸散	蒸腾	蒸发	冠层截留	地表径流
农田	0.0	-0.22	-23.7	24.7	-59.4	1.8
灌木	1.8	-0.02	23.2	-21.5	84.6	0.2
针叶林	5.4	-0.01	22.8	-21.1	84.6	0.1
落叶阔叶林	9.2	0.71	30.5	-29.7	247.4	-5.6
混交林	2.6	0.26	-15.7	18.1	-54.2	-2.1
草地	-0.3	0.20	14.9	-12.2	23.4	-1.6
荒漠	-1.1	-16.87	-100.0	64.2	-100.0	134.5

Model applications----explore the response of hydrological elements to climate change

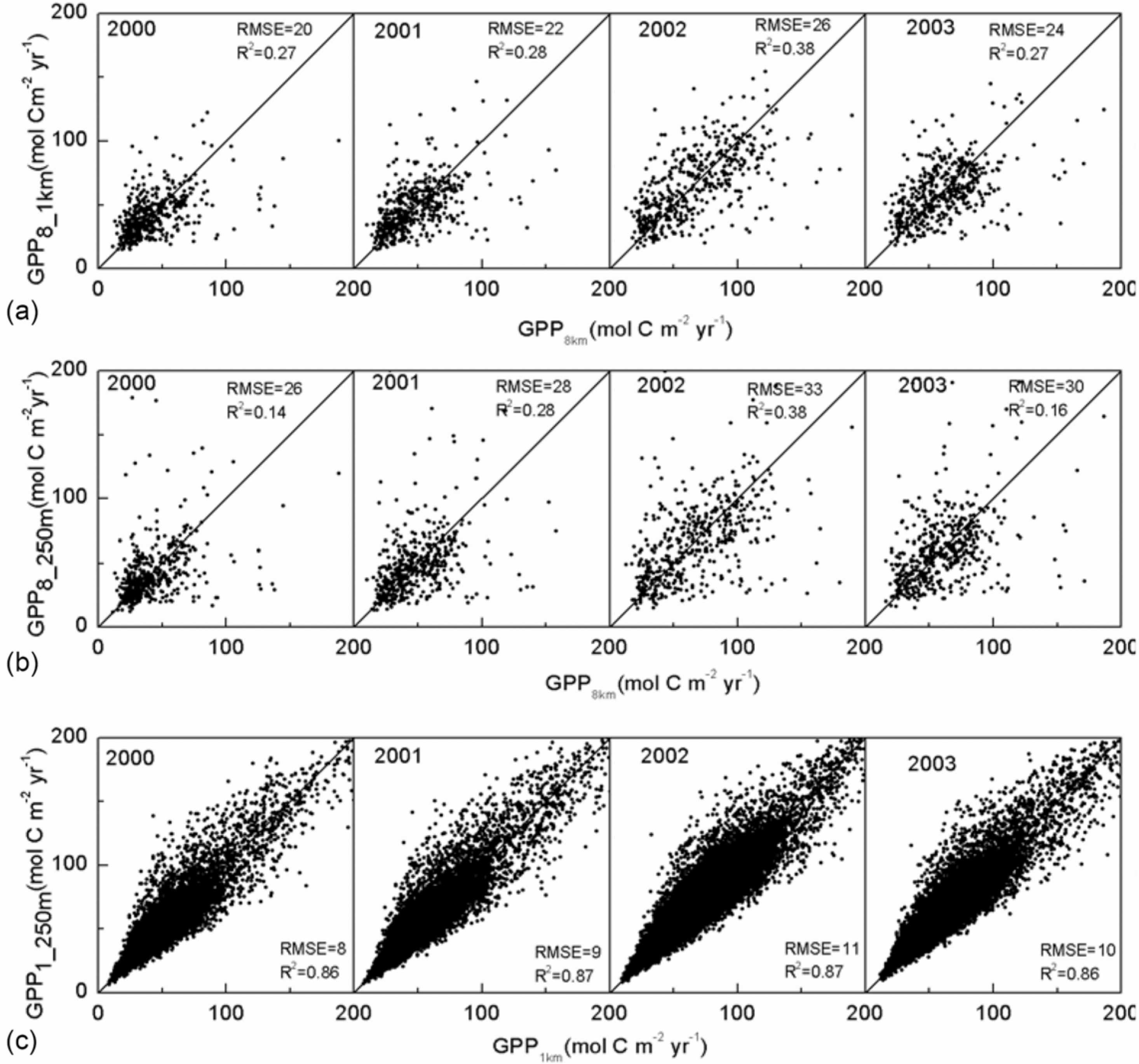
dT, dP	C	L	Q	H	S	D	B
+0.5k, +10%	0.19	0.15	0.13	0.16	0.15	0.18	0.19
+0.5k, -10%	-0.20	-0.15	-0.13	-0.16	-0.17	-0.17	-0.20

- Response exists spatial variability。
- Response to precipitation is proportional
- When p increases, the response will be larger with the temperature gain
- When p decreases, the response will be smaller with the temperature gain



1km Rule,

Mo X, Liu S, et al, HSJ, 2009



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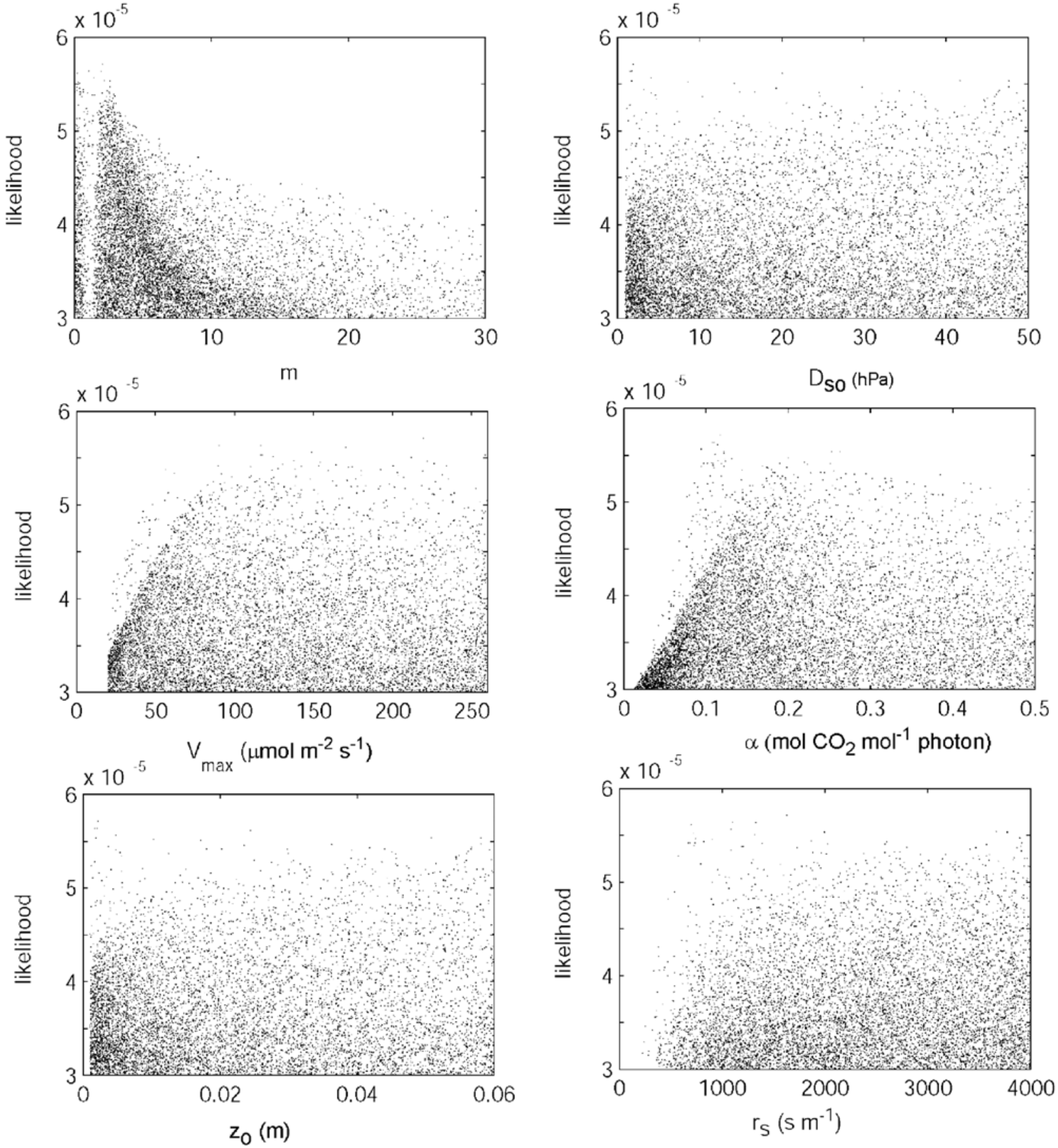


Uncertainty

Mo X, Liu S, et al, HSJ, 2006

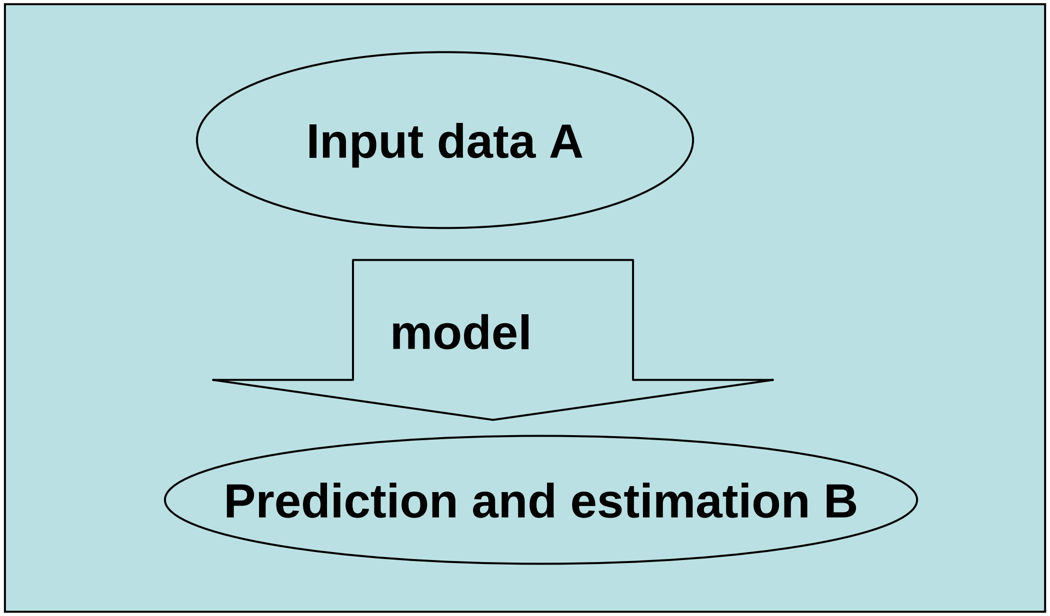
The VIP model, although in very detail, but no need for calibration,can catch the mechanisms of the response for ungauged basin, which is useful to provide scientific basis for decision makers for water-saving agriculture, making reasonalbe adaptation measures to climate change and land-use/cover change.

(explain why, tell how)

How？to maximize the predictive value of available data in ungauged basins

（2.1）Replace _from the same region

- By using **rational formula (model)**



$$Q_m = 0.278 SFP(1 - RS^{r-1}) t_Q^{-n'}$$

$$t_Q = P_1 x Q_m^{-y}$$

$$n' = \frac{rP_1(1-P_1)^{r-1}}{1-(1-P_1)^r}$$

$$P = \frac{f}{F} = 1 = (1 - \frac{t}{\tau})^r$$

$$P_1 = \frac{t}{\tau}$$

$$\tau = \frac{0.278 L_2^{0.5} F^{0.5}}{A_2 I_2^{0.33} Q_m^{0.5}} + \frac{0.278 L_1}{A_1 I_1^{0.35} Q_m^{0.3}}$$

$$x = k_1 + 0.95 k_2$$

$$y = 0.5 \left[1 - \log \frac{3.12(k_1/k_2) + 1}{1.246(k_1/k_2) + 1} \right]$$

$$k_2 = \frac{0.278 L_2^{0.5} F^{0.5}}{A_2 I_2^{0.33}}$$

$$k_1 = \frac{0.278 L_1}{A_1 I_1^{0.35}}$$

$$\tau = k_2 Q_m^{-0.5} + k_1 Q_m^{-0.3}$$

$$r = 2.1(k_1 + k_2)^{-0.06}$$

Liu and Wang，Water Resources Research，16（5），1980

WATER RESOURCES RESEARCH, VOL. 16, NO. 5, PAGES 881–886, OCTOBER 1980

The Estimation of Small-Watershed Peak Flows in China

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A small-watershed model based on the analysis of data measured from a number of small experimental watersheds and various physical geographic factors in our country is formulated for predicting the flood peak discharge resulting from storm rainfall. As the relevant factors and field measurements cover a wide range of conditions, this method is now being widely used for railway design works in the northwest and for hydraulic engineering design in certain other regions in China with fairly good results.

INTRODUCTION

China has a vast territory with innumerable streams. It is impossible to set up hydrometric stations to measure all their discharges. Nevertheless, a large number of new structures are to be built across these ungauged streams each year. To safeguard against flood damage, the evaluation of the flood peak discharge according to the physical geographic conditions of their watersheds becomes an important task to us.

So far as the formation of runoff is concerned, the process of stream runoff in watersheds may be regarded as the combination of two component parts, the processes of overland flow and channel flow. Obviously, these processes are relevant to a number of geographic factors and their distribution in space.

precipitation on the southeastern coast is about 1000 mm, while that in the northwestern interior is less than 100 mm. However, in contrast, storm rainfall intensity of short duration is much greater in the north than in the south. For example, the greatest intensity rainfall in 5 min is 53.1 mm, appeared in the western part of Taiuyan Shi of Shanix province, while that on the southeastern coast is only 35 mm (in Jin-Jiang Xian of Fujian province). These statistics present a brief sketch of the regional distribution of storm rainfall in China.

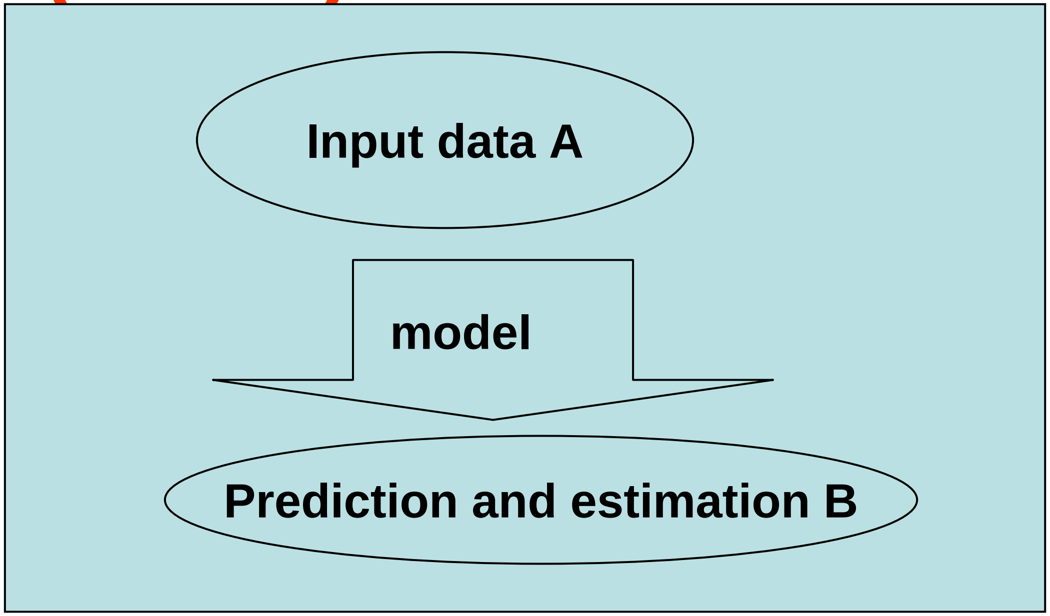
As to the influence of terrain conditions on runoff, vegetation cover in the northwestern region is very sparse, the capability of surface storage and regulation is small, the velocity of concentration or travel of overland flow is comparatively fas-

The above rational formulae have been successfully used in designing the culvert and bridge construction along the 8 important railways in western ungauged area of China.

How？ to maximize the predictive value of available data in ungauged basins

（2.1）Replace _from the same region

- Example by using **innovational ideas(model)**

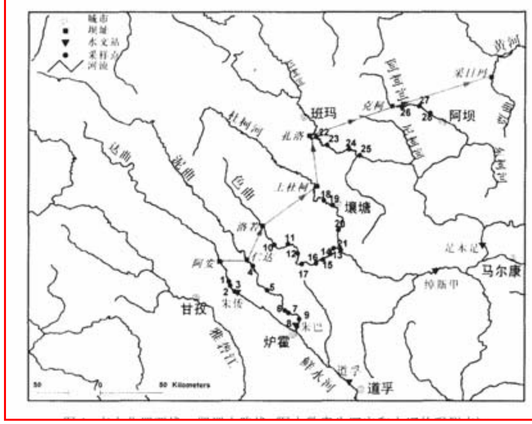


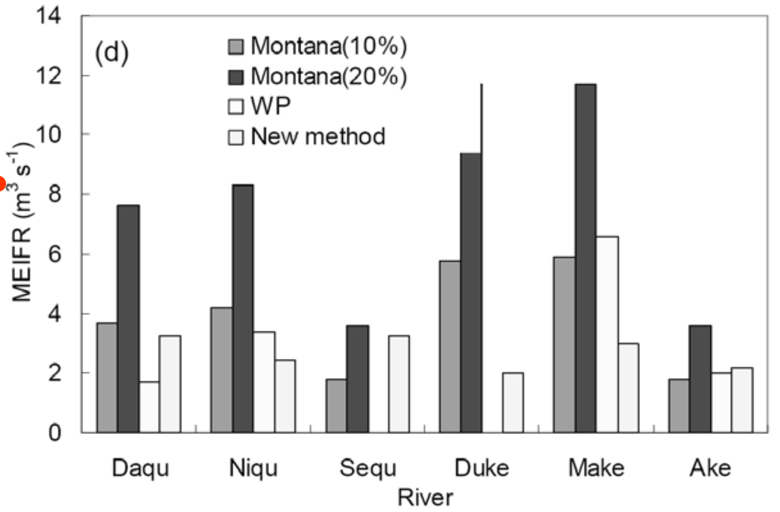
Eco-hydraulic Radius method, Liu et al. 2008, Progress in Natural Sciences

LIHAFLOVA method, Liu et al. 2008, NSDBYSLKJ,

Relation between Amphibians and flow regimes, Liu et al. GWSP newsletter, 2008,

Analytical Wetted Perimeter method, Liu et al.Journal of Geographical Sciences, 2006,





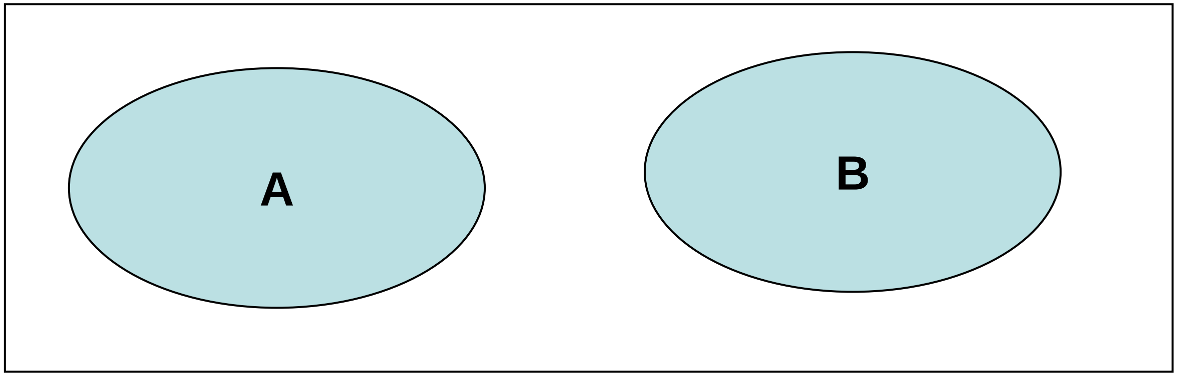
Environmental Flow

The above new methods were successfully used in western ungauged area of China for decisions-makers for planning the project to transfer water from South to North.

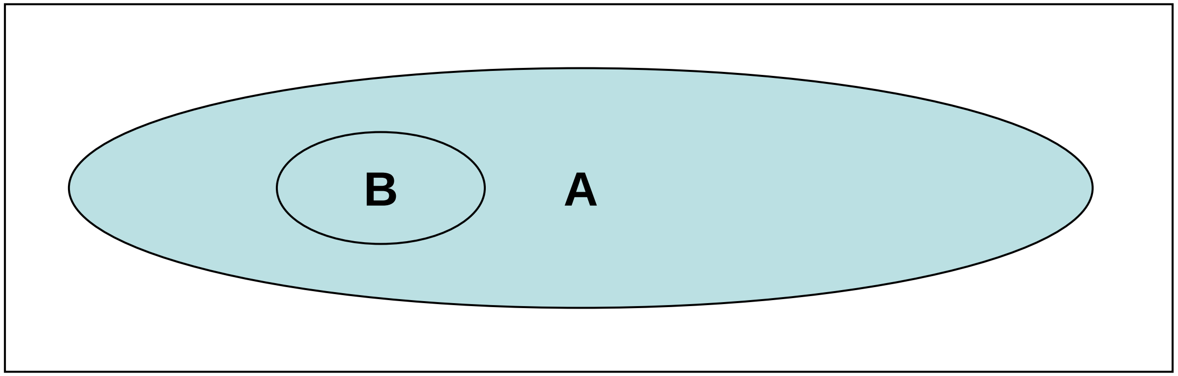
How？ to maximize the predictive value of available data in ungauged basins

（2.2）Replace_from the other region

- Comparative analysis



- or



Comparative Hydrology (CH)

$$R_x = \frac{R_0 P_x}{P_0}$$

- Brankov (1946)
- Chapman, T, G, Philosophy and analytical approaches, Section 1, Comparative Hydrology, draft 2, June 1986
- 1986 , IHP_III, CH workshop
- M. Falkenmark and T. Chapman, Editors, Comparative hydrology. An ecological approach to land and water resources, UNESCO, Paris (1989).
- Ming-Ko Woo, Changming Liu, Mountain hydrology of Canada and China: A case study in comparative hydrology Hydrological Processes,8(6)573-587,1994
- FRIEND-UNESCO, 1999-2000

Comparative Hydrology (CH)

- 。。。。。。。
- McDonnell, J.J. and R. Woods (2004) Editorial: On the need for catchment classification. Journal of Hydrology, 299 (1-2), 2-3….
- G. Blöschl, R. Merz, Thoughts on a process-based catchment classification，Geophysical Research Abstracts,Vol. 10, EGU2008-A-08153, 2008

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1987 年 6 月　　ACTA GEOGRAPHICA SINICA　　June, 1987

关于比较水文学的研究

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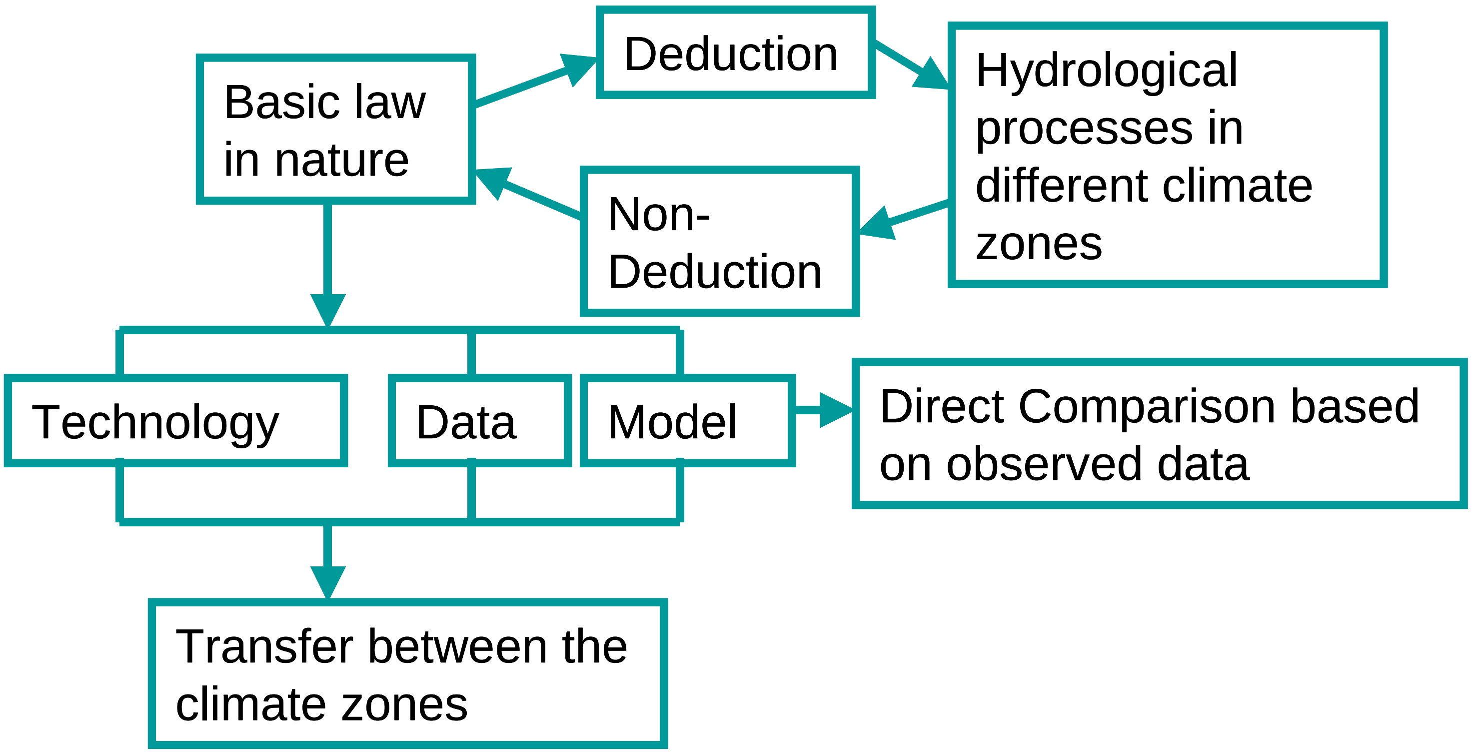
提　　要

比较水文学是水文研究中的新课题。作者根据国际水文计划（IHP）组织的研究活动介绍了这一课题最新动向；探讨了比较水文的概念，目的与研究方法；提出在我国开展这一研究的有利条件。认为及早起步开展工作，可望走在世界前列；最后建议从水文类型系统、水文过程、水文实验方面打好基础，建立比较水文信息系统，发展水文成因模型，制定应用方案。

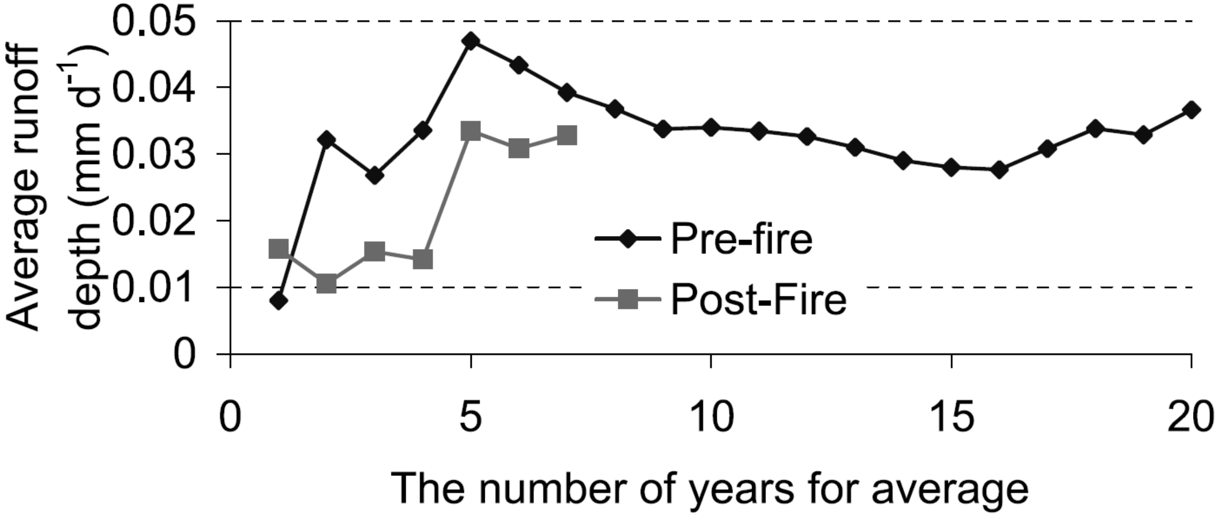
二、研 究 内 容

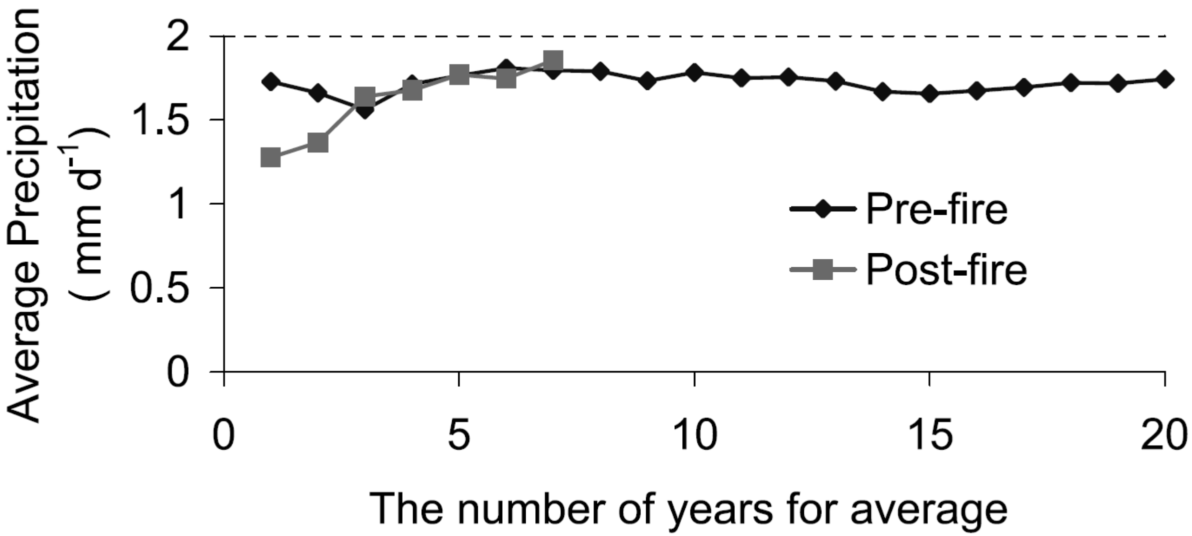
水文学中的比较研究的方法并不年轻，从文献上看，狭义的比较水文方法有较早的历史：人们利用相似流域或参证流域来估算无观测资料流域的正常径流已有半个世纪左右的时间，如维尔德（Вильде）的方法。布兰科夫[3] 1946 年发表的“水文分析与计算”，认为自然地理条件相似的河流，可假定它们的径流系数相近，由具有实测资料流域的正常径流（R_0）作为参证，估算无实测资料流域的正常径流（R_{-}）.

Significance in Comparative Hydrology is to provide a base for understanding the dissimilarity and similarity in runoff formation of gauged and ungauged basins that is needed for deduction of the hydrological processes.



paired-catchment analysis





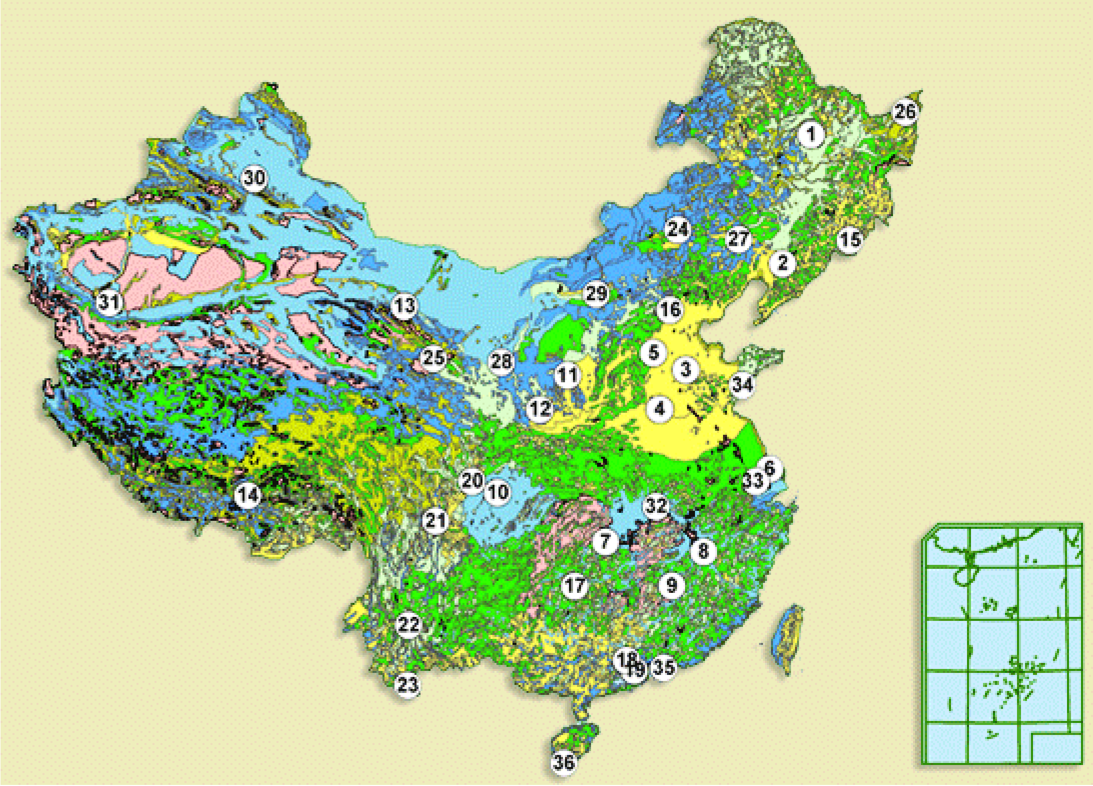
Liu et al. MAP, 2004

How？ to maximize the predictive value of available data in ungauged basins

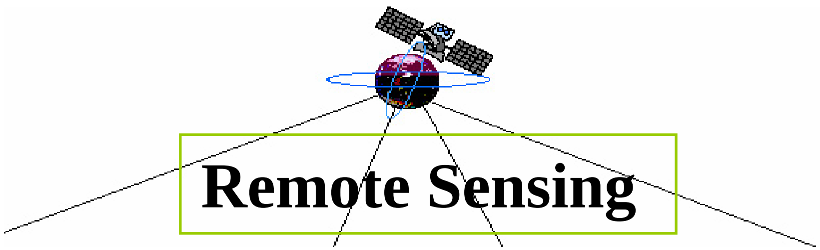
（3）Generate

- Field and laboratory experiments, remote sensing

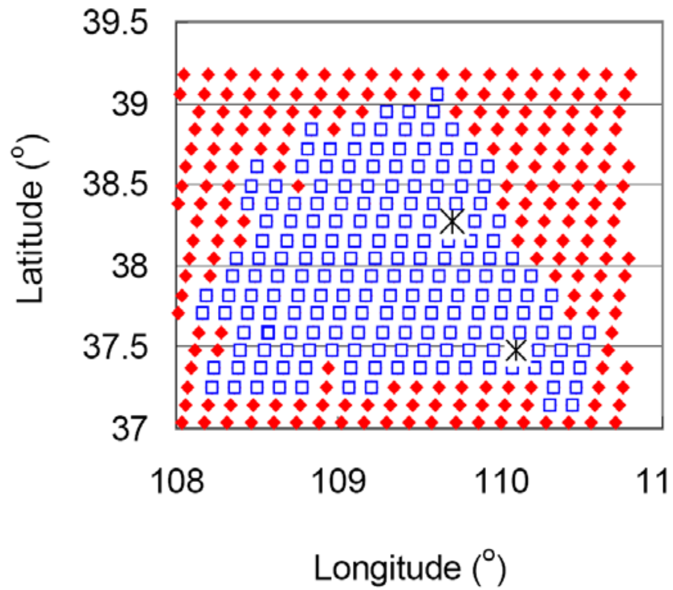
Field survey and artificial rainfall-runoff experiments

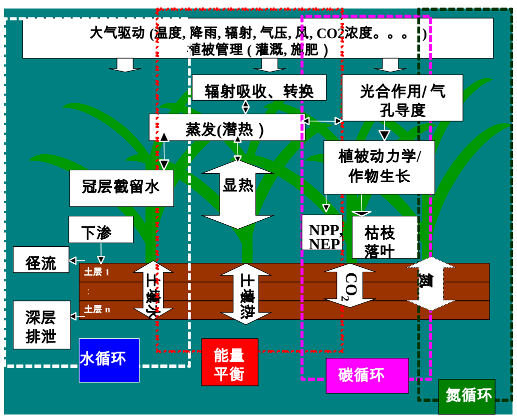


Field survey and artificial rainfall-runoff experiments over many different basins.



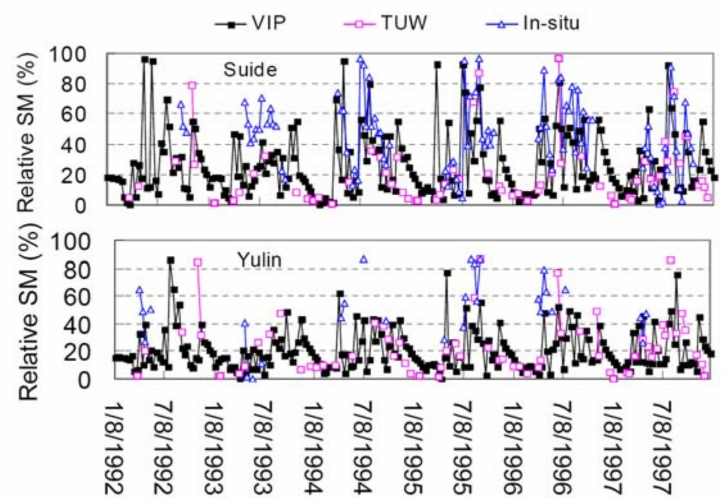
Remote Sensing





Data Assimilation

VIP model



Long-term soil moisture data

Liu et al. HESS, 2009

Some more to be done in the near future

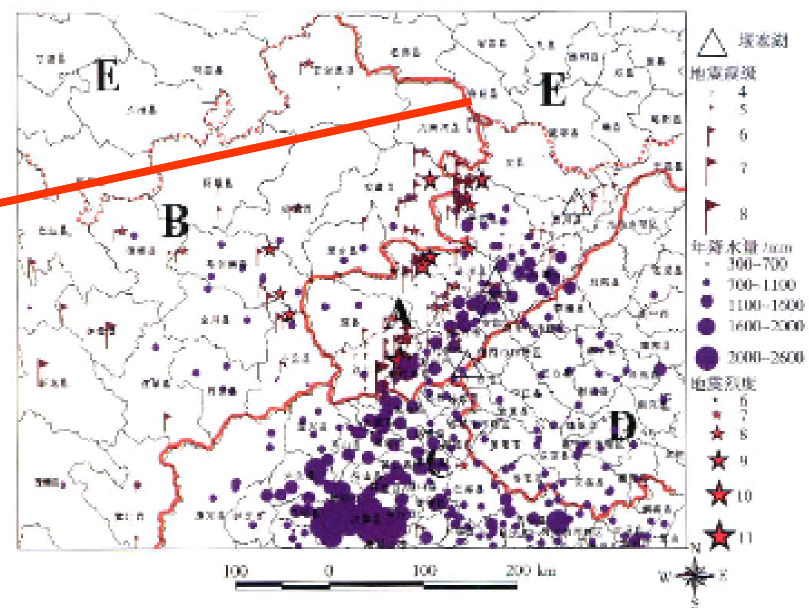
- **Strengthen PUB theoretical study:** now more in skill; theory in regional hydrology, comparative hydrology, PUB theoretical framework， in-situ experiments and general models, are highly wanted.

Some more to be done in the near future

- **Aim for innovative methods: Now all the methods are still in the general framework of the methodology**

Some more to be done in the near future

- **Find more applications of PUB. Now more in theoretical study, few on the practical problem solving**



Thank you!

Welcome your comments.....

How to maximize the predictive value of available data in ungauged basins ?

By

Suxia Liu, Changming Liu and Weimin Zhao