From Nonpoint Source Pollution to Climate Change: Case Studies for the SWAT Applications in China

Zongxue Xu

College of Water Sciences

Beijing Normal University

OUTLINE

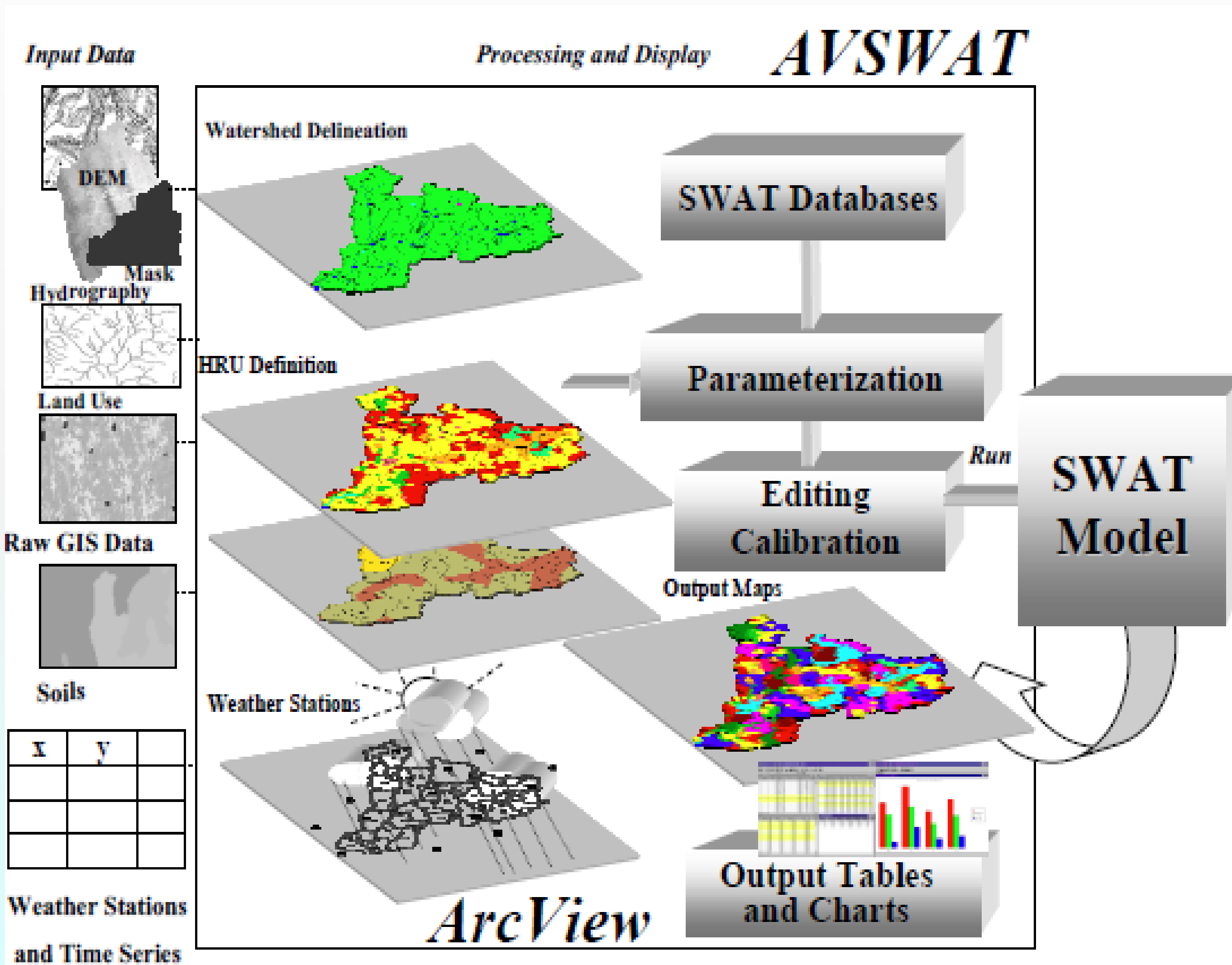
1. Introduction
2. Nonpoint source simulation
3. Climate change assessment
4. Discussion and conclusions

SWAT Model

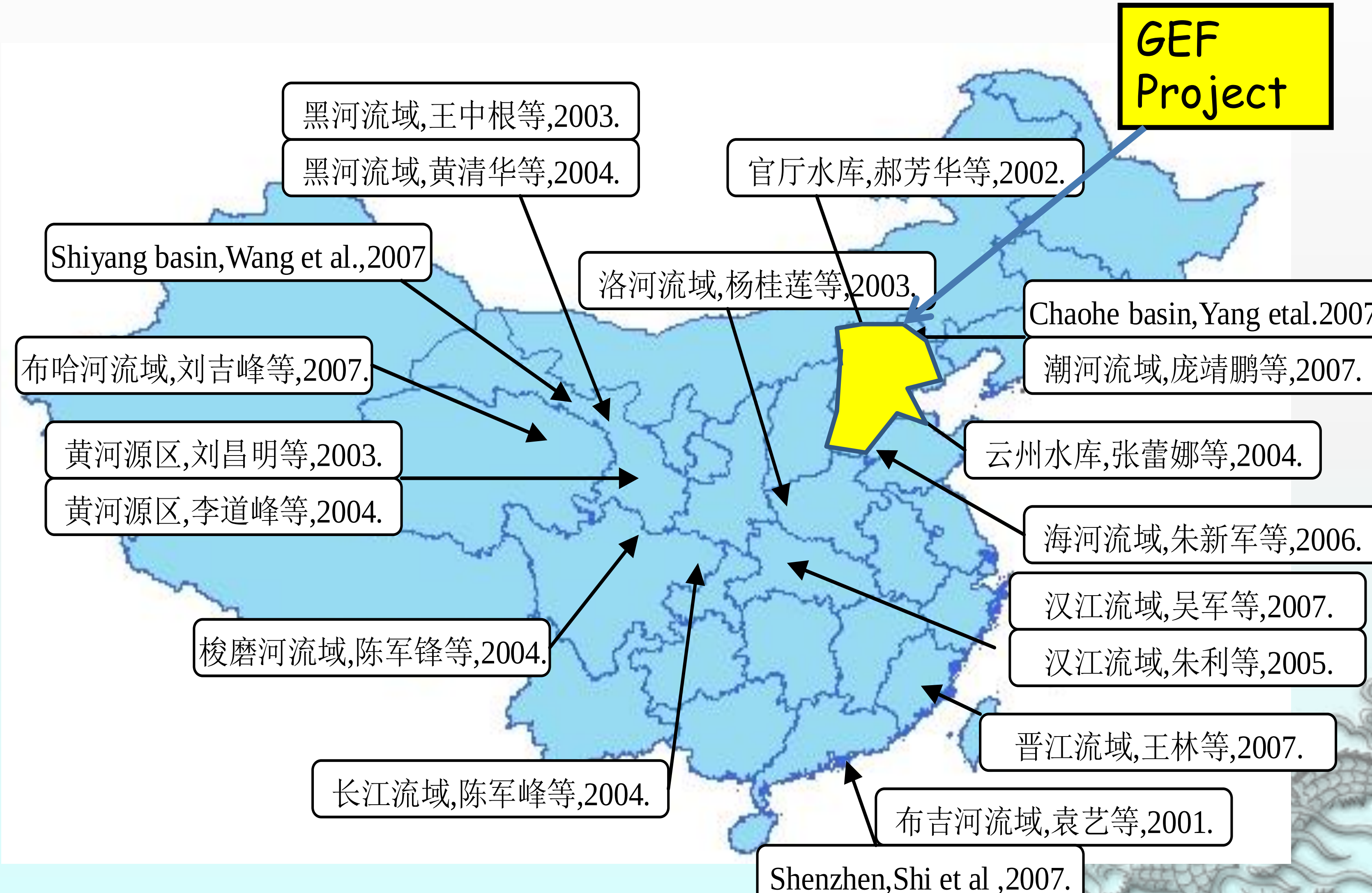
More then 12 years experiences

More than 10 research projects

More than 10 students working on SWAT



SWAT Applications in China

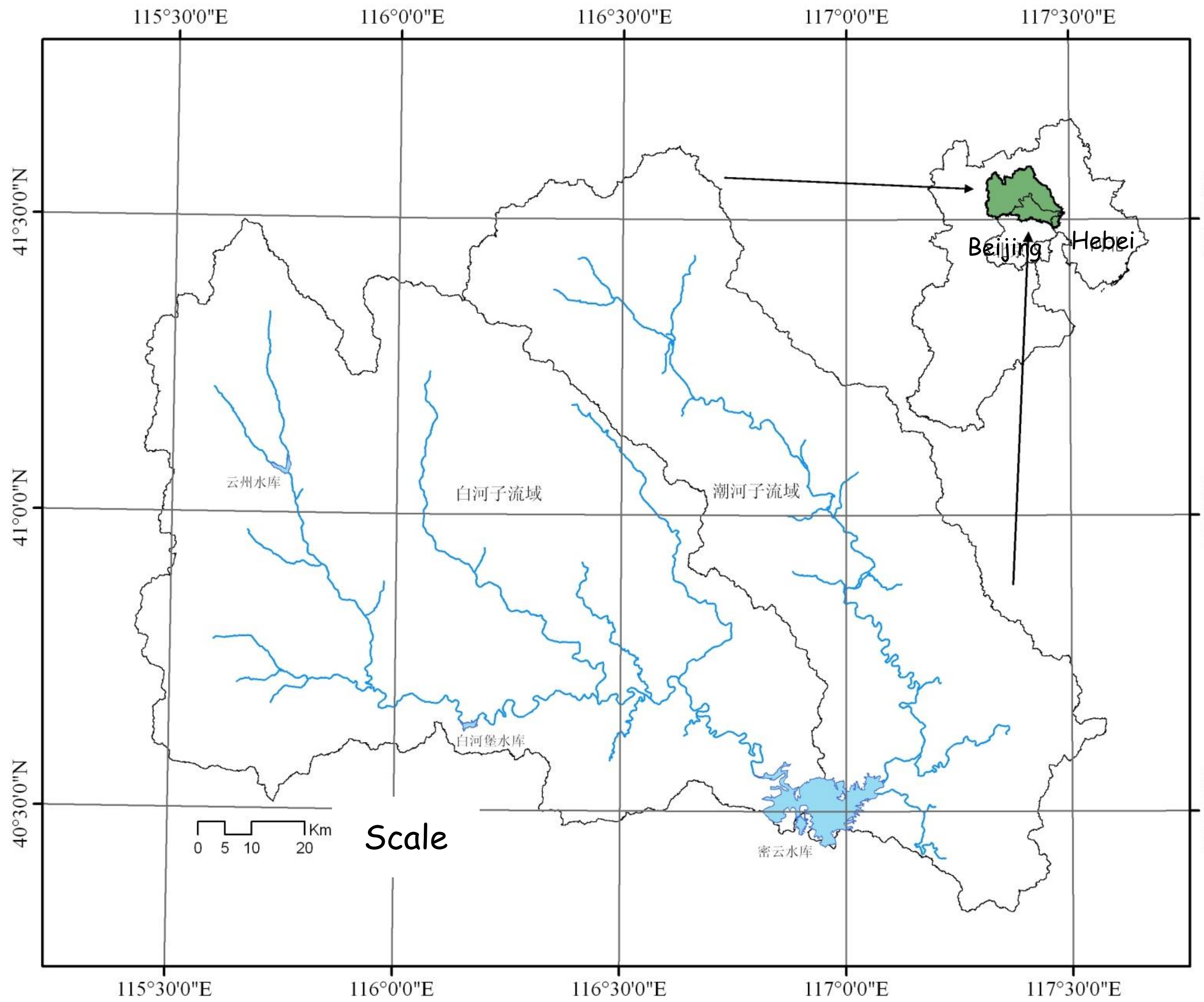


Case Study I:

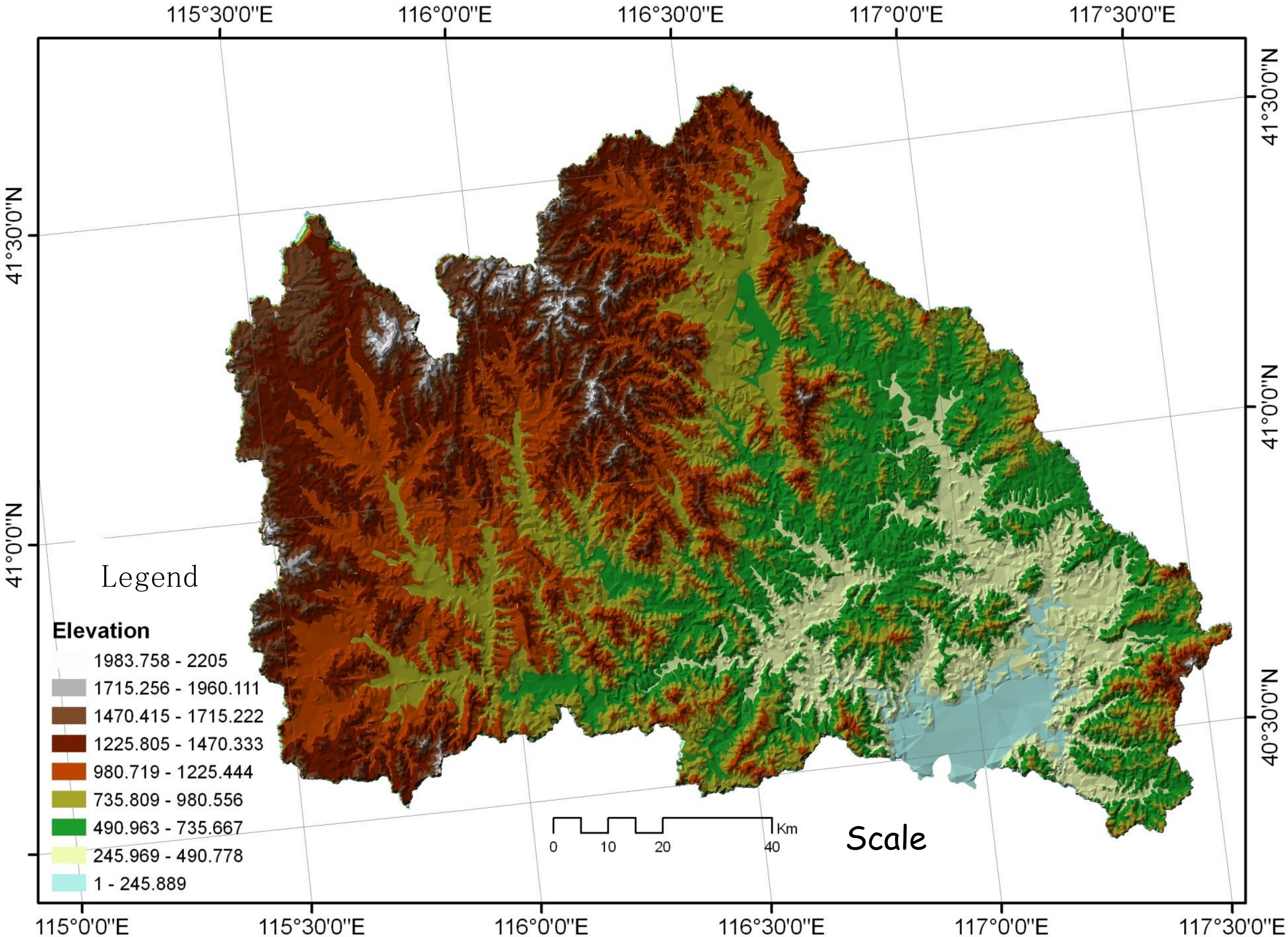
Nonpoint Sources Pollution Simulation

Objectives

- **Assessment of Nonpoint Source Pollution (NSP)**
- **Identification of critical NSP areas**
- **Pollutant control and scenario analysis**

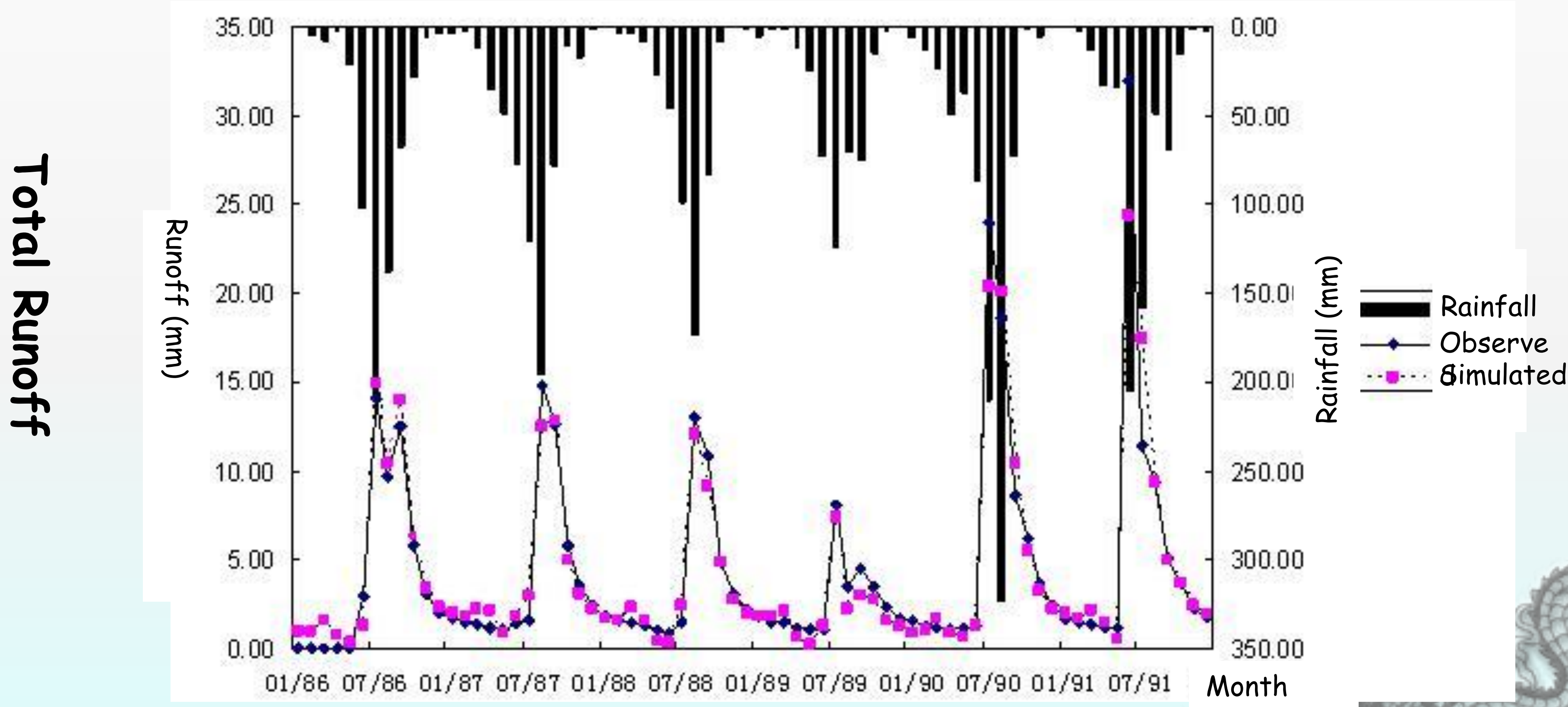


Location of the Miyun Reservoir catchment



DEM of the Miyun Reservoir catchment

Calibration and Validation



Observed and simulated monthly runoff for Xiahui station at the Chao River watershed

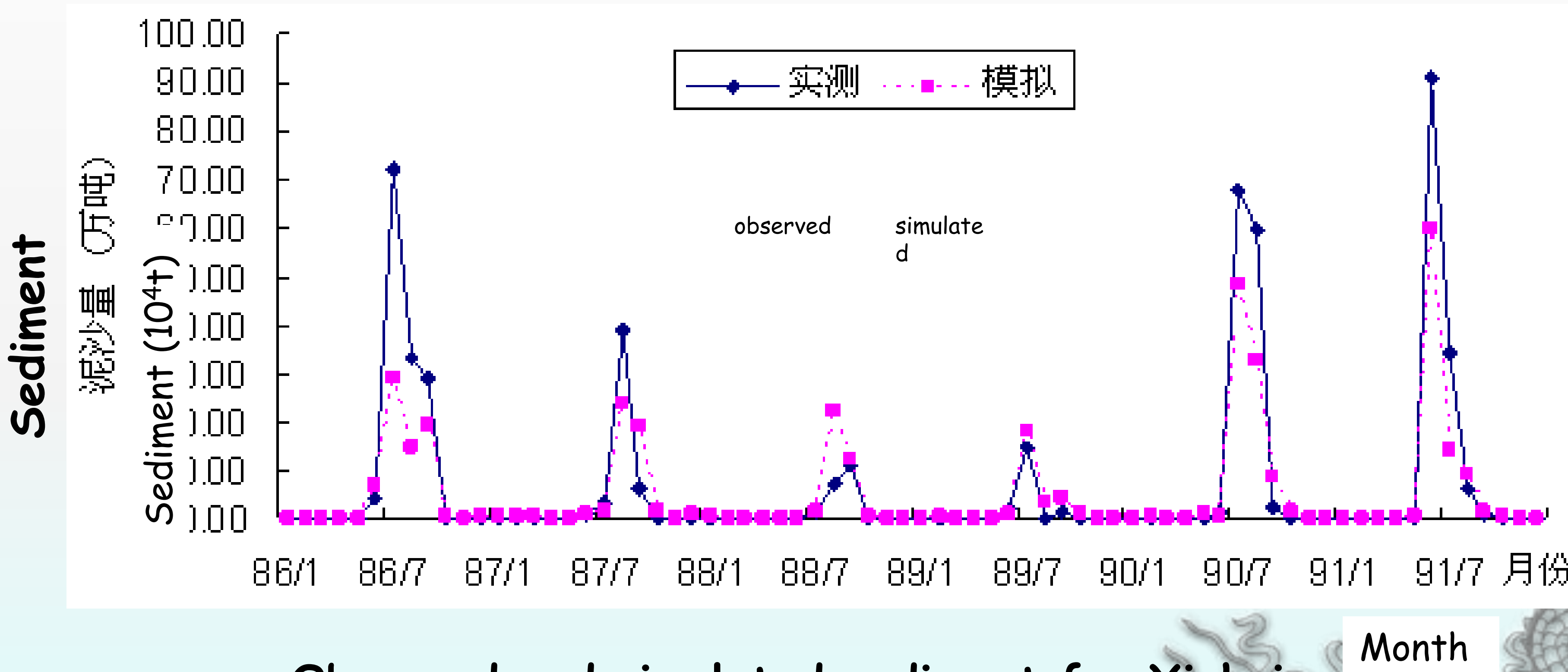
Calibration and Validation

Total Runoff

Results

Data	Xiahui						Zhangjiafen					
	E_{NS}		r^2		b		E_{NS}		r^2		b	
1987-1988	Month	Day	Month	Day	Month	Day	Month	Day	Month	Day	Month	Day
Calibration	0.95	0.62	0.97	0.76	0.87	0.70	0.92	0.90	0.92	0.90	1.01	1.07
1989-1991	Month	Day	Month	Day	Month	Day	Month	Day	Month	Day	Month	Day
Validation	0.91	0.67	0.93	0.76	0.88	0.74	0.87	0.60	0.90	0.61	1.21	1.10

Calibration and Validation



Observed and simulated sediment for Xiahui station at the Chao River watershed

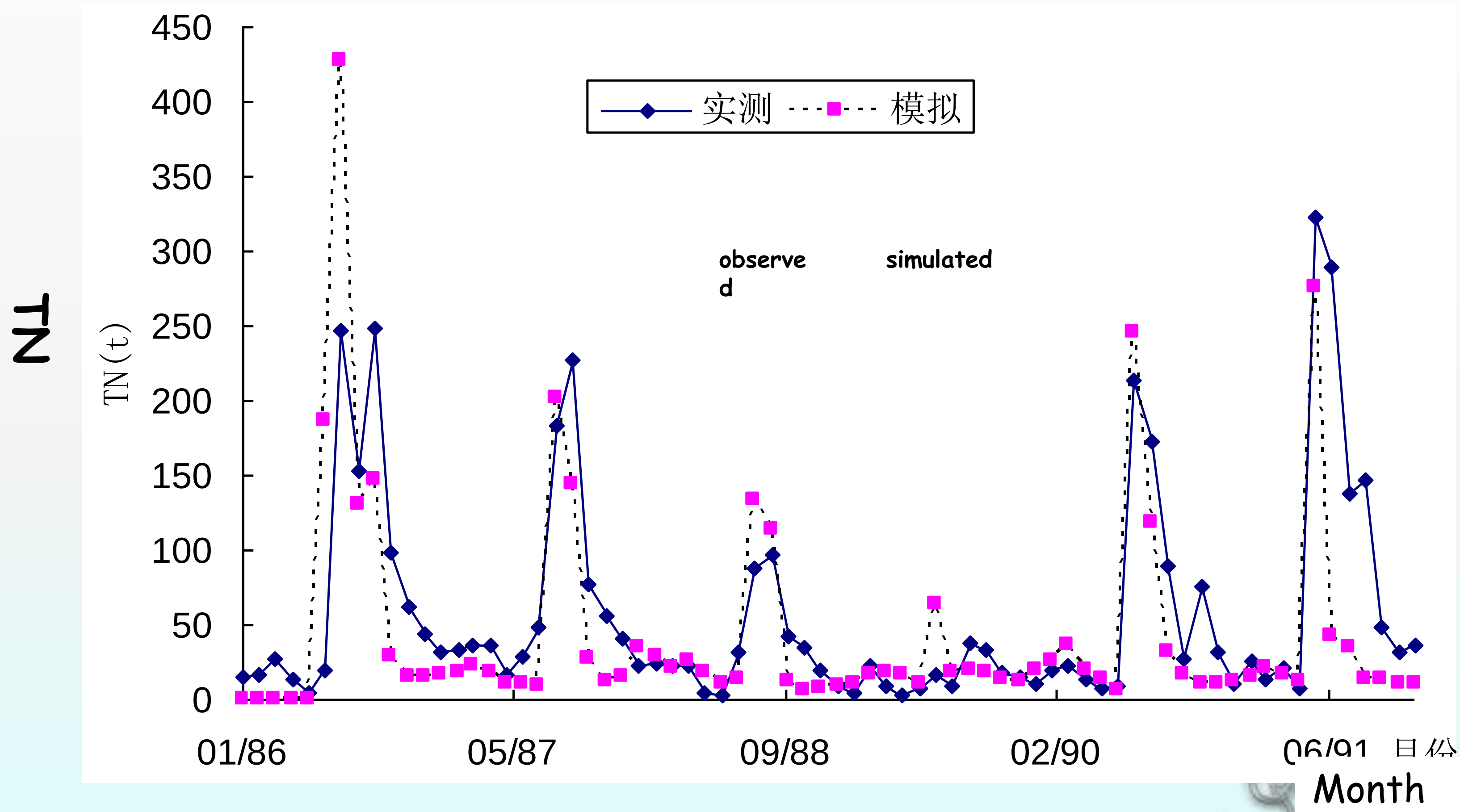
Calibration and Validation

Sediment

Results

Data		Xiahui station			Zhangjiafen station		
		E_{NS}	r^2	b	E_{NS}	r^2	b
Calibration	1987-1988	0.58	0.61	0.86	0.48	0.61	0.70
Validation	1989-1991	0.84	0.96	1.52	0.97	0.98	1.12

Calibration and Validation



Observed and simulated monthly TN for Xiahui station at the Chao River watershed

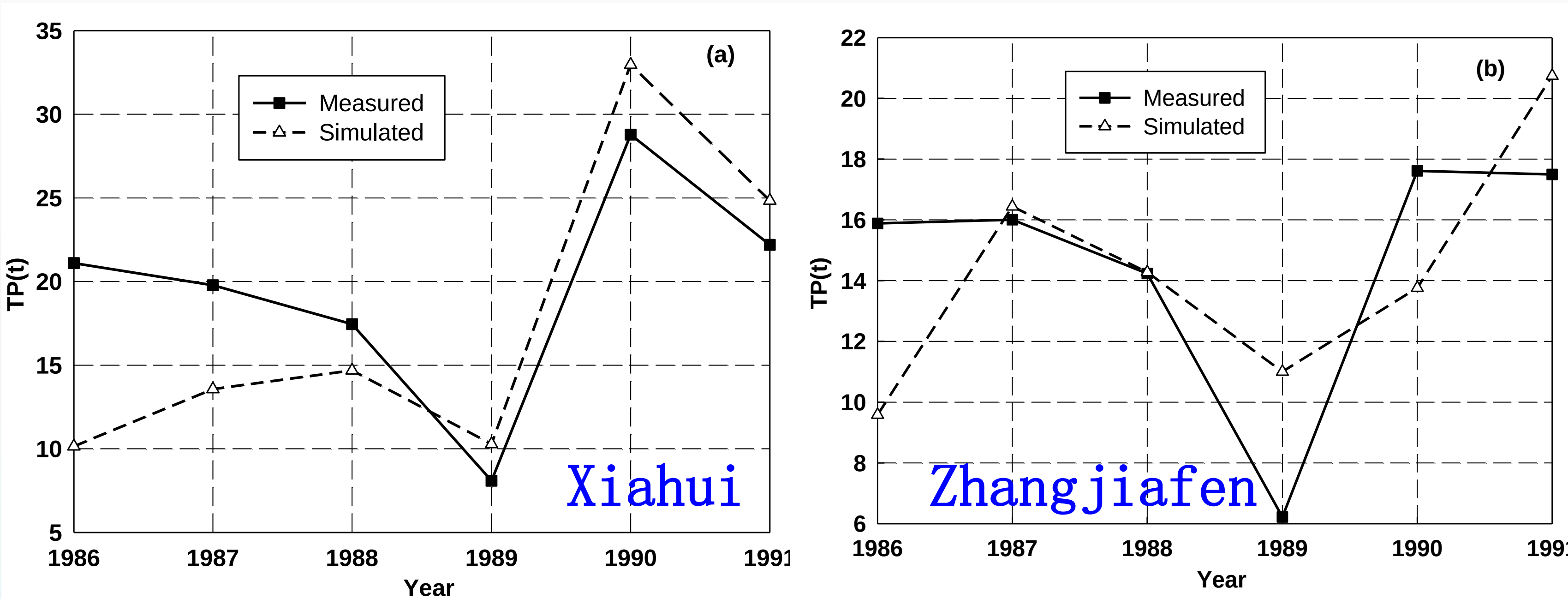
Calibration and Validation

Results

Data		Xiahui station			Zhangjiafen station		
		E_{NS}	r^2	b	E_{NS}	r^2	b
Calibration	1987-1988	0.84	0.88	1.18	0.54	0.76	1.72
Validation	1989-1991	0.94	0.98	1.22	0.79	0.93	1.57

Calibration and Validation

TP



Observed and simulated yearly TP

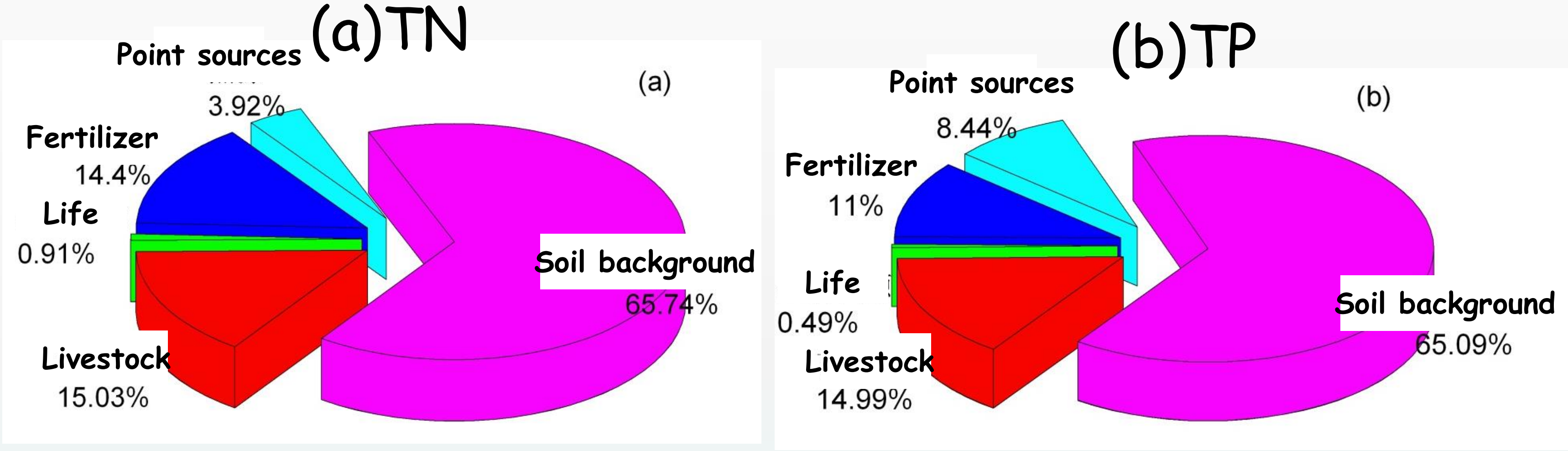
Nonpoint Source Pollution Simulation

The nonpoint source pollution load flowing into the reservoir from Chao and Bai river watersheds

Year	Chaohe basin				Baihe basin			
	Preci. (mm)	Sedi. (10^4t)	TN (t)	TP (t)	Preci. (mm)	Sedi. (10^4t)	TN (t)	TP (t)
1986	620.53	24.58	898.13	10.45	533.17	25.35	570.63	9.04
1987	666.40	27.90	665.21	18.52	571.52	22.11	448.45	18.73
1988	483.43	23.97	667.80	19.86	427.22	16.64	362.63	15.99
1989	447.42	17.38	392.65	14.82	378.93	5.60	381.00	13.69
1990	696.23	34.45	783.80	42.67	550.99	20.90	494.54	15.76
1991	608.60	40.13	652.71	29.50	538.85	34.30	535.81	22.93
Average	587.10	28.07	676.70	22.63	500.12	20.82	465.48	16.02

Relative Coefficient: 0. 68、0. 69、0. 51 0. 79、0. 88、0. 57

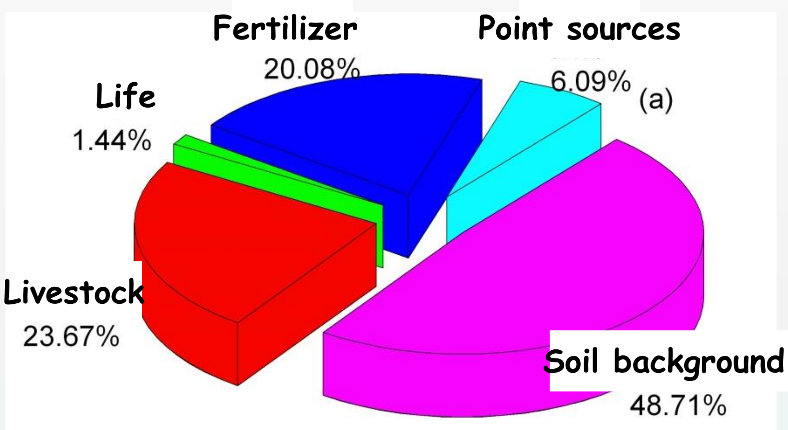
Nonpoint Source Pollution Simulation



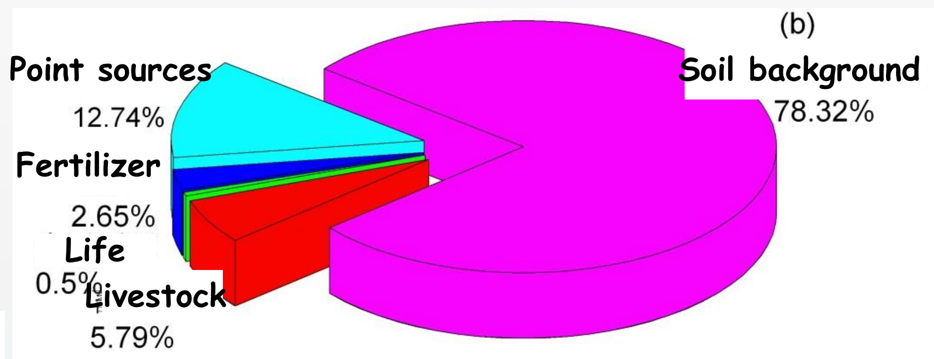
Contribution ratio of different pollutions from Chao river watershed （1986-1991）

Nonpoint Source Pollution Simulation

(a)TN



(b)TP

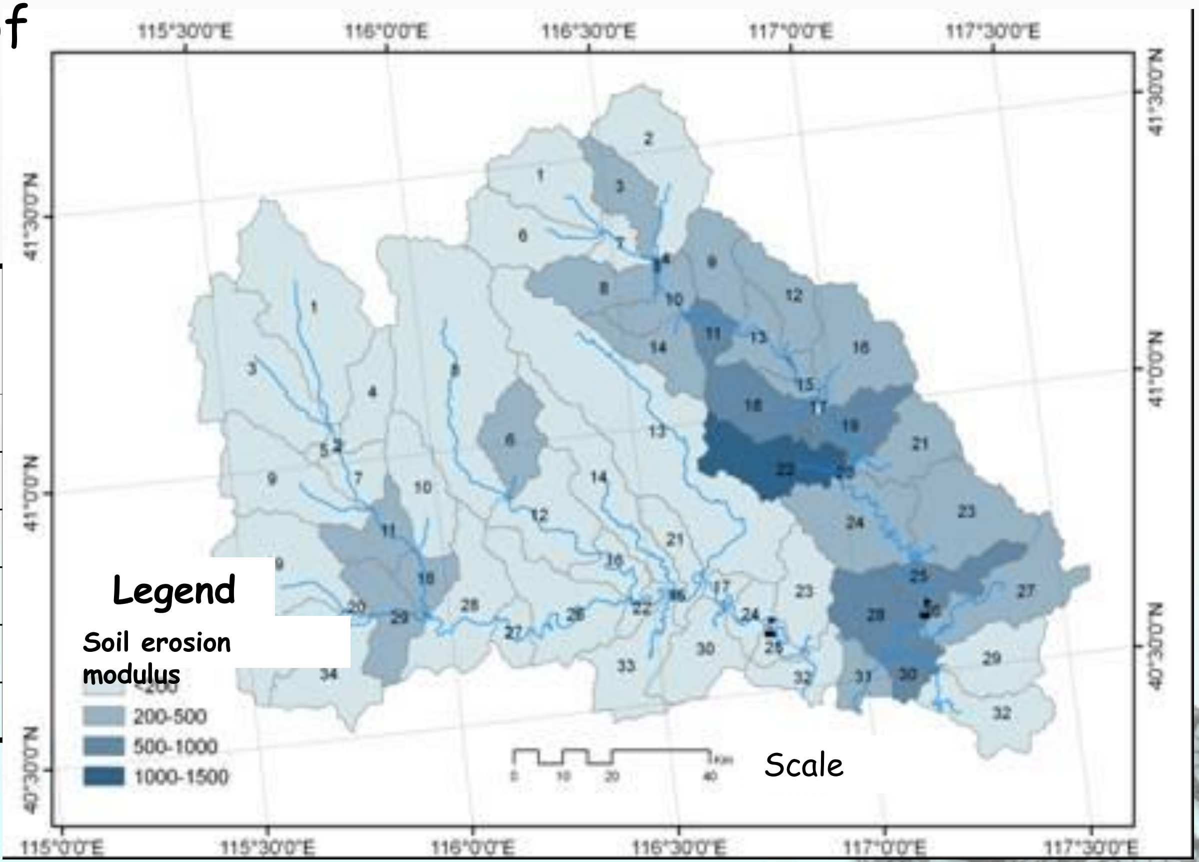


Contribution ratio of different pollutions from Bai river watershed (1986-1991）

Identification of NSP Critical Areas

1.Identification of the critical areas for soil erosion

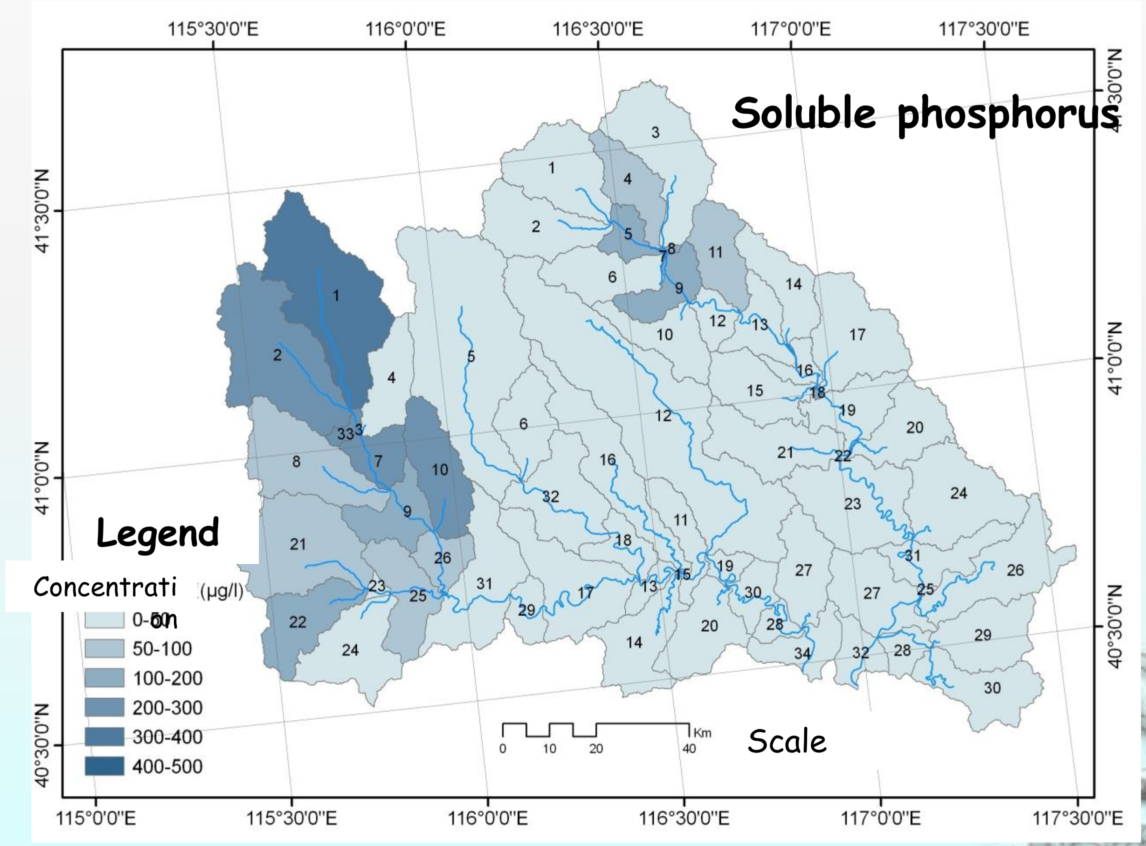
level		Average erosion modulus (t·km^{-2}·a^{-1})
I	Low	<200、500、1000
II	↓	200、500、1000-2500
III		2500-5000
IV		5000-8000
V		8000-15000
VI	High	>15000



Soil erosion intensity level map

Identification of NSP Critical Areas

The critical areas of phosphorus losses



Pollutant Control and Scenario Analysis

The reduction rate of the pollution load under different scenarios

scenario	Flowing into Miyun from Chaohe basin		Flowing into Miyun from Baihe basin	
	TN reduction (%)	TP reduction (%)	TN reduction (%)	TP reduction (%)
1	0.07	7.33	0.05	0.68
2	9.09	10.26	12.51	3.40
3	8.03	4.92	9.05	3.86
4	1.09	3.58	1.47	4.62
5	9.12	3.67	3.93	10.58
6	1.04	1.52	——	——
7	0.98	0.76	——	——
8	2.55	1.55	——	——
9	15.97	16.84	20.17	9.52

Summaries

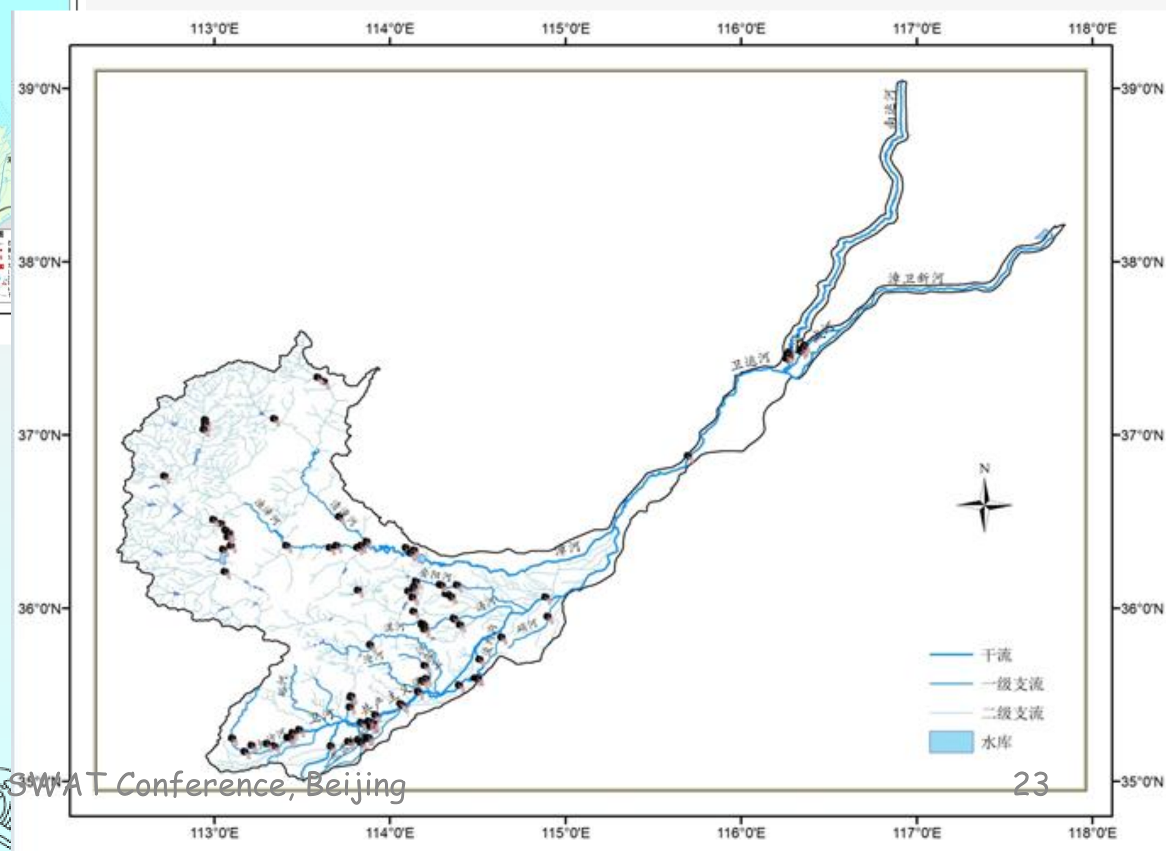
1、Nonpoint source pollution mainly takes place in flood season, and it is more serious in the Chao River watershed than that in the Bai River watershed.

2. The emphasis of river basin management should be putted on the nonpoint source pollution control in the Miyun Reservoir cachment.

Xu, Z. X., Pang, J. P., Liu, C. M., and Li, J. Y. (2009). Assessment of runoff and sediment yield in the Miyun Reservoir catchment by using SWAT model. *Hydrol. Process.* 23, 3619–3630 (DOI: 10.1002/hyp.7475)

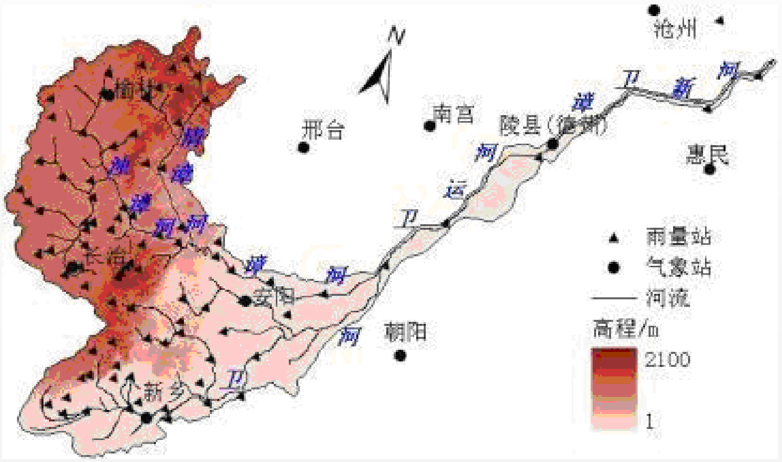
Zhangweinan River Basin

- **Area: 37,700 km^2**

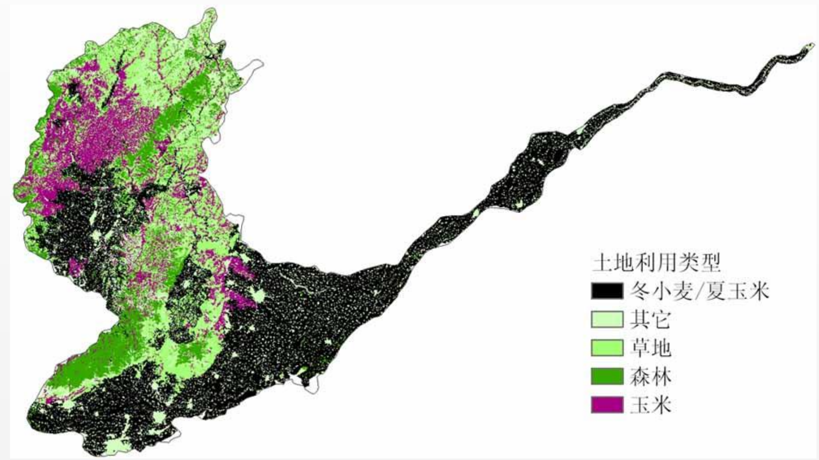


- **Shanxi, Henan, Hebei, and Shandong provinces including 13 cities, and 70 counties**

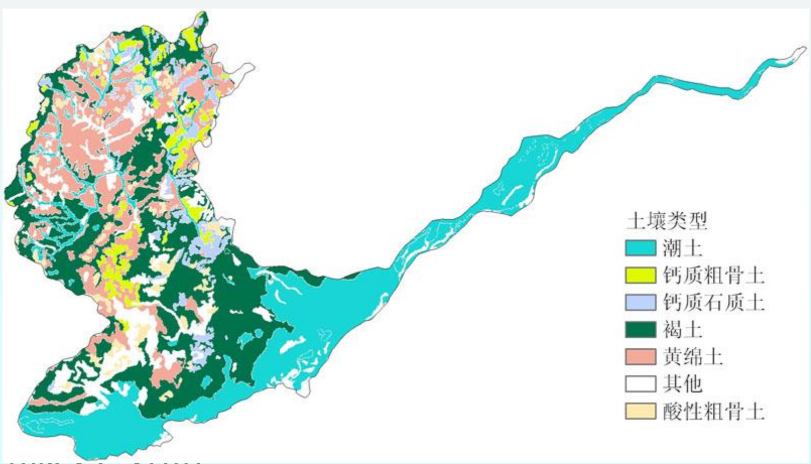
Zhangweinan River Basin



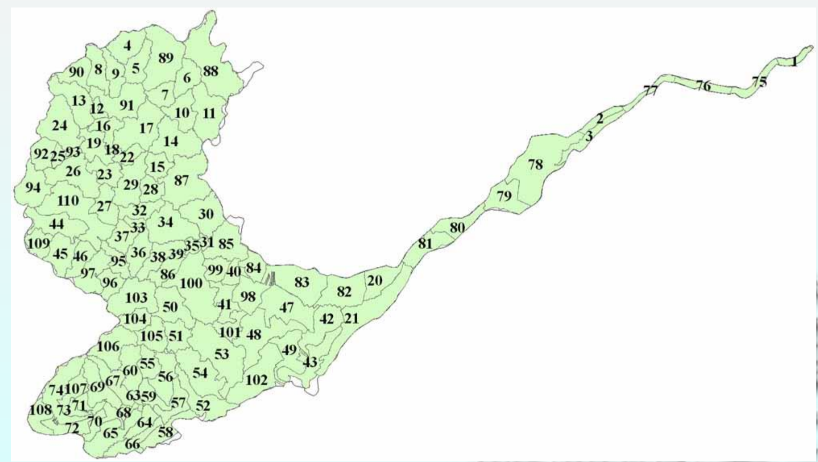
DEM, Reservoir



Land Uses



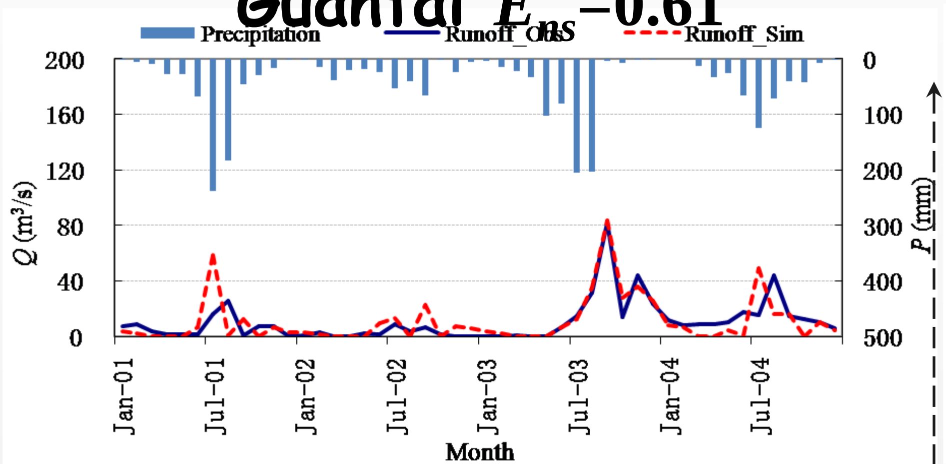
Soil Types



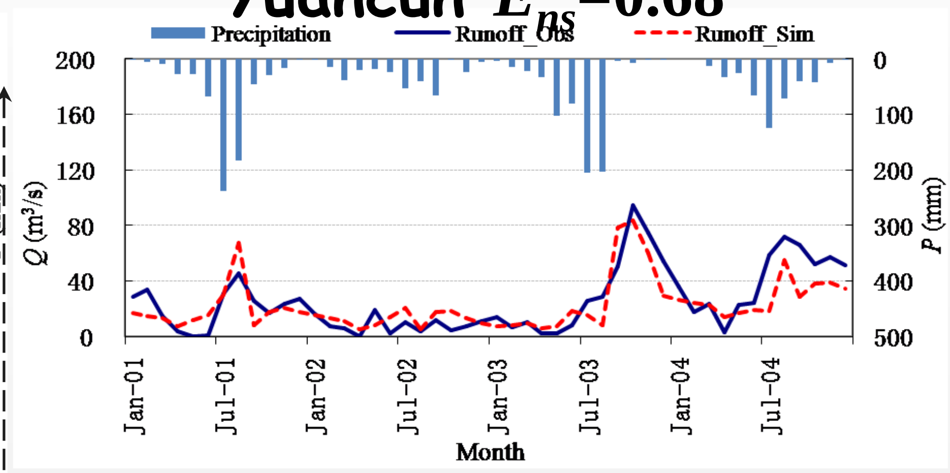
Subbasin

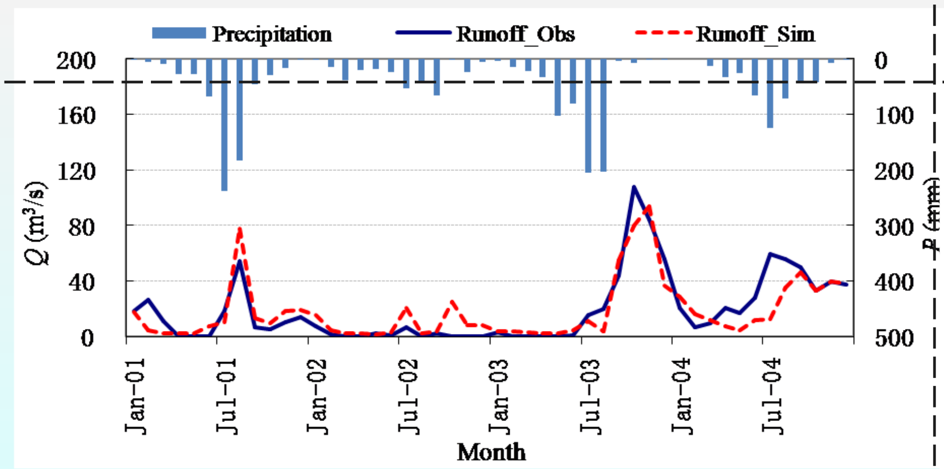
Model Calibration

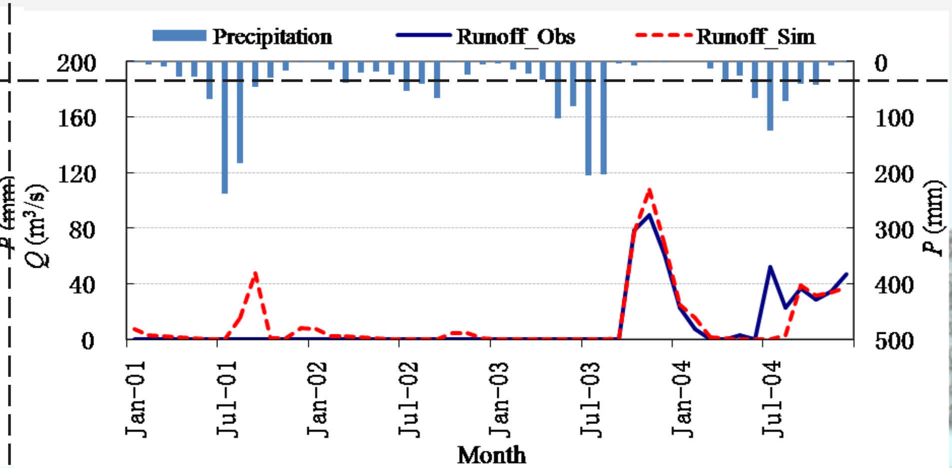
Guantai E_{ns}=0.61



Yuancun E_{ns}=0.68







Linqing E_{ns}=0.81

Xinji E_{ns}=0.81

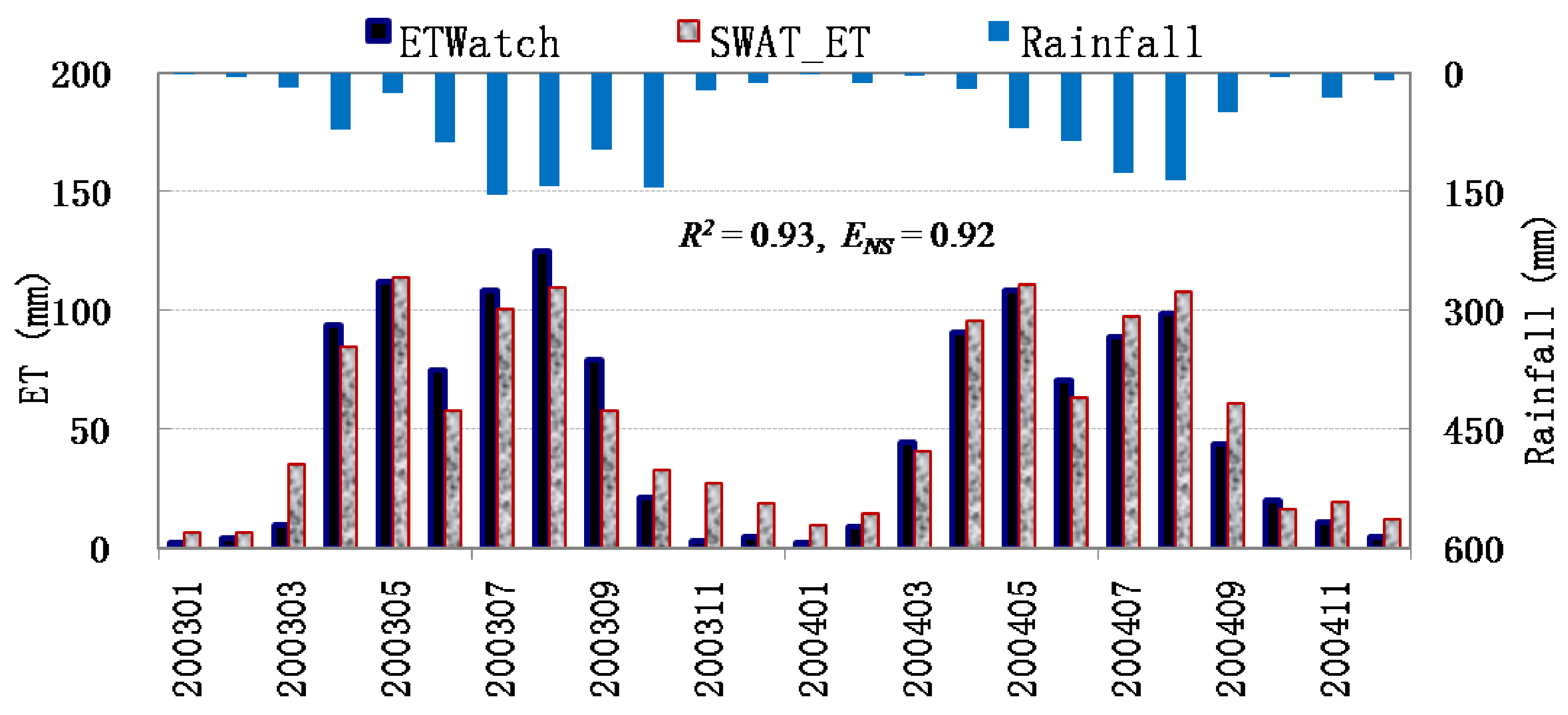
Model Calibration and Validation

Calibration：2001-2003；Validation：2003-2005)

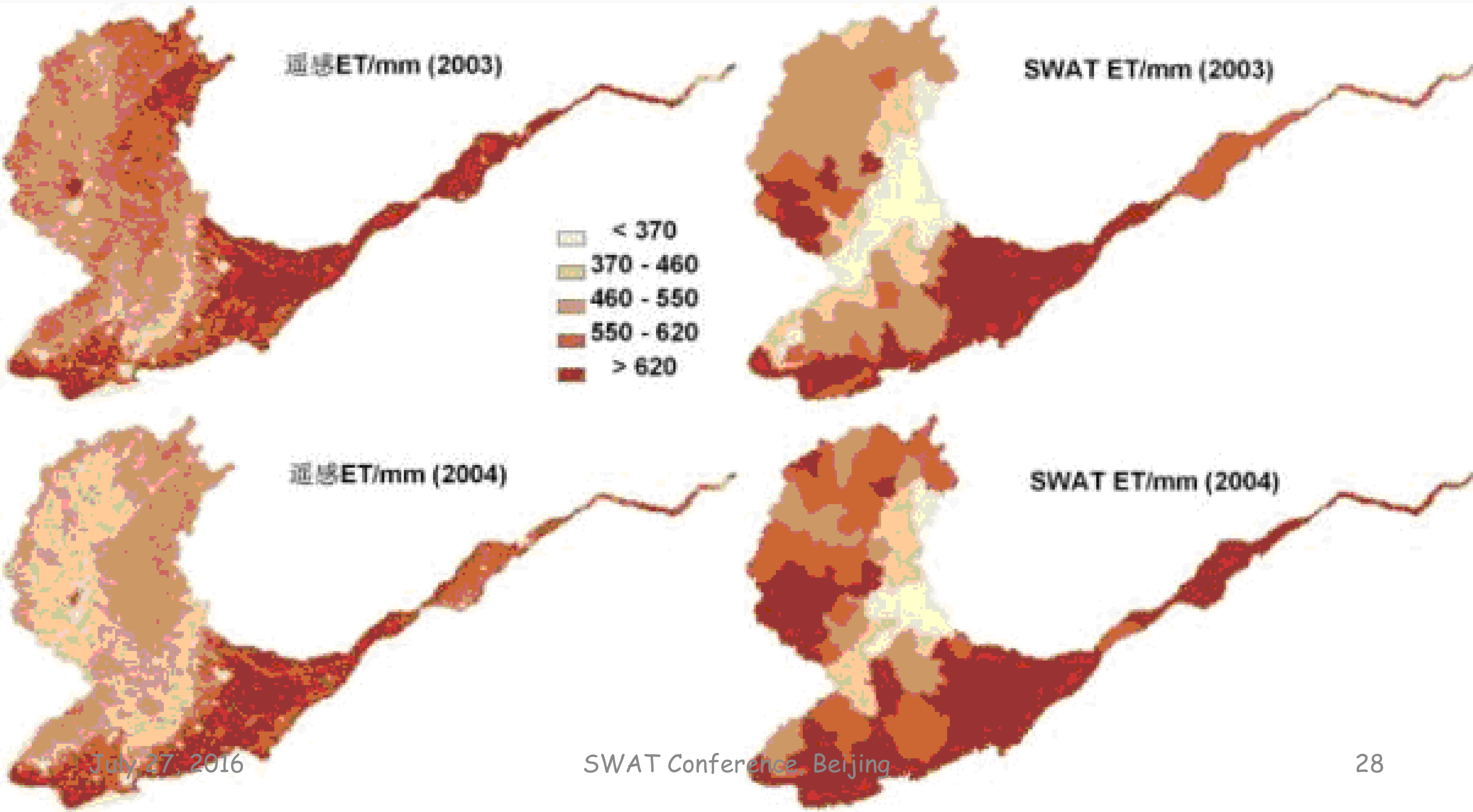
	Guantai		Yuancun		Linqing		Xinji	
	Cal.	Val.	Cal.	Val.	Cal.	Val.	Cal.	Val.
R^2	0.71	0.61	0.68	0.66	0.82	0.78	0.88	0.84
E_{NS}	0.61	0.47	0.68	0.59	0.81	0.75	0.81	0.77

ET Calibration

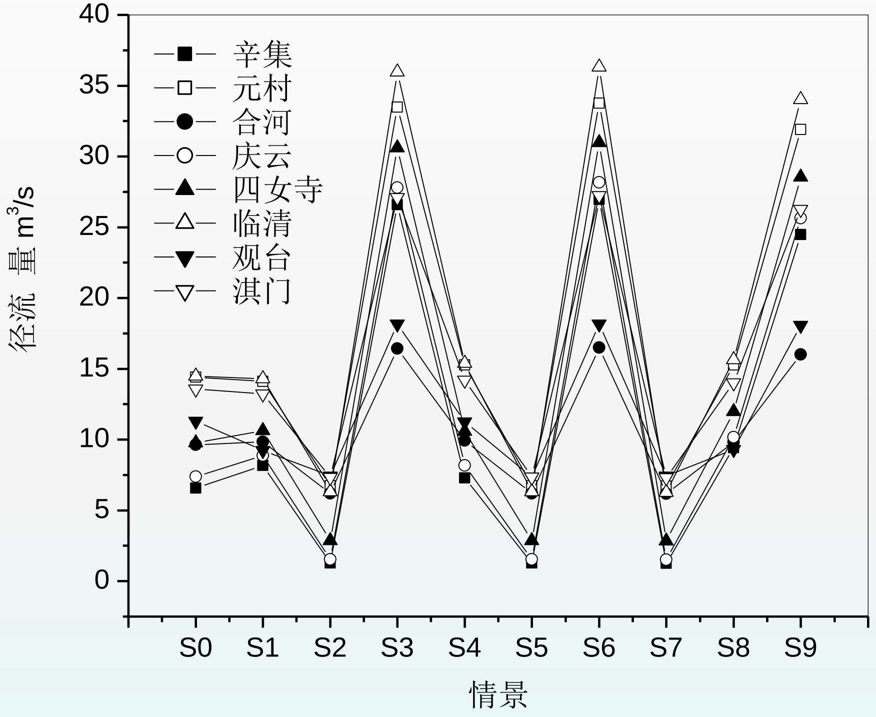
- R^2 and *ENS* are 0.93 and 0.92, respectively.



ET Distribution

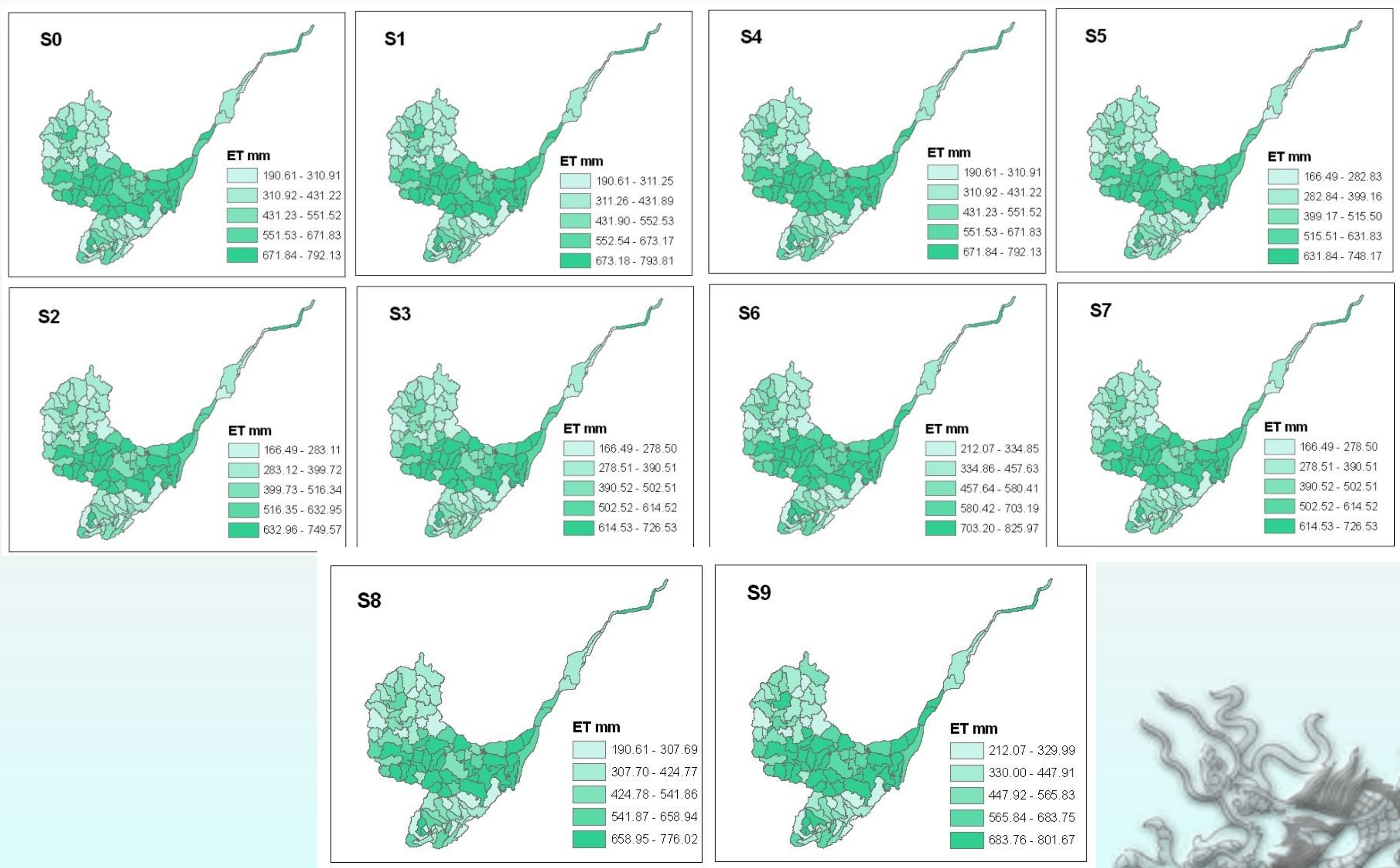


Changes of Runoff under different Scenarios



情景	(S1-S0)/S0	(S2-S0)/S0	(S3-S0)/S0	(S4-S0)/S0	(S5-S0)/S0	(S6-S0)/S0	(S7-S0)/S0	(S8-S0)/S0	(S9-S0)/S0
径流量变化%	1.4	-54.0	146.6	5.6	-54.0	148.8	-54.1	9.6	133.8

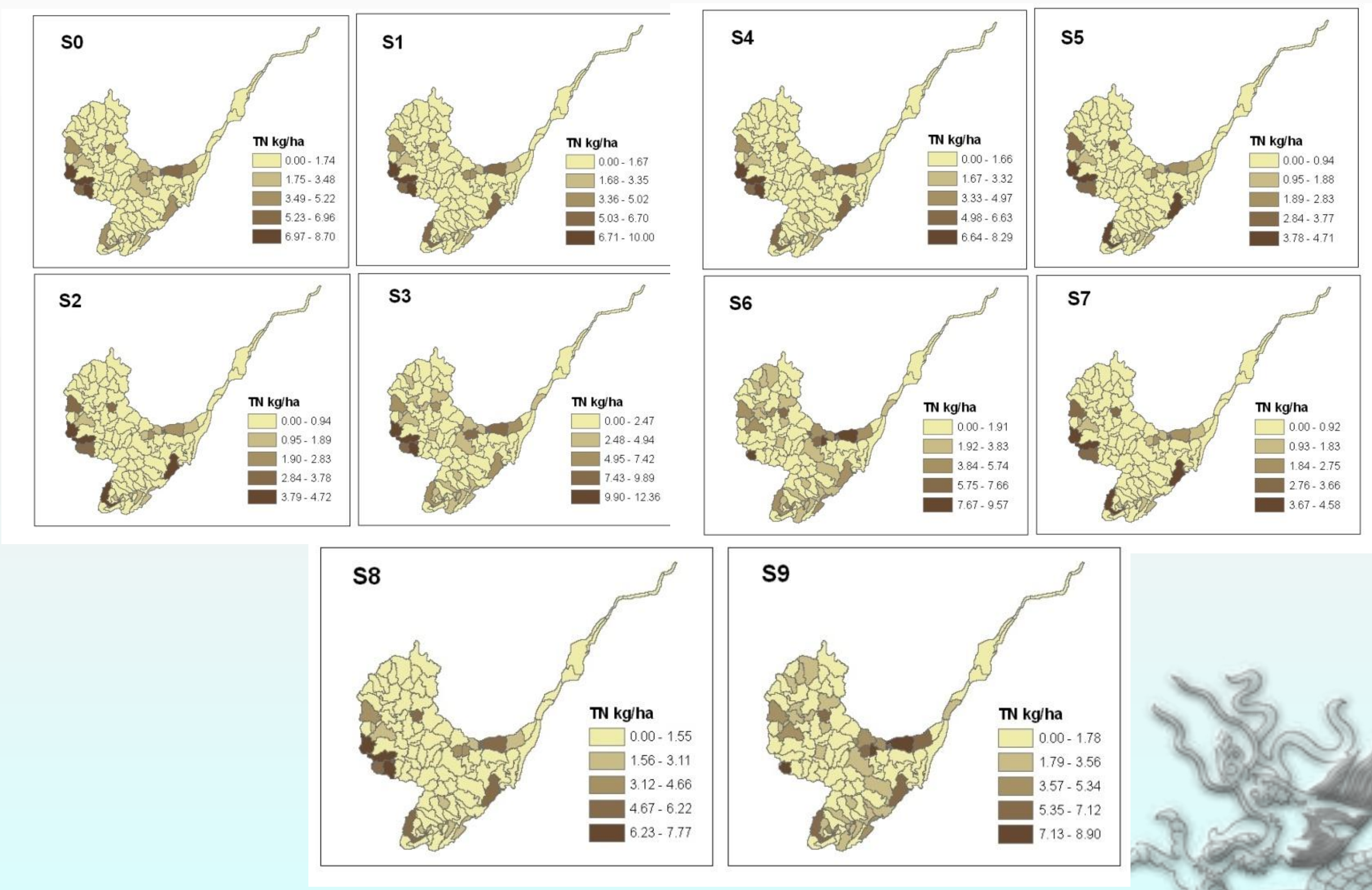
ET Distribution under Different Scenarios



Changes of TN and TP under Different Scenarios

情景	(S1-S0) /S0	(S2-S0) /S0	(S3-S0) /S0	(S4-S0) /S0	(S5-S0) /S0	(S6-S0) /S0	(S7-S0) /S0	(S8-S0) /S0	(S9-S0) /S0
总氮	-24.4	-61.7	26.5	-28.7	-61.9	25.8	-50.9	-30.9	33.5
总磷	-8.7	-56.2	77.1	-10.2	-56.4	75.1	-57.6	-12.4	61.9

Distribution of TN (kg/ha) under Different Scenarios



Changes of TN and TP under Different Scenarios

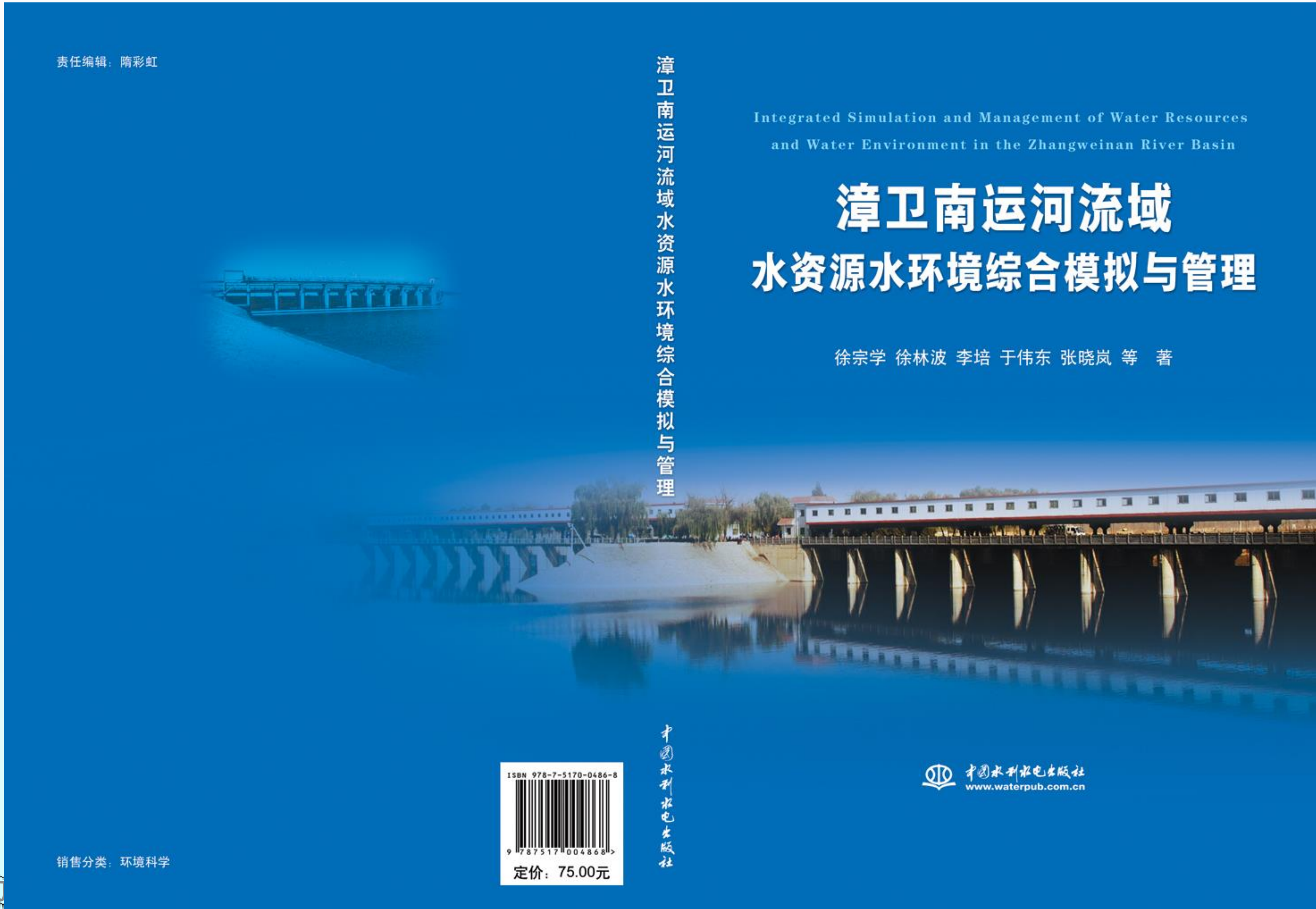
Sce.	(S1-S0) /S0	(S2-S0) /S0	(S3-S0) /S0	(S4-S0) /S0	(S5-S0) /S0	(S6-S0) /S0	(S7-S0) /S0	(S8-S0) /S0	(S9-S0) /S0
TN	-3.63	-52.44	78.22	-4.21	-52.72	76.85	-53.43	-7.93	67.95
TP	-3.63	-54.00	85.39	-4.38	-54.25	83.23	-54.79	-8.26	73.17

Summaries

- **Runoff will increase by 147% if precipitation increase by 25%, while runoff will increase by 4% if irrigation water decreases by 10%;**
- **If nonpoint source pollutant decreases by 15%, TN will decrease by 7%, and TP 15%; If the nonpoint source pollutants reach the standard, TN will decrease by 24%, and TP will decrease by 8%.**

徐宗学，徐林波，李培，于伟东，张晓岚等著，《漳卫南运河流域水资源水环境综合模拟与管理》，中国水利水电出版社，**2013**年

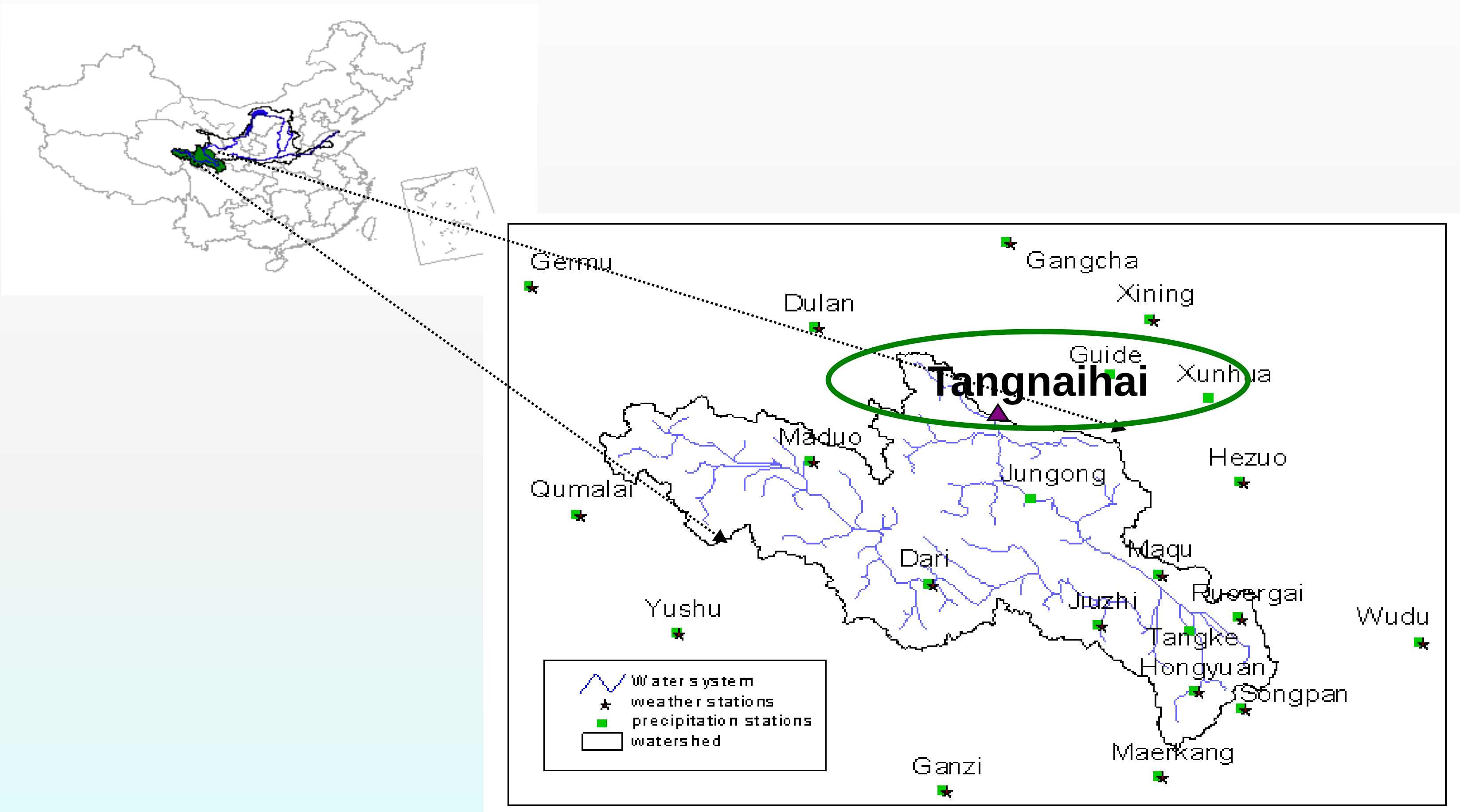
Integrated Simulation and Management of Water Resources and Water Environment in the Zhangweinan River Basin



Case Study II:

Impact of Climate Change on Hydrologic Cycle

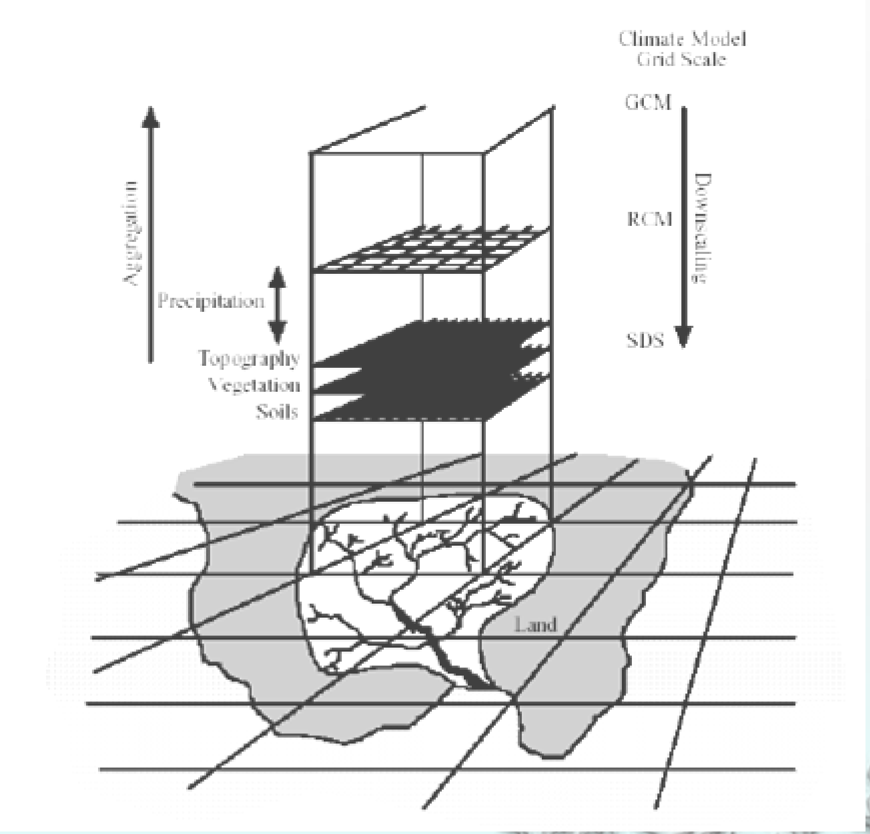
Study Area



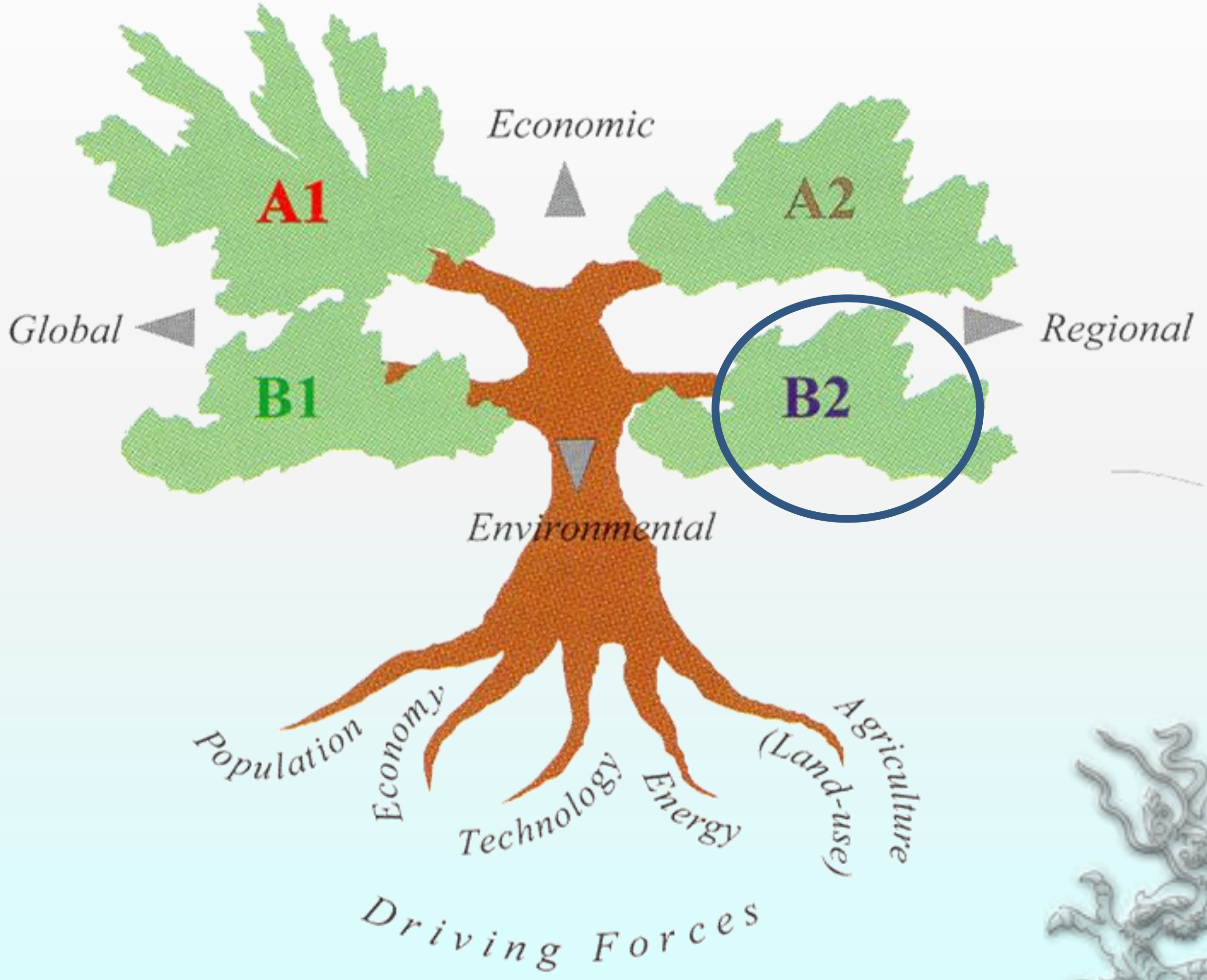
Location of headwater catchment of the Yellow River Basin and the gauging stations

Downscaling

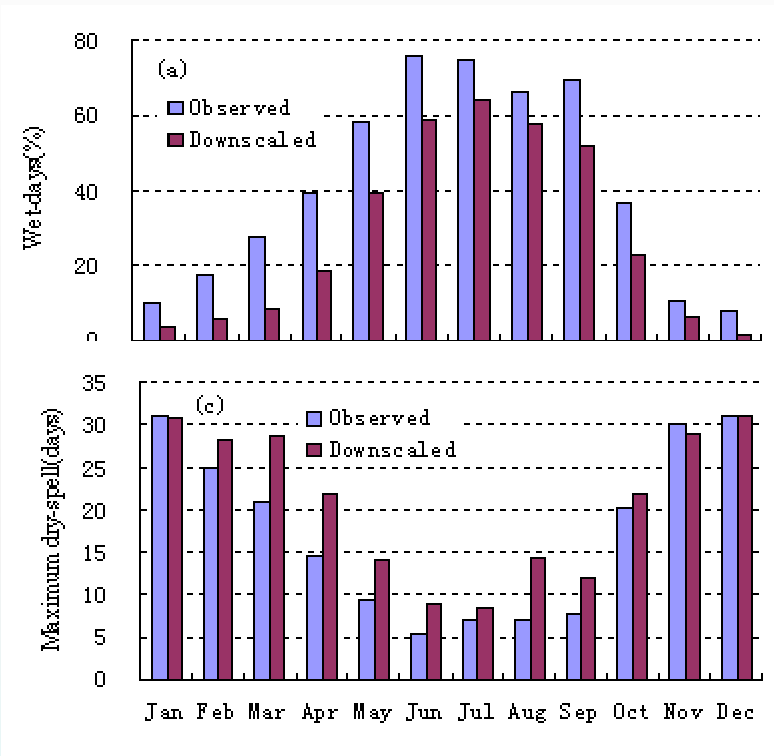
- Objective: Increase spatial and temporal information from GCMs output
- Concept: Regional and local climate is widely influenced by large-scale atmosphere dynamics (GCM)

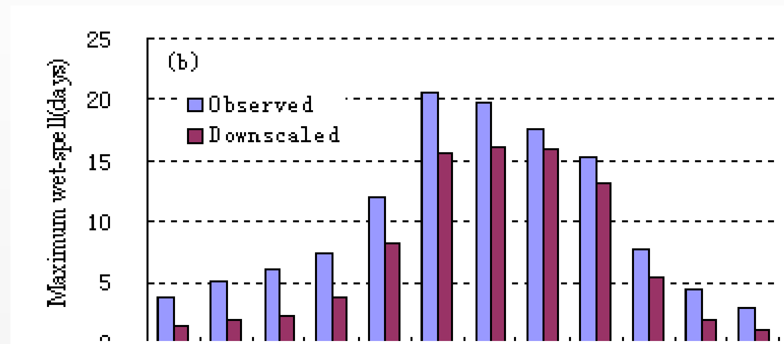


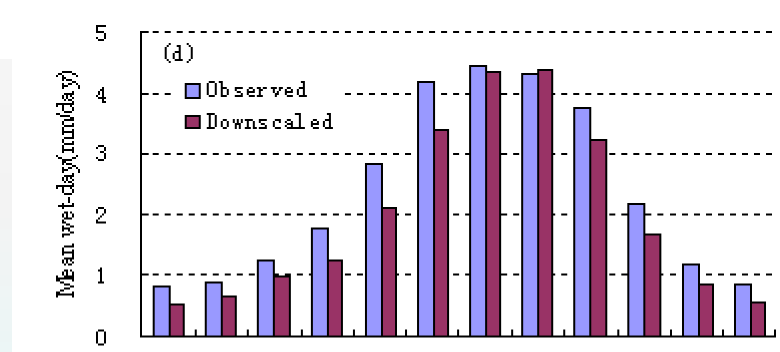
Scenarios

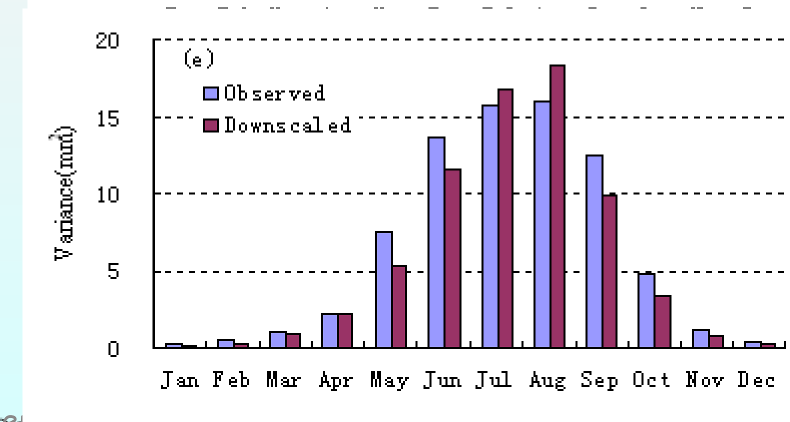

Economic
A1
A2
Global
Regional
B1
B2
Environmental
Population
Economy
Technology
Energy
(Land-use)
Agriculture
Driving Forces

Validation for SDSM



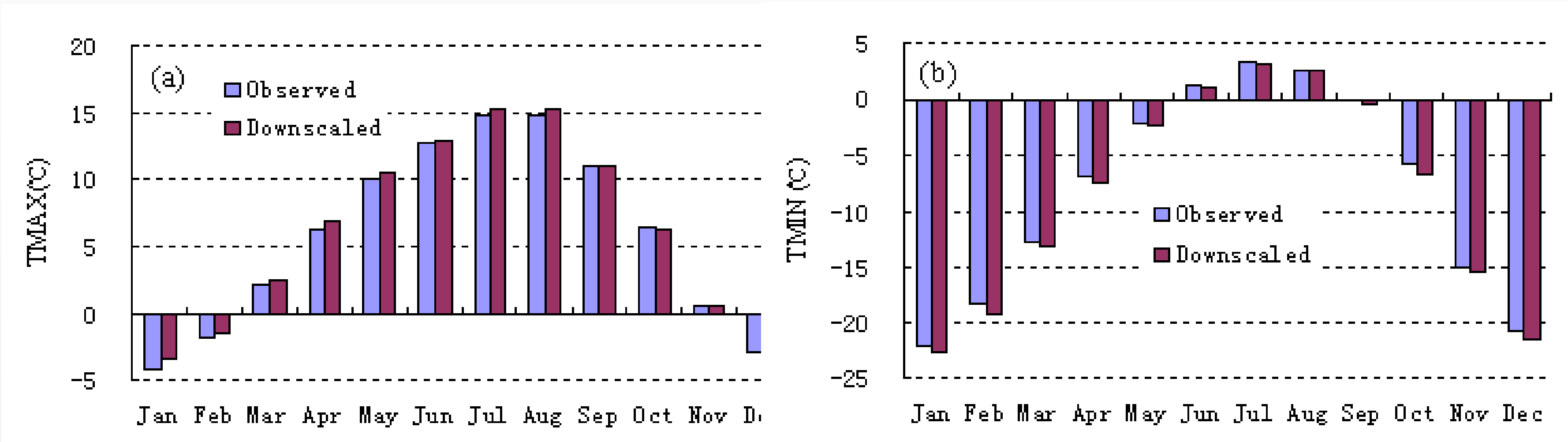






PCP results

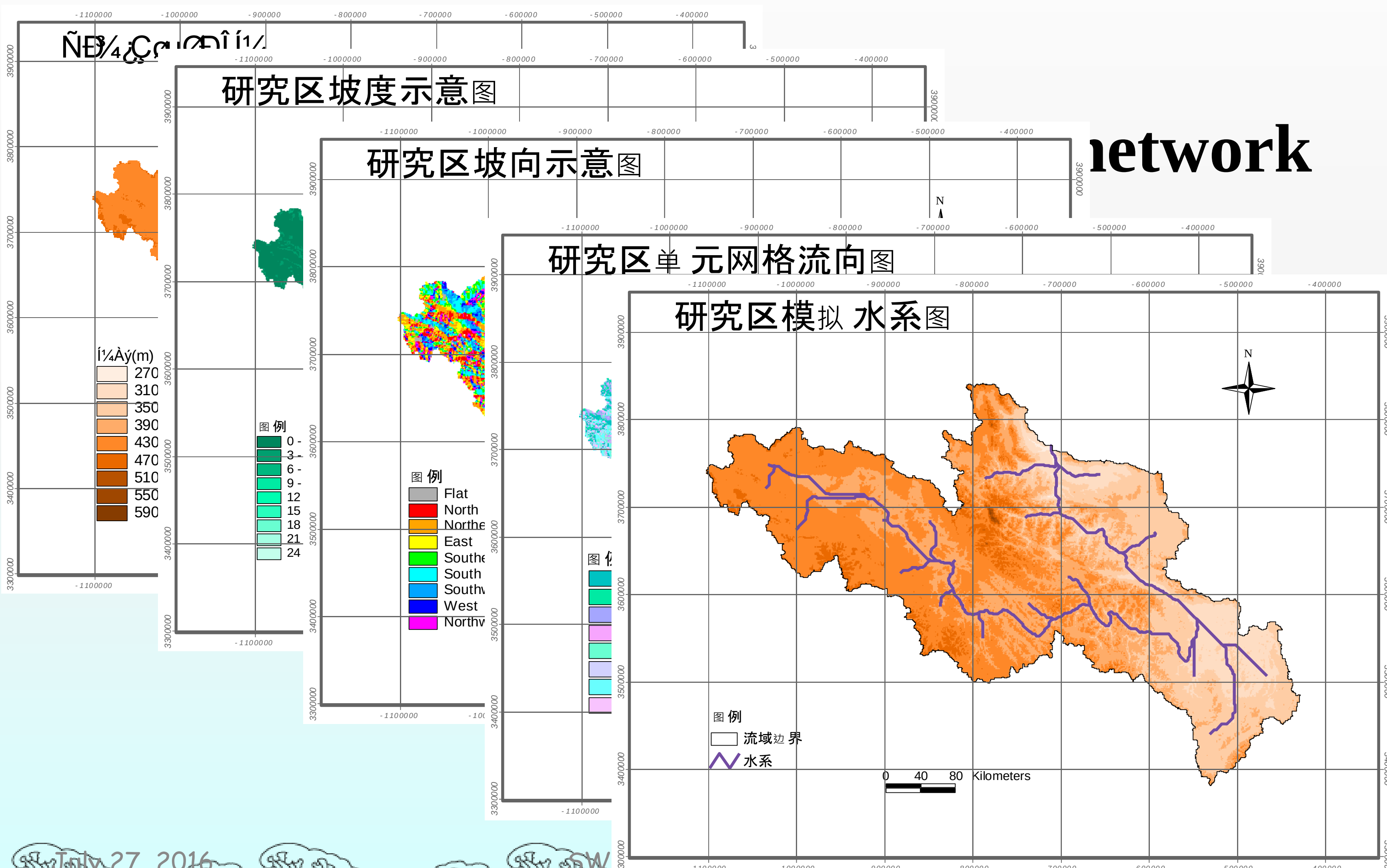
Validation for SDSM (cont.)



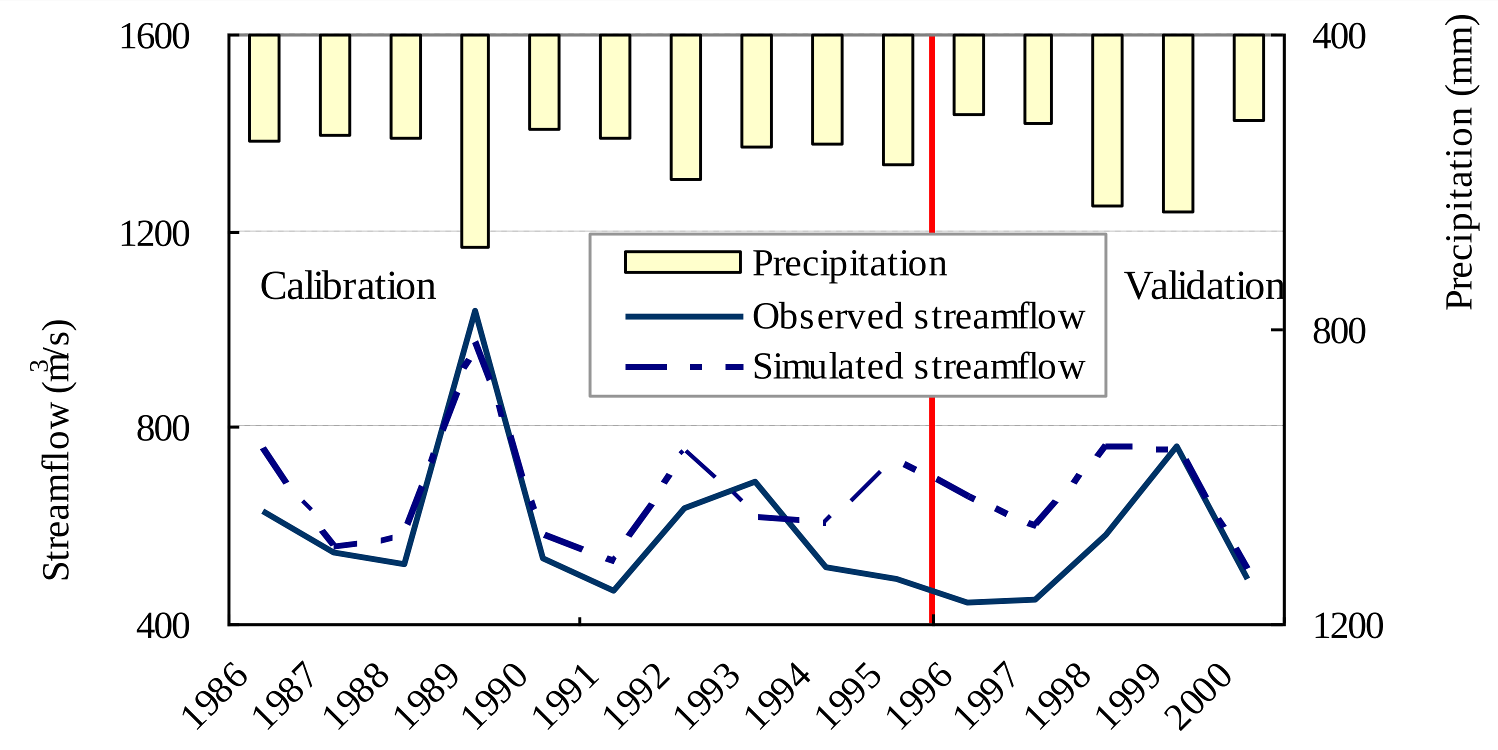
Comparison between observed and downscaled monthly mean Tmax and Tmin in HYRB, 1976-1990

Streamflow Simulation by Using SWAT

etwork

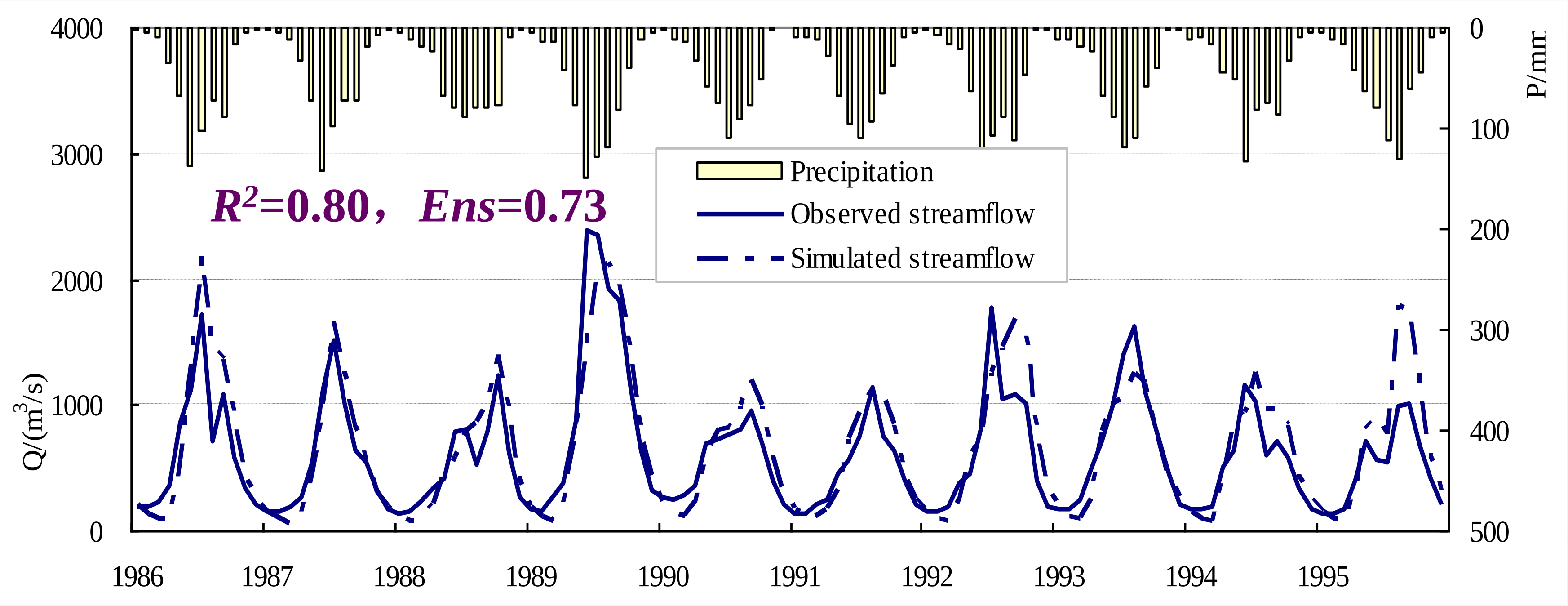


Annual Streamflow Simulation



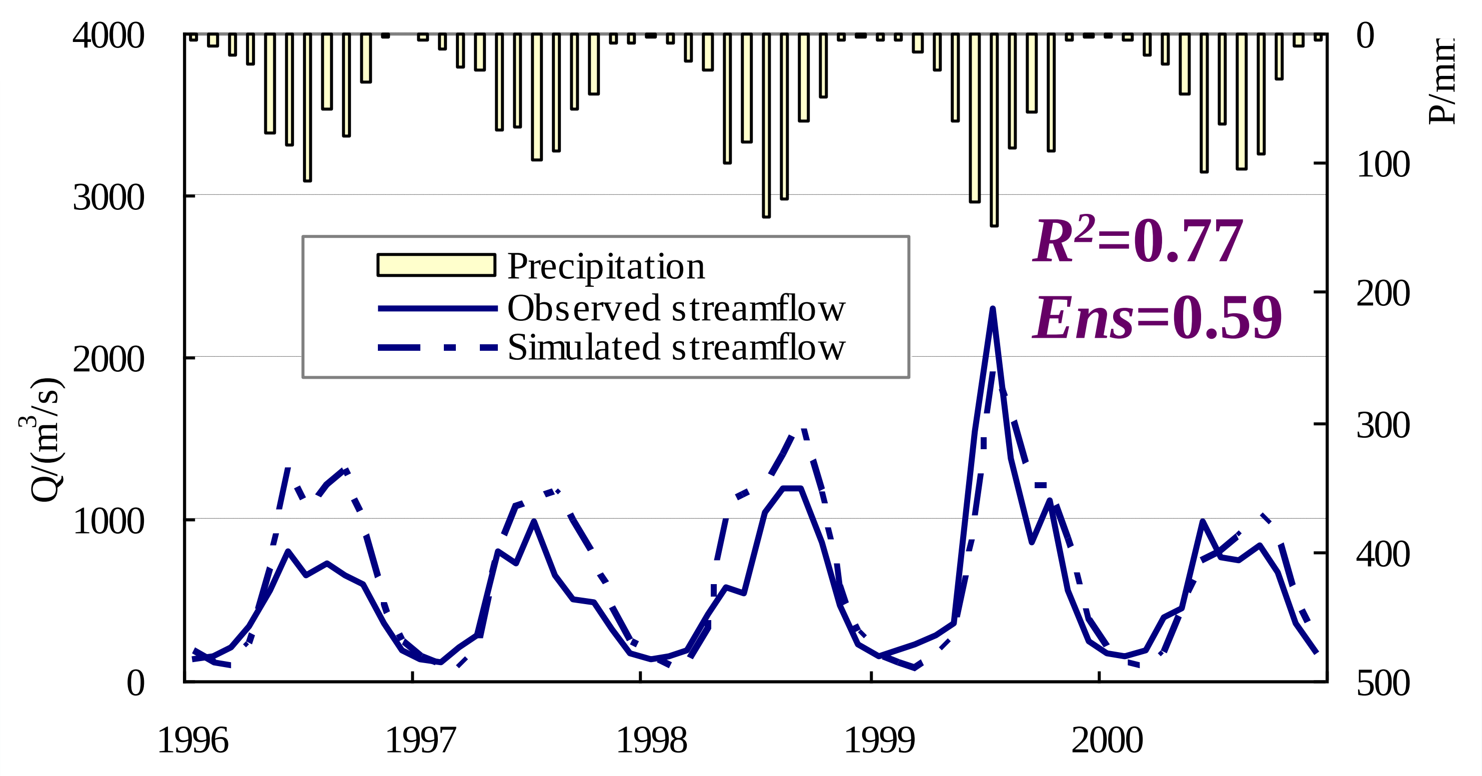
Comparison between measured and predicted annual streamflow during calibration period (1986-1995) and validation period (1996-2000)

Model Calibration



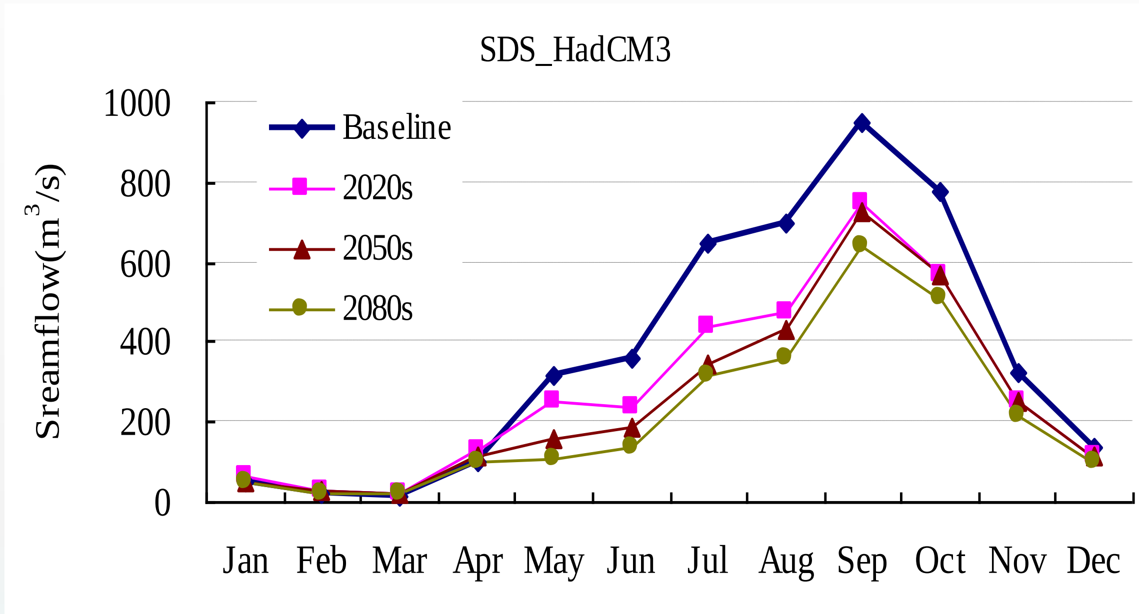
Comparison between measured and predicted monthly streamflow during calibration period (1986-1995)

Model Validation



Comparison between measured and predicted monthly streamflow during validation period (1996-2000)

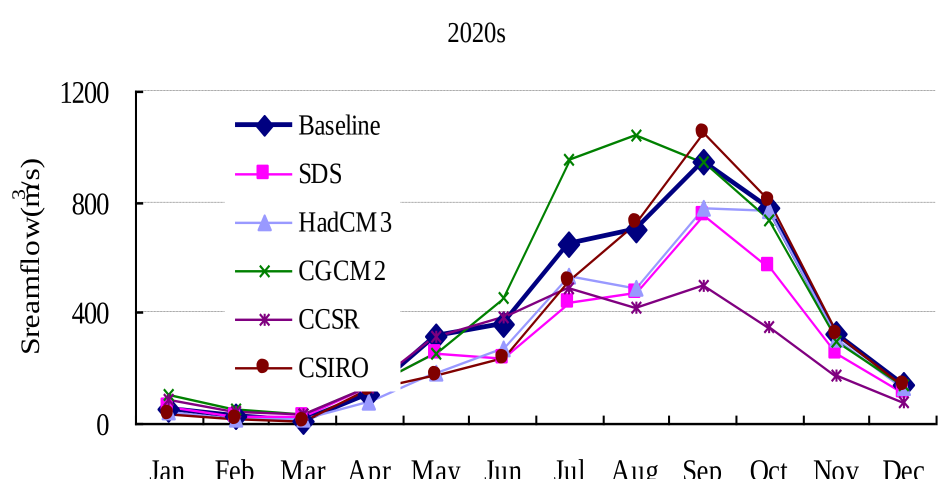
Long-term Streamflow Simulation (Scenarios)

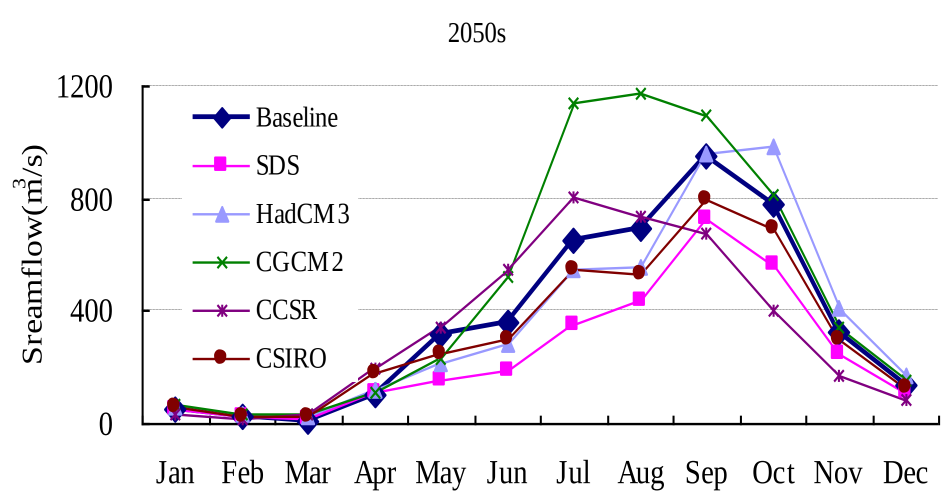


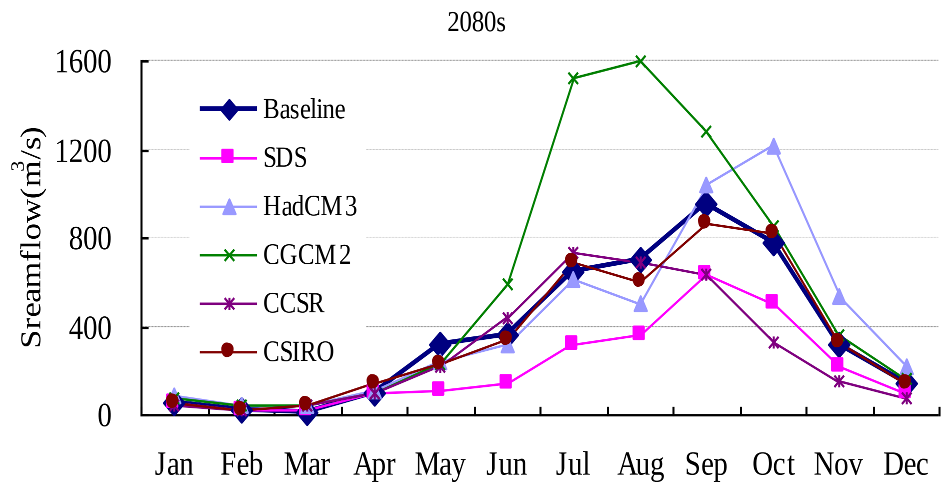
Comparison of simulated mean monthly stream flows in the baseline and those driven by SDS scenarios in the future

For SDS scenarios, the streamflow will decrease by 88.61m^3/s (24.15%), 116.64m^3/s (31.79%) and 151.62m^3/s (41.33%), based on 3 benchmark periods in the future, especially in flood season

Simulation for Different Climate Change Scenarios

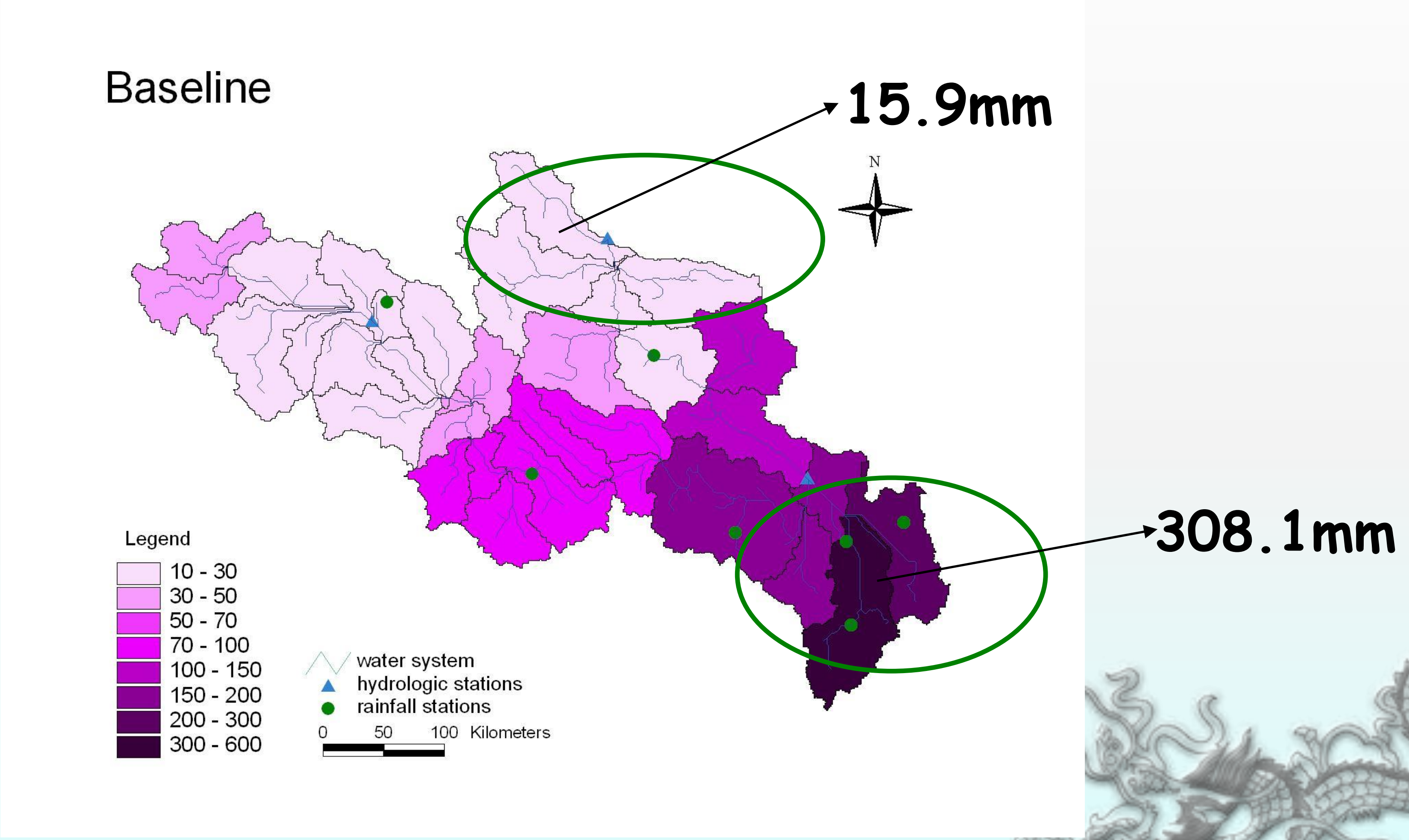






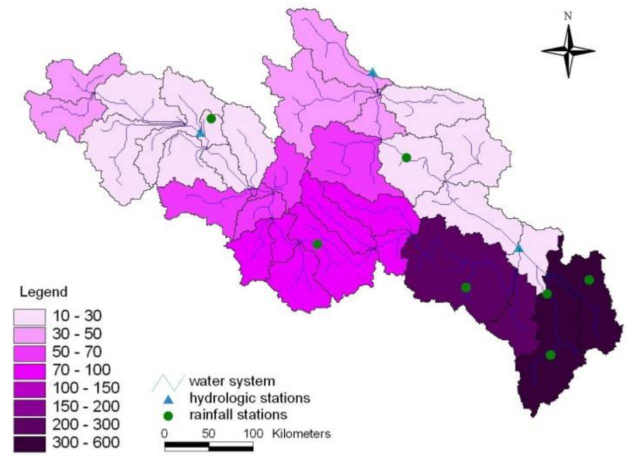
Comparison of simulated mean monthly streamflows in the baseline and those driven by different scenarios in the future

Spatial Distribution of Simulated Runoff Depth

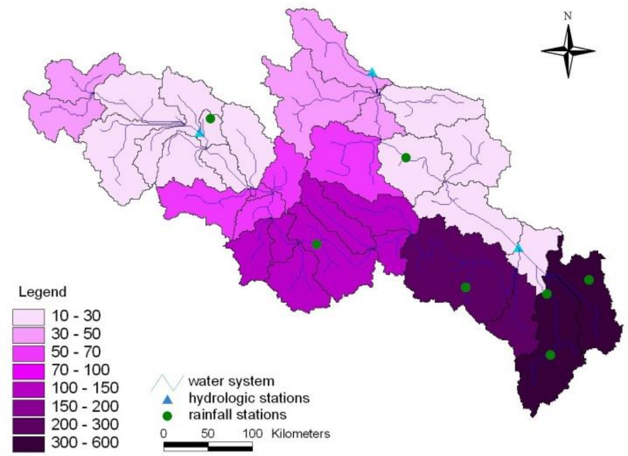


Spatial Distribution of Simulated Runoff Depth

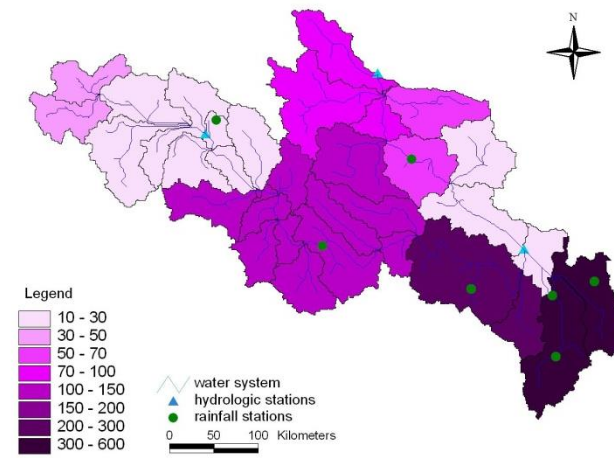
HadCM3_2020s



HadCM3_2050s



HadCM3_2080s



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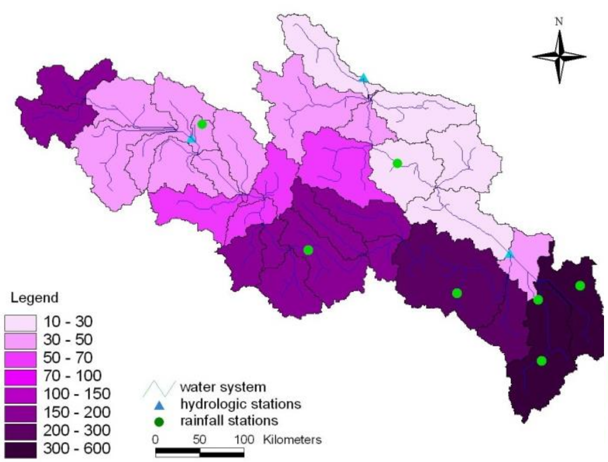

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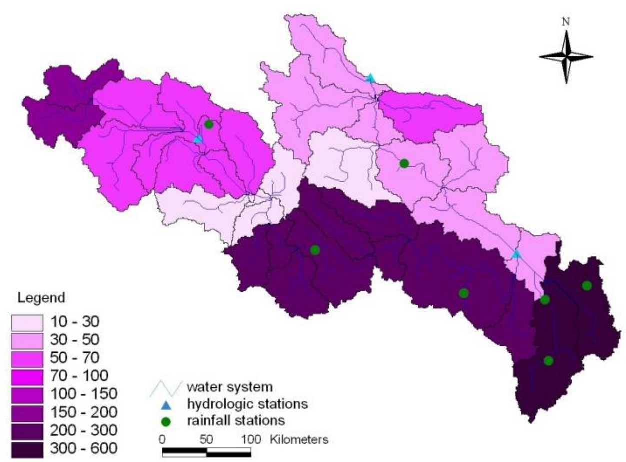

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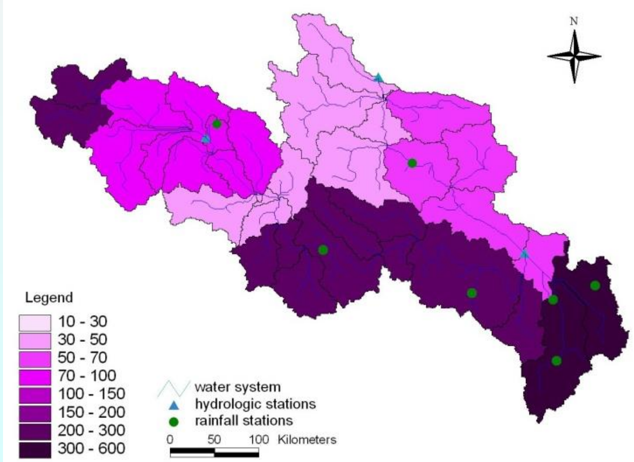
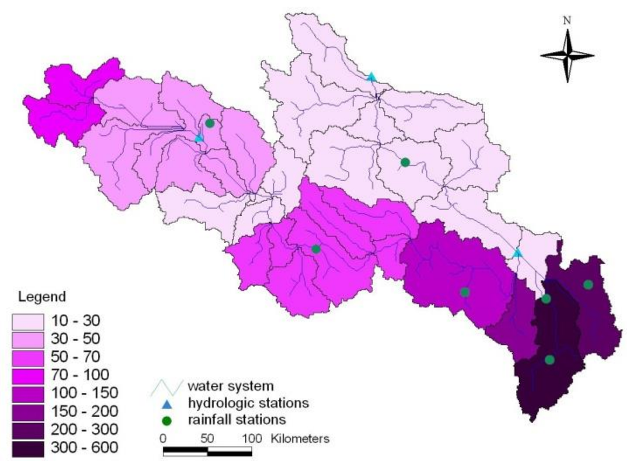


Spatial Distribution of Simulated Runoff Depth

CCSR_2020s



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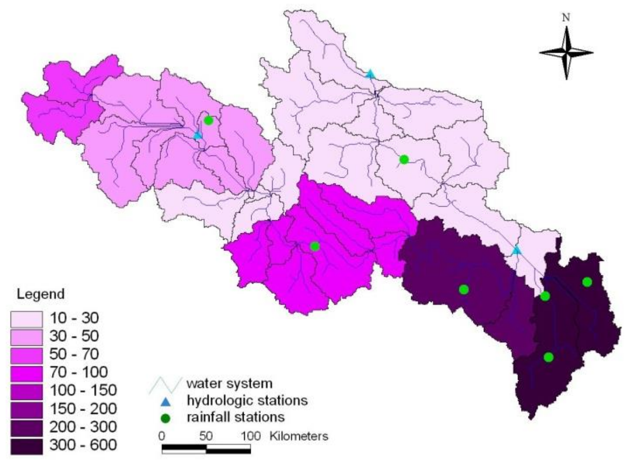
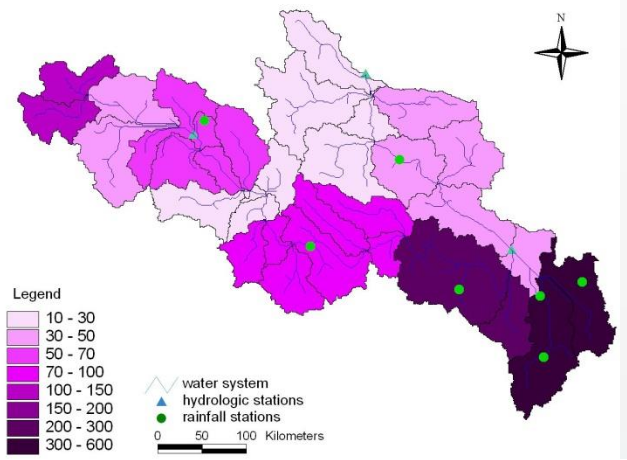


CSIRO_2080s



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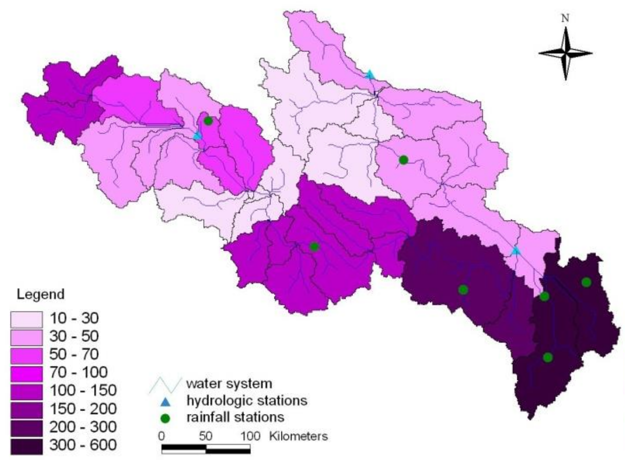

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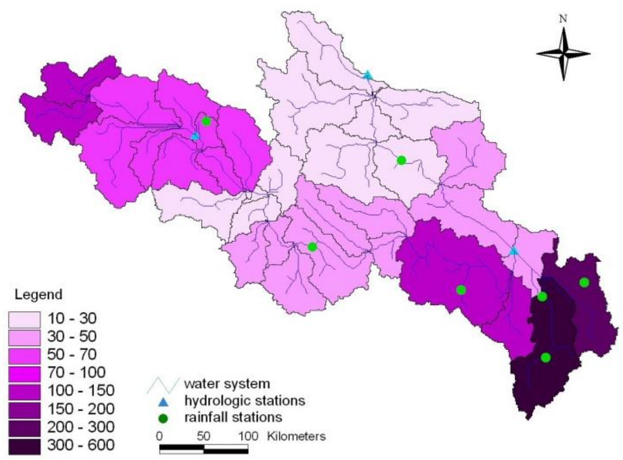
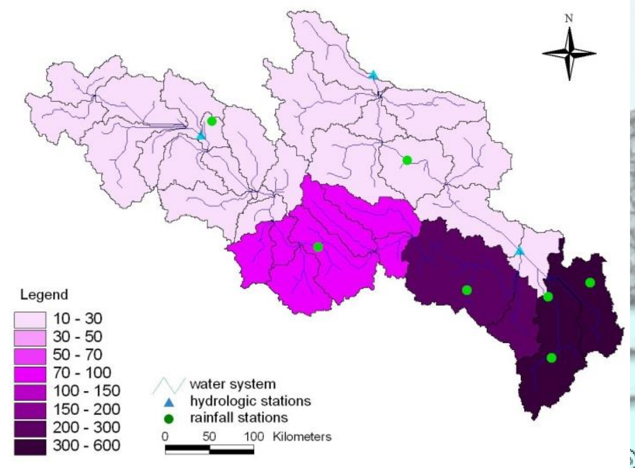
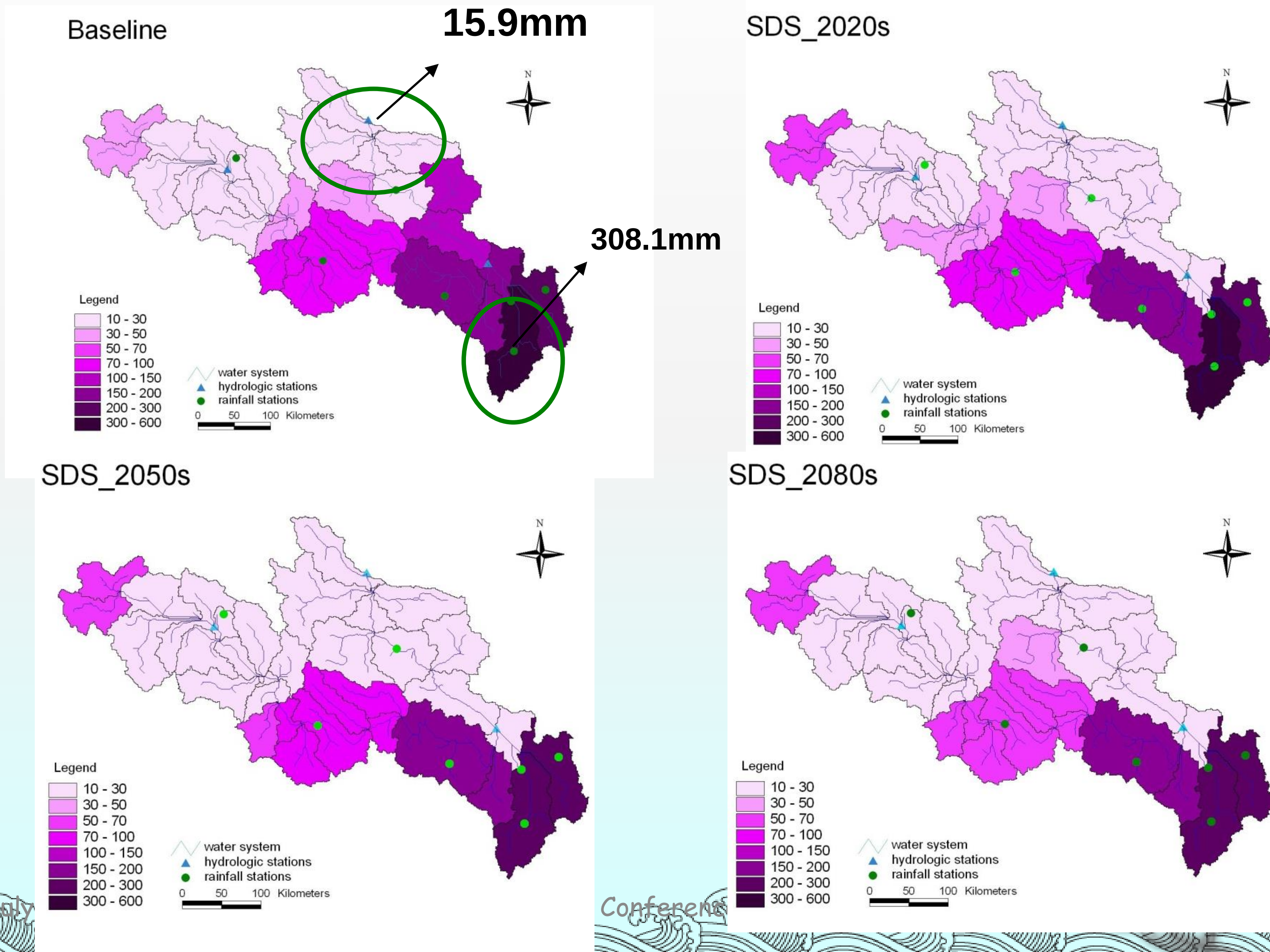


CCSR_2080s



Spatial Distribution of Simulated Runoff Depth



Summaries

- The hydrological processes in HYRB are very sensitive to future climate changes, the streamflow may decrease in the future
- Simulated streamflow under SDS scenarios: 2020s(-24.15%), 2050s(-31.79%), 2080s(-41.33%)

- Xu, Z. X., Zhao, F. F., and Li, J. Y. (2008). Response of streamflow to climate change in headwater catchment of the Yellow River basin. *Quarter. Intl.* (DOI:10.1016/j.quaint.2008.09.001).

Hydrological Cycle in River Basins under the Background of Climate Change

Conclusions
&
Discussion

Improvement of SWAT Model

- SWAT model is a very good tool
- Runoff generating mechanism:

  SCS Curve Number
- Reservoir operation
- Large area irrigation
- Impact of human activities: Urbanization
- Ecological module/function

Thank You for Your Attention！

Prof. Zongxue Xu
College of Water Sciences
Beijing Normal University
E-mail: zongxuexu@vip.sina.com
Website: http://www.zxxu.org/