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SWAT model calibration and validation under extreme climatic conditions in Fuhe River Basin of Poyang Lake, China

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1 Introduction

- According to the fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013), As the climate becomes warmer, high temperature and heat wave will become more frequent and last longer. It indicated that the probability of extreme weather events may further increase in the future.
- An ideal hydrologic calibration data set should include combined climatic conditions of extreme weather years and average years while in a practical application. In fact, we often calibrate and validate the model based on data easily available.
- In previous studies, researchers have found that during extreme climatic condition years or seasons, discrepancies between simulated results and observed data often occurred and were larger than that in average climatic condition years or seasons.
- It is necessary to assess the model stability to the extreme climatic condition before predicting hydrologic response to the future climate change.

2.1 Study Area

- **Fuhe river basin of Poyang Lake**

Locate in subtropical humid monsoon region

Area: 14,778 km^2

Length of main stream: 348 km

Runoff: 12.6×10^9 m^3/year

Rainy days: 160/year

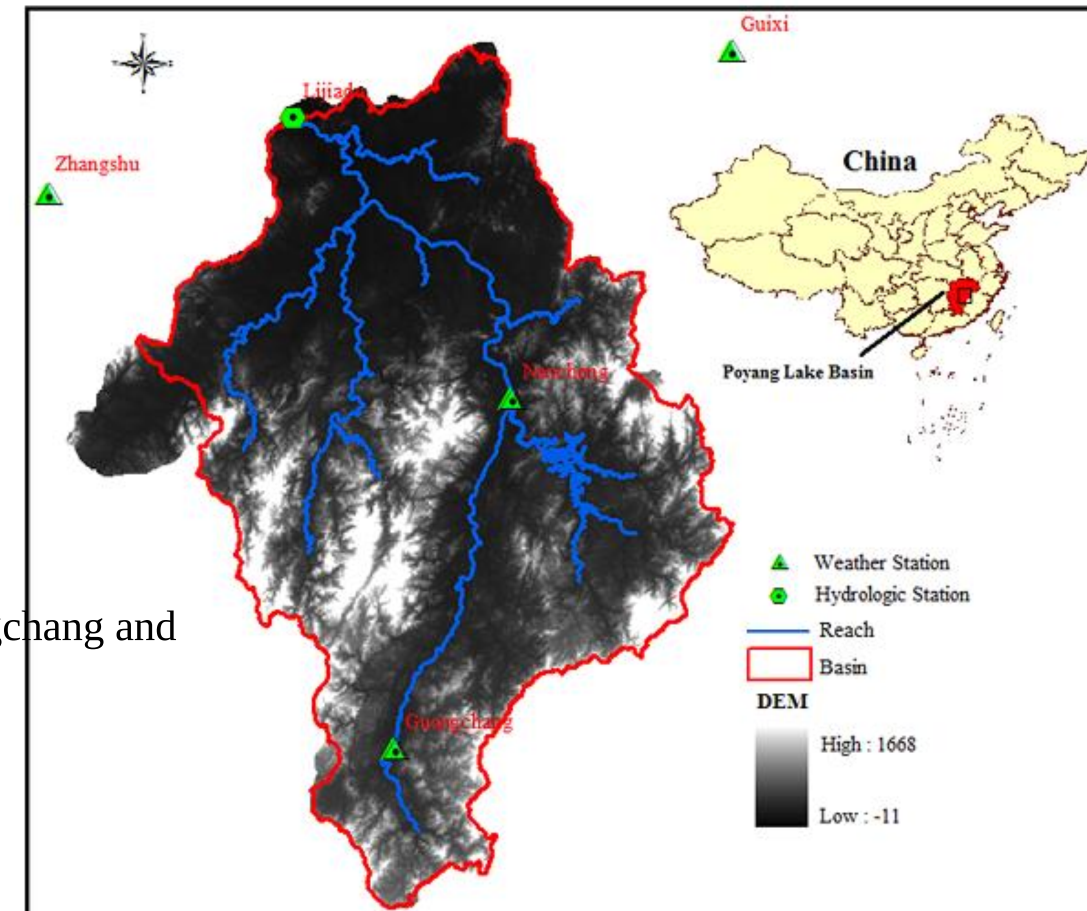
Precipitation: 1500-2000mm/year

Mean temperature:16.9-18.2℃

Mean humidity: 80%.

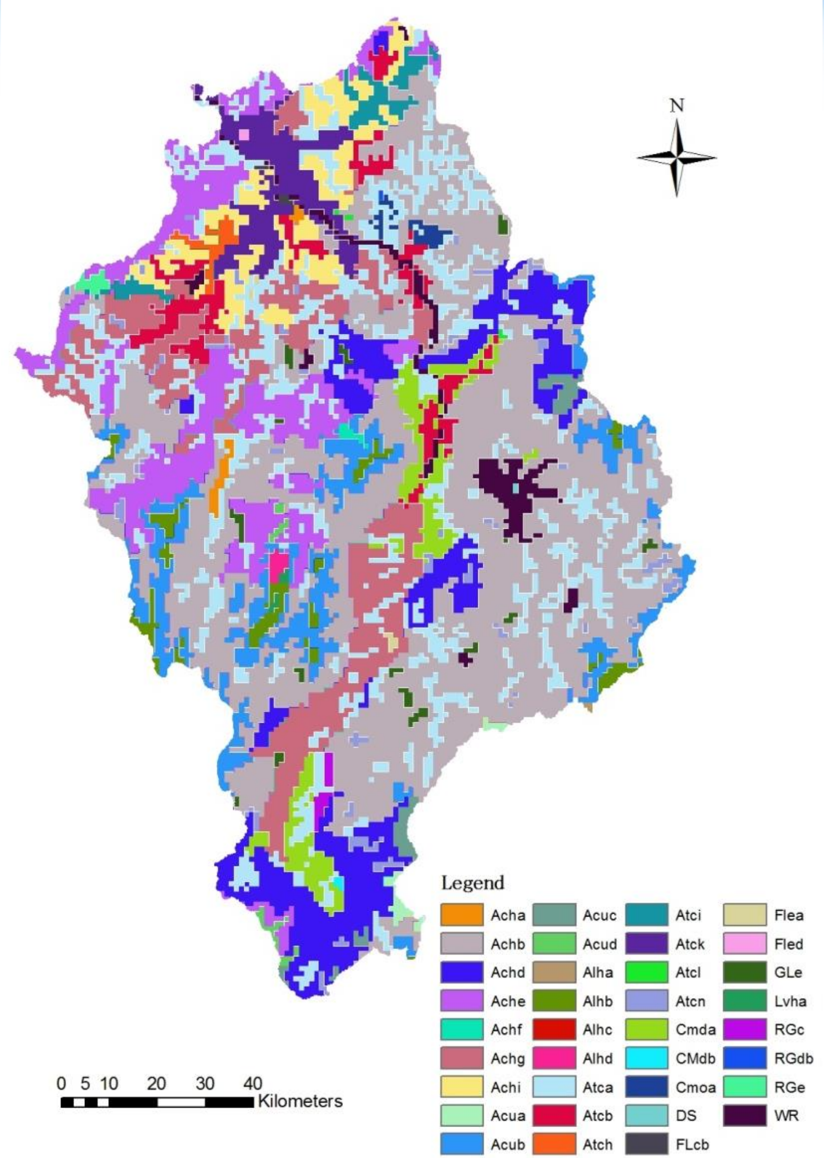
Weather stations: Zhangshu, Guixi, Guangchang and Nancheng

Control hydrologic station: Lijiadu



2.2 SWAT model setup for Fuhe river basin

- The main soil type in Fuhe river basin is red soils, in the 65.9% of the total area.
- Soil map was generated by Harmonized World Soil Database (HWSD)
- The *SOL_AWC* and *SOL_K* for each soil type were calculated by the SPAW software, developed by U.S. Department of Agriculture,.

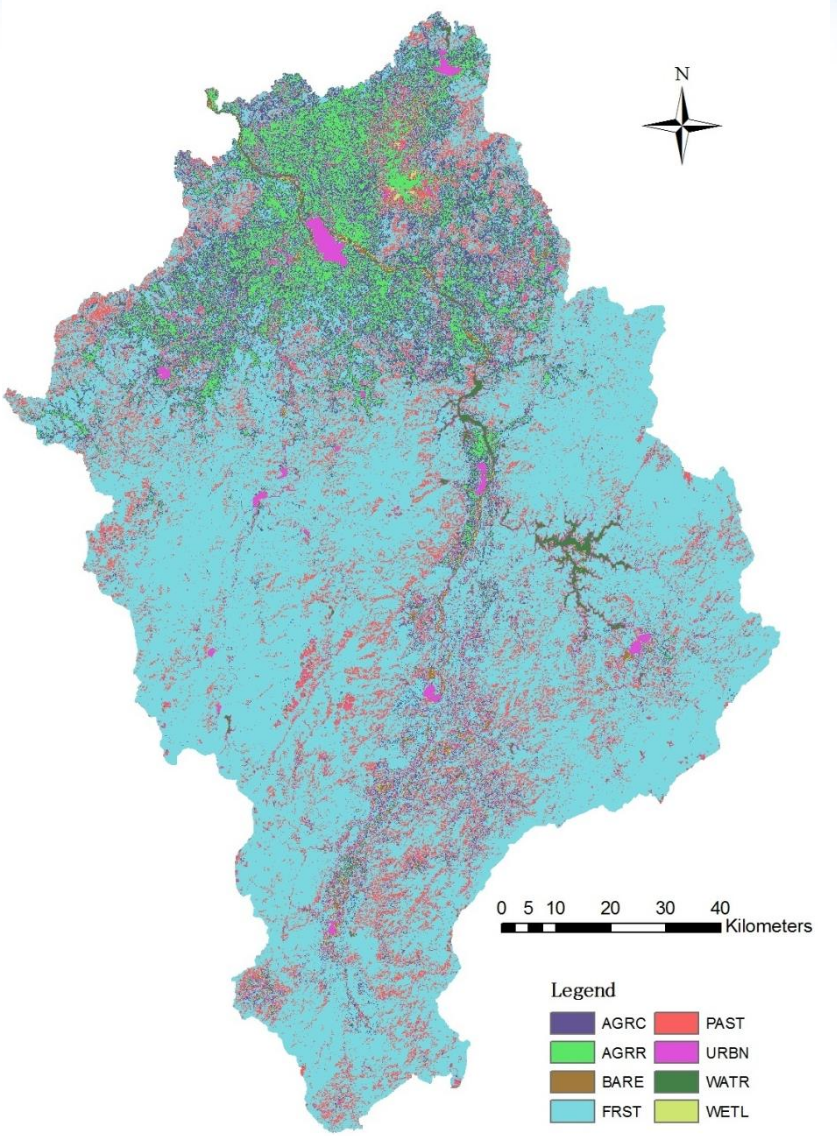


2.2 SWAT model setup for Fuhe river basin

- The land use map was derived from Landsat TM/ETM+ (1990, 30m resolution) remote sensing images.

- Land uses classifications
  - *Land-close-grown*
  - *Agricultural*
  - *Forest*
  - *Pasture*
  - *Residential*
  - *Water*
  - *Wetland*
  - *Bare land*

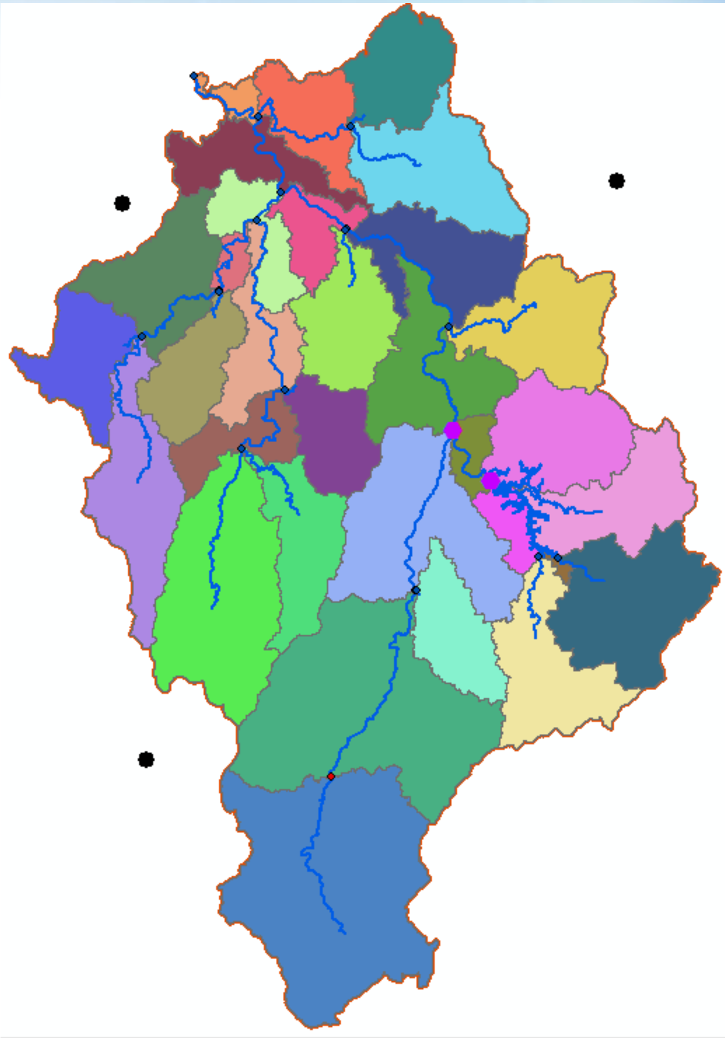
- Forest is the main land use type with 60% of the whole areas, and agricultural land is the second, which are over 15 % of the area.



2.2 SWAT model setup for Fuhe river basin

- The basin and sub-basin boundaries, as well as stream networks were delineated using the ArcHydro Tools software with ArcGIS interface based on DEM data with the resolution of 30 m.

- The Basin was divided into 31 sub-basins and 511 HRUs by overlaying soil, land use and slope maps.



2.2 SWAT model setup for Fuhe river basin

- Index to assess model performance

  - *Nash-Sutcliffe efficiency:*

$$E_{ns} = 1 - \frac{\sum_{i=1}^{n} (Q_{obs,i} - Q_{\sin,i})^2}{\sum_{i=1}^{n} (Q_{obs,i} - \overline{Q}_{obs})^2}$$

  - *Coefficient of determination:*

$$R^2 = \left[\frac{\sum_{i=1}^{n} (Q_{obs,i} - \overline{Q}_{obs})(Q_{sim,i} - \overline{Q}_{sim})}{\sqrt{\sum_{i=1}^{n} (Q_{obs,i} - \overline{Q}_{obs})^2} \sqrt{\sum_{i=1}^{n} (Q_{sim,i} - \overline{Q}_{sim})^2}} \right]^2$$

  - *Relative error index:*

$$R_e = \frac{Q_{sim} - Q_{obs}}{Q_{obs}} \times 100\%$$

2.2 SWAT model setup for Fuhe river basin

- Sensitivity analysis and parameters calibration by data in average years

- Data in the year 1981-1988 were used for sensitivity analysis.

- Parameters to calibrate

  Cn2（Initial SCS runoff curve number for moisture condition II）

  ESCO（Soil evaporation compensation factor）

  Gwqmn（Threshold depth of water for return flow）

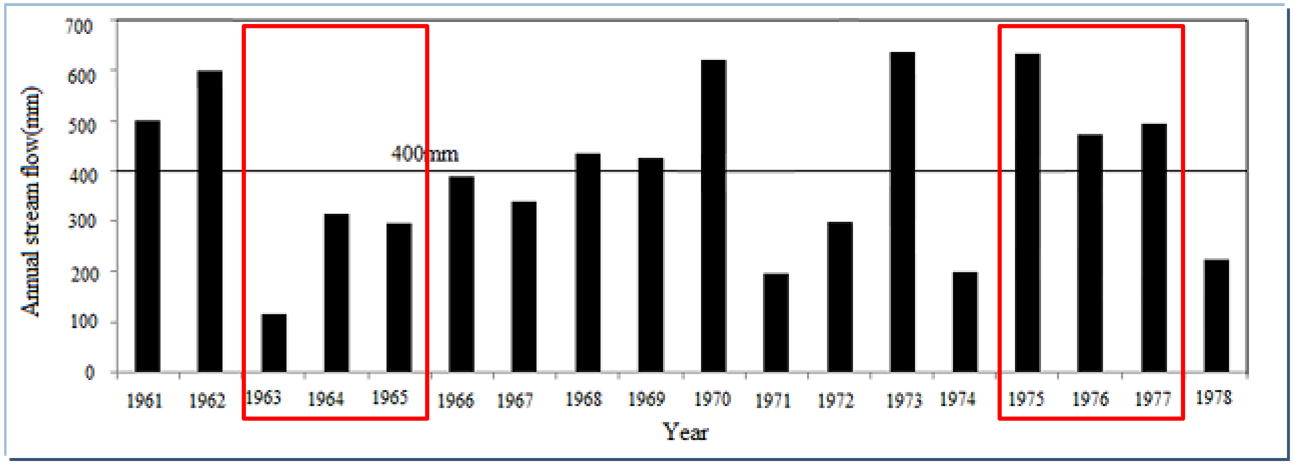
  Sol_Awc（Available water capacity of the soil layer）

  Alpha_Bf（Baseflow alpha factor）

  Ch_K2（Effective hydraulic conductivity in main channel alluvium）

2.3 Extreme climate periods selection

- **Selection of dry and wet years**



Average annual streamflow of Lijiadu hydrologic station in the year 1961-1978

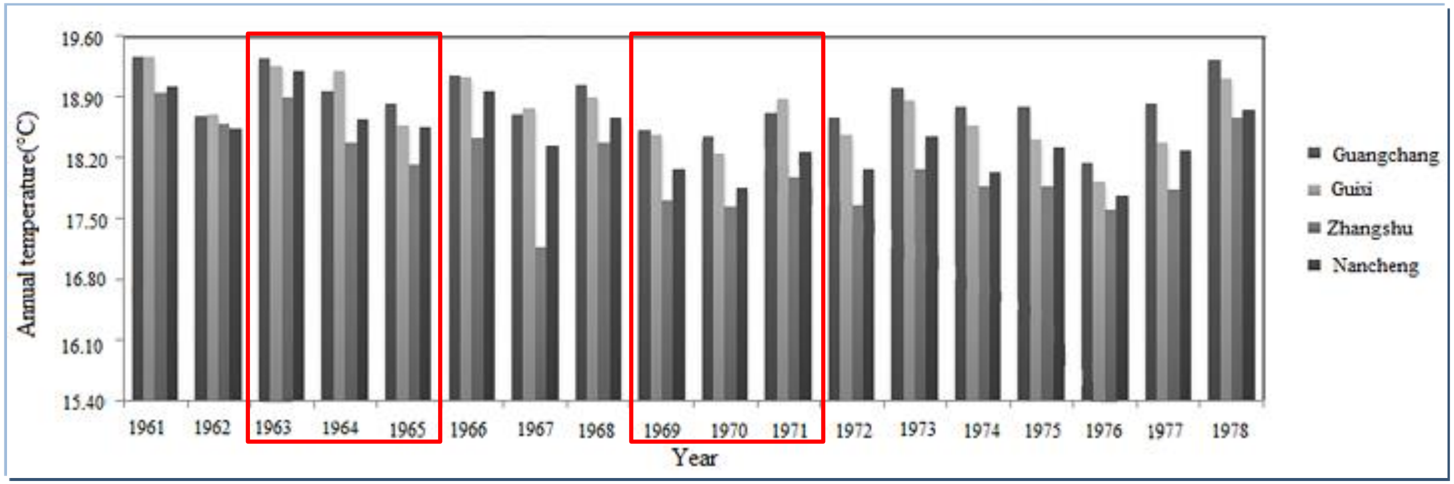
- Calculating average annual streamflow at Lijiadu hydrological station;
- Choosing continuous years in which streamflow was relative higher or lower than that in the other years.

wet year: 1975-1977

dry year: 1963-1965

2.3 Extreme climate periods selection

- **Selection of high temperature and low temperature years**



Average annual temperature of Guangchang, Guixi, Zhangshu and Nancheng weather station during the period of 1961-1978

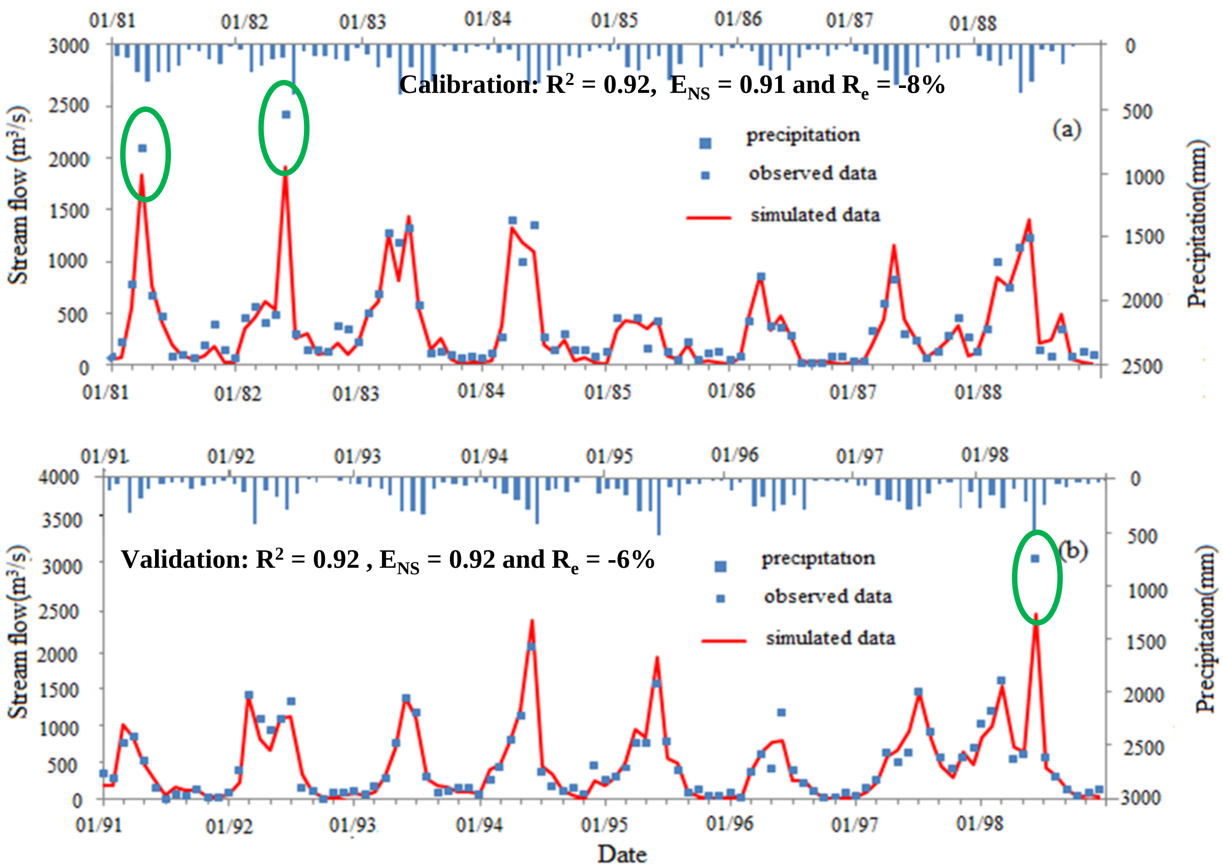
- Calculating average annual temperature at Zhangshu, Guangchang, Nanchen and Guixi weather stations;
- Selecting continuous years in which average annual temperature was relative higher or lower than that in the other years

high temperature year: 1963-1965

low temperature year: 1969-1971

3 Results and discussion

3.1 Calibration and validation by data in average years



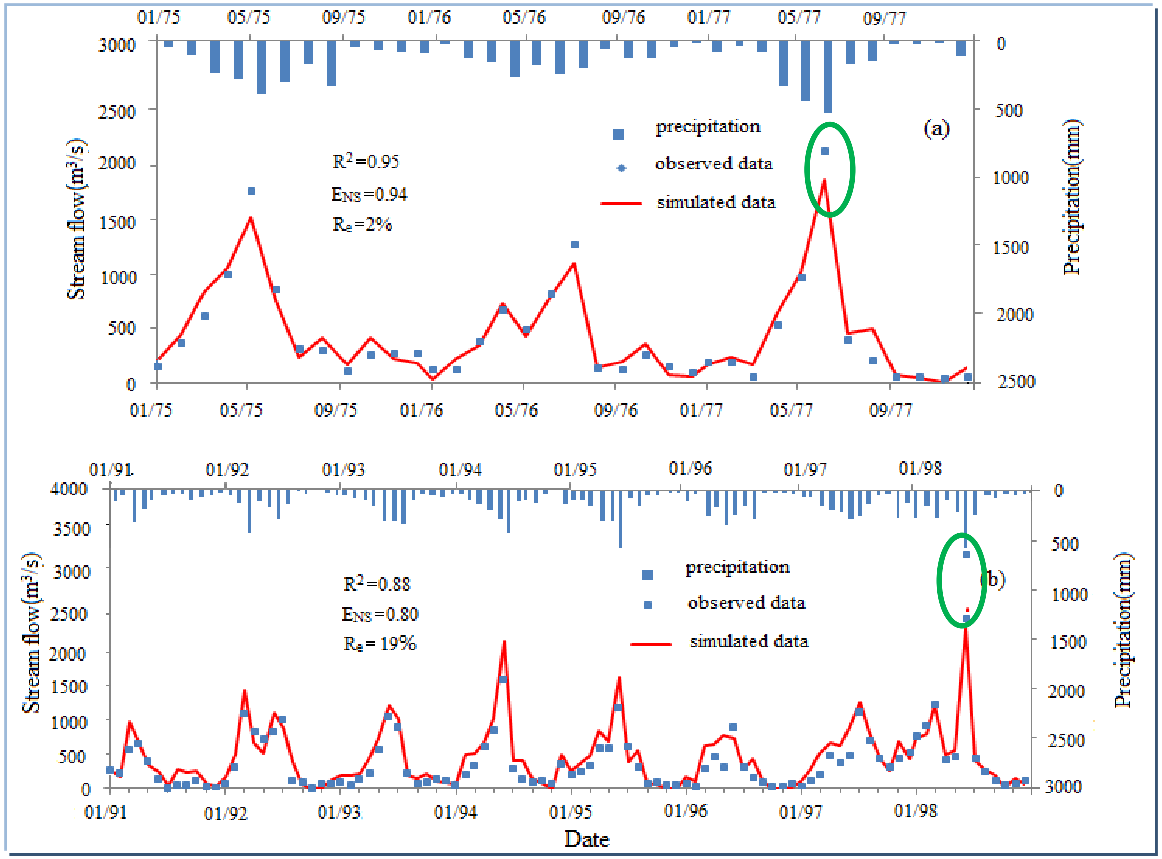
There are three bigger errors of the flow peak in April 1981 and June 1982 in calibration and in July 1998 in validation, which the biggest Re (26%) happened in July 1998, and the other two were 12% and 21%, respectively.

Floods often occurred in summer, which can cause surface runoff increase quickly, leading to a degree of errors between observed data and simulated results.

Underestimating evapotranspiration may be one of the reasons for overestimating stream flows.

3.2 Model validation by extreme climate condition

Model calibration and validation in wet years



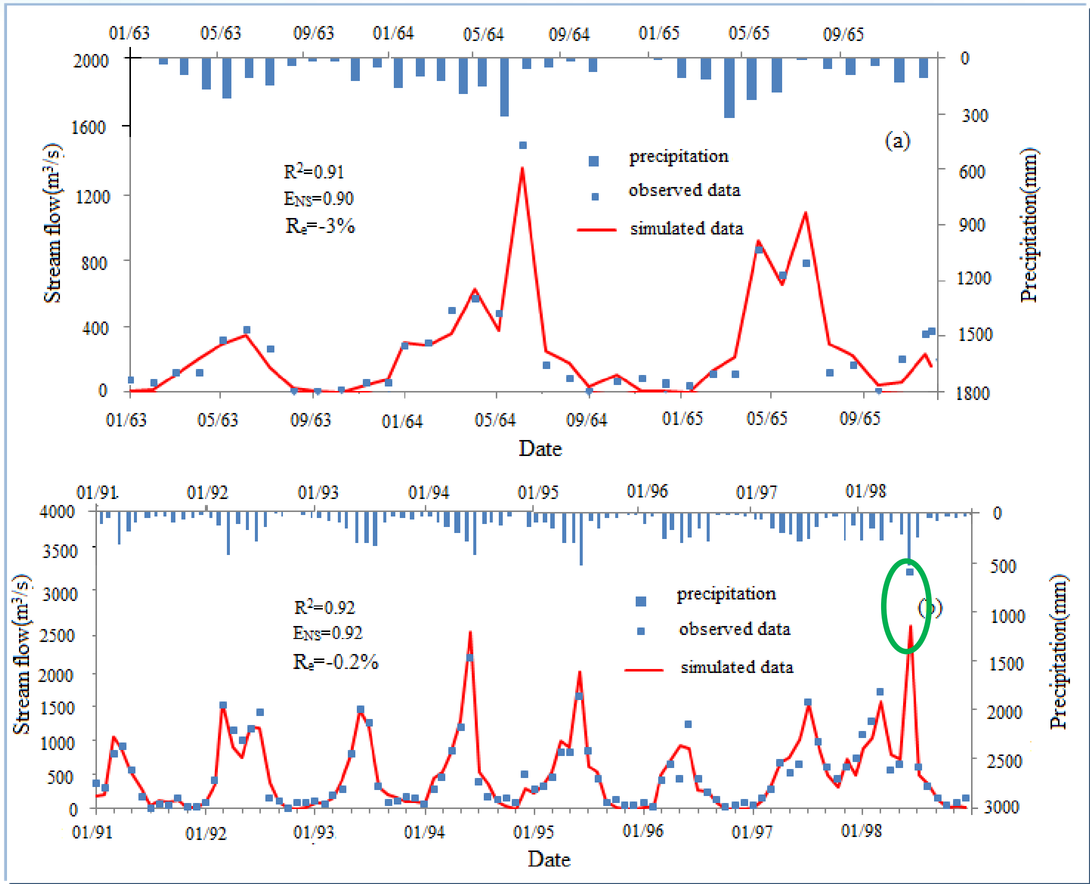
- A larger error appeared in June 1977 which may be caused by underestimating evapotranspiration in summer .
- During the validation period, the SWAT model overestimated the stream flow with the R_e 19%, and especially in the flow peaks, the SWAT model more often overestimated stream flow.

The model built had certain stability in wet years.

R^2 , $E_{NS} \geq 0.8$ and $R_e \leq 19\%$.

3.2 Model validation by extreme climate condition

Model calibration and validation in dry years

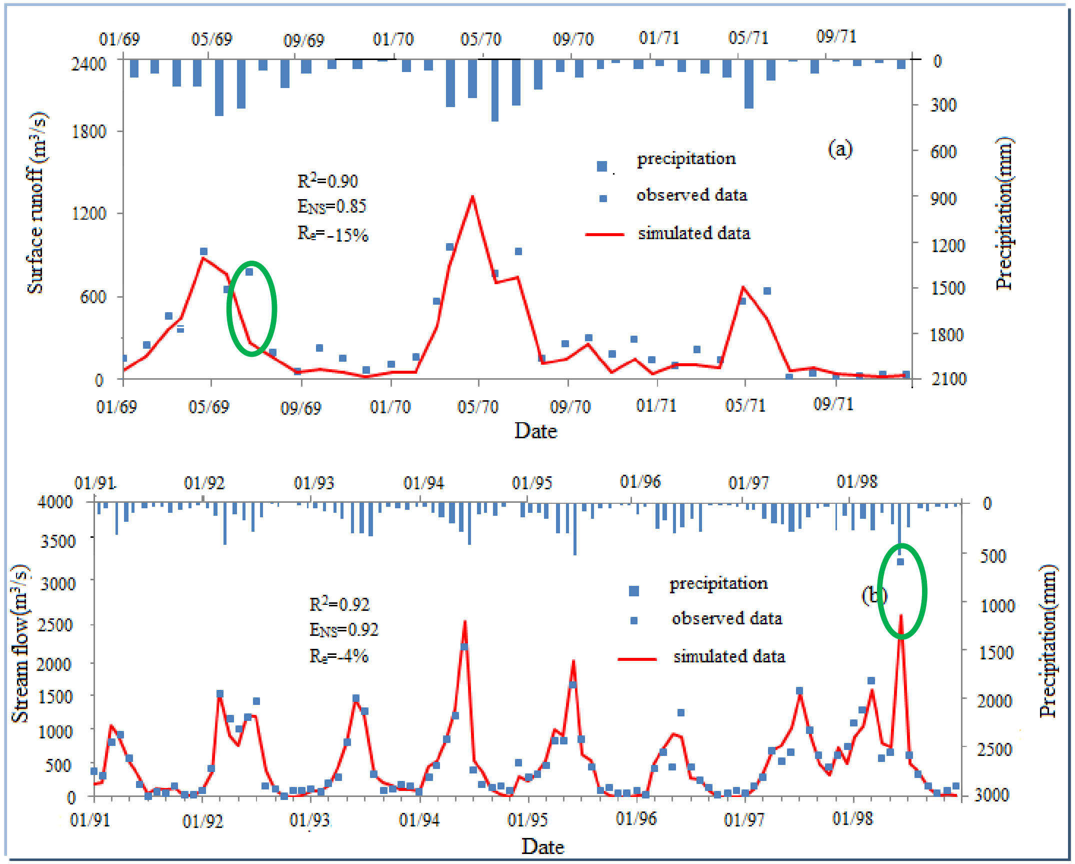


- SWAT model tended to underestimate the stream flow indicated by R_e with -3% and -0.2%, respectively .
- In the validation, there was a larger deviation (22%) occurring in flow peaks in June 1998.
- The model was calibrated equally well to satisfactorily simulate the stream flow, which can be proved by the correlation coefficient with more than 0.90.

The model in dry year were suitable for assessing the hydrologic process of potential climate change.

3.2 Model validation by extreme climate condition

- **Model calibration and validation in low temperature years**



- Only low temperature year were used to verify the model because high temperature years and dry year were in the same period.
- The largest discrepancy (67%) occurred in July 1969, which was mainly caused by the floods.
- The trend of simulated results complied with observed data in validation period, except for a large difference (23%) in June 1998.

And the model was also proved to be stable to a degree, with the E_{NS} and R^2 more than 0.85, R_e -15% and -4%, respectively.

Conclusions

- From model calibration and validation under extreme conditions in history, It is found that the discrepancies between observed and simulated data mainly occurred in flow peaks.

- The dry-years calibration of the model performed much better during the validation period (1991–1998) (R_2=0.92, E_{ns}=0.92, R_e= -0.2%) than did the average-years calibration.

- In general, the SWAT model was proved to be stable for predict the hydrologic response of the climate change under extreme climate conditions. It can be suitable to simulate hydrology under future climate change with a large variation range.

Thank you !

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