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Hydrology Prediction and Validation in Poyang Lake Ungauged Zone Using SWAT Model

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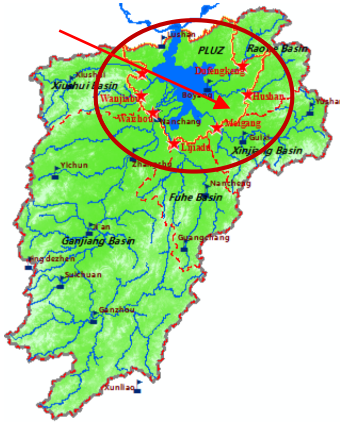
Introduction

- **Poyang Lake, the largest freshwater lake in China, has suffered from extreme droughts and floods in recent decades. So to fully understand the volume of water resources of the Poyang Lake basin is important .**
- **However, a buffer area around thef Poyang Lake called Poyang Lake Ungauged Zone (PLUZ) has not been gauged for any streamflow records. What's more, PLUZ has an area of about 19,000 km^2, amounting to 12% of the whole basin.**
- **No streamflow records in PLUZ restrains hydrological engineers and scientists to predict the volume of water resource and analyze the water balance for the Poyang Lake basin.**



Therefore, it is important to develop a method to predict streamflow in such a data scarce area.

2.1 Study Area

- **PLUZ (Poyang Lake Ungauged Zone)**

  Position: Located between the five river systems and Poyang Lake

  Area: about **19,000 km2,** amounting to 12% of the whole basin

  Topography: 0-5degree(>80%) alluvial plain

- **the Poyang Lake basin excluding Poyang Lake which contains PLUZ**

  Area: about 162,000 km2

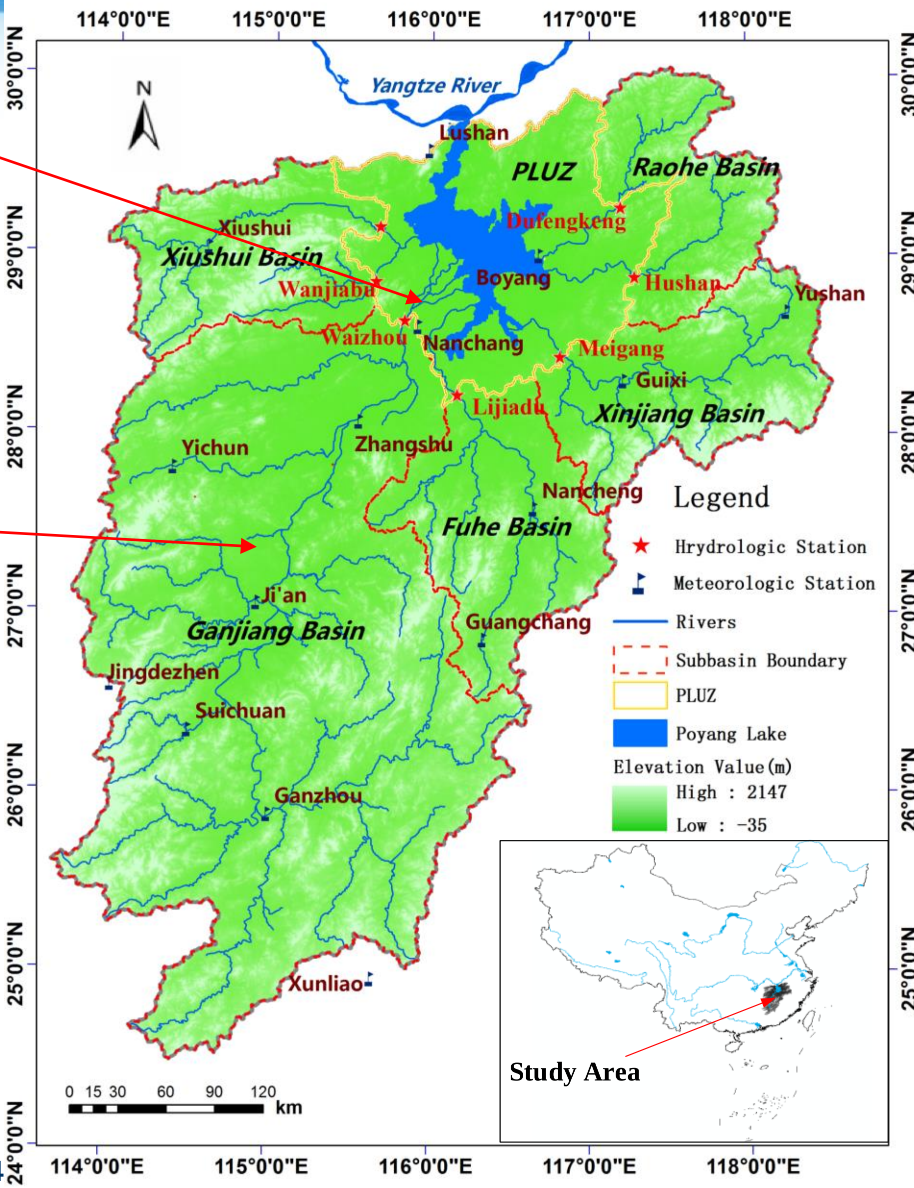
  Annual Runoff: 1.2×10^{11} m^3/year

  Rainy days: 160/year

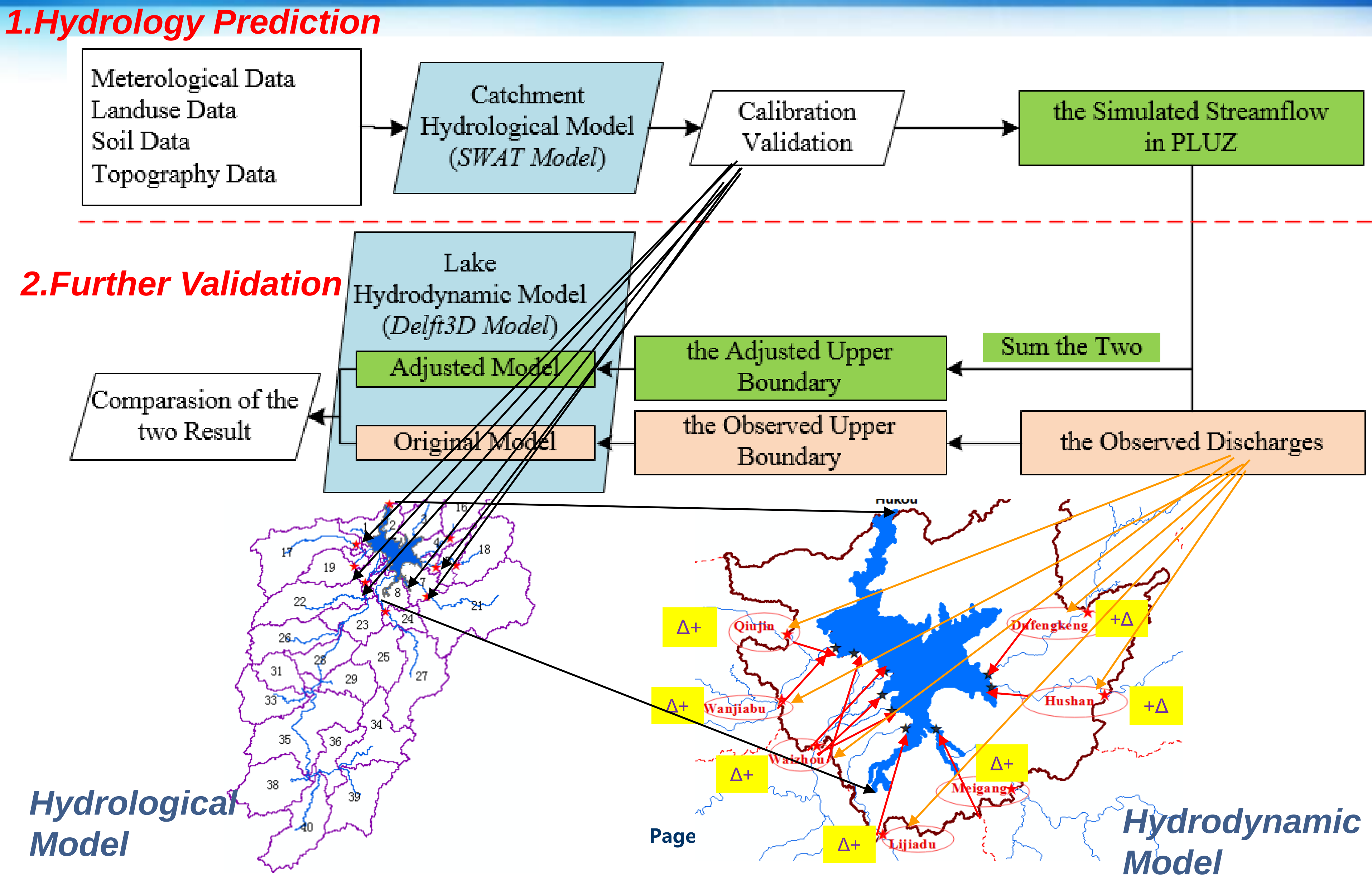
  Precipitation: 1680mm/year

  Mean temperature: 17.5℃

  Hydrological stations: Dufengkeng、Lijiadu、Wanzhou、Meigang、Wanjiabu、Hushan

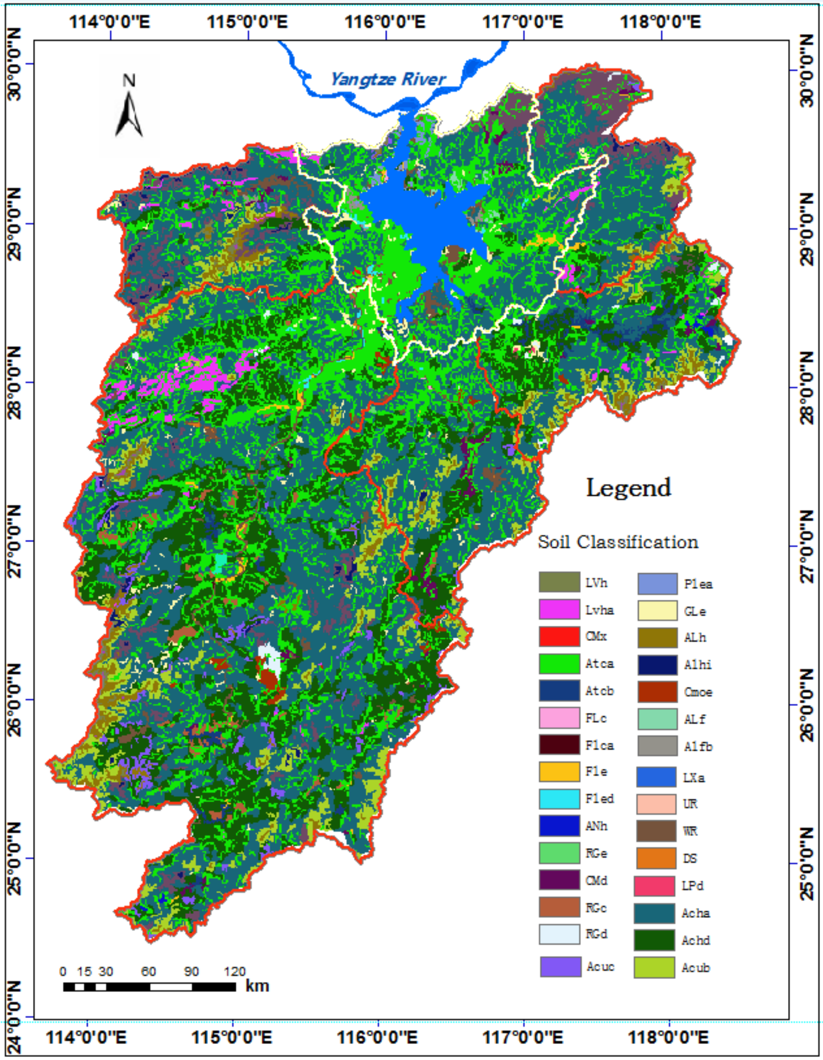


2.2 Methods


1.Hydrology Prediction
Meterological Data
Landuse Data
Soil Data
Topography Data
Catchment Hydrological Model (SWAT Model)
Calibration Validation
the Simulated Streamflow in PLUZ
2.Further Validation
Lake Hydrodynamic Model (Delft3D Model)
Adjusted Model
Original Model
Comparasion of the two Result
the Adjusted Upper Boundary
Sum the Two
the Observed Upper Boundary
the Observed Discharges
Qiujin
Dufengkeng
Wanjiabu
Hushan
Waizhou
Meigang
Lijiadu
Δ+
+Δ
Hydrological Model
Hydrodynamic Model

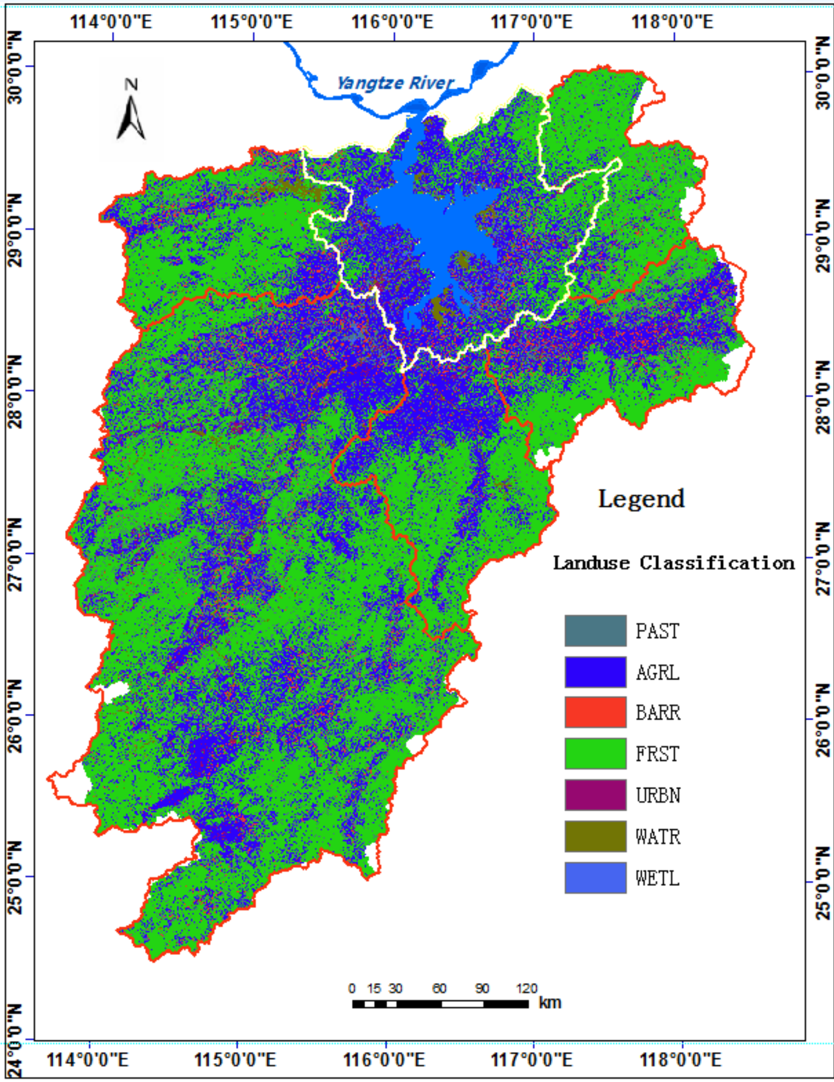
2.3 Hydrological Prediction: SWAT Model Setup for the Poyang Lake basin

- 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.
- Soil Type
  - Haplic Acrisols 56.07%
  - Cumulic Anthrosols 22.36%
  - Humic Acrisols 11.10%
  - Haplic Alisols 2.86%
  - Haplic Luvisols 1.81%
  - Others 6.80%



2.3 Hydrological Prediction: SWAT Model Setup for the Poyang Lake basin

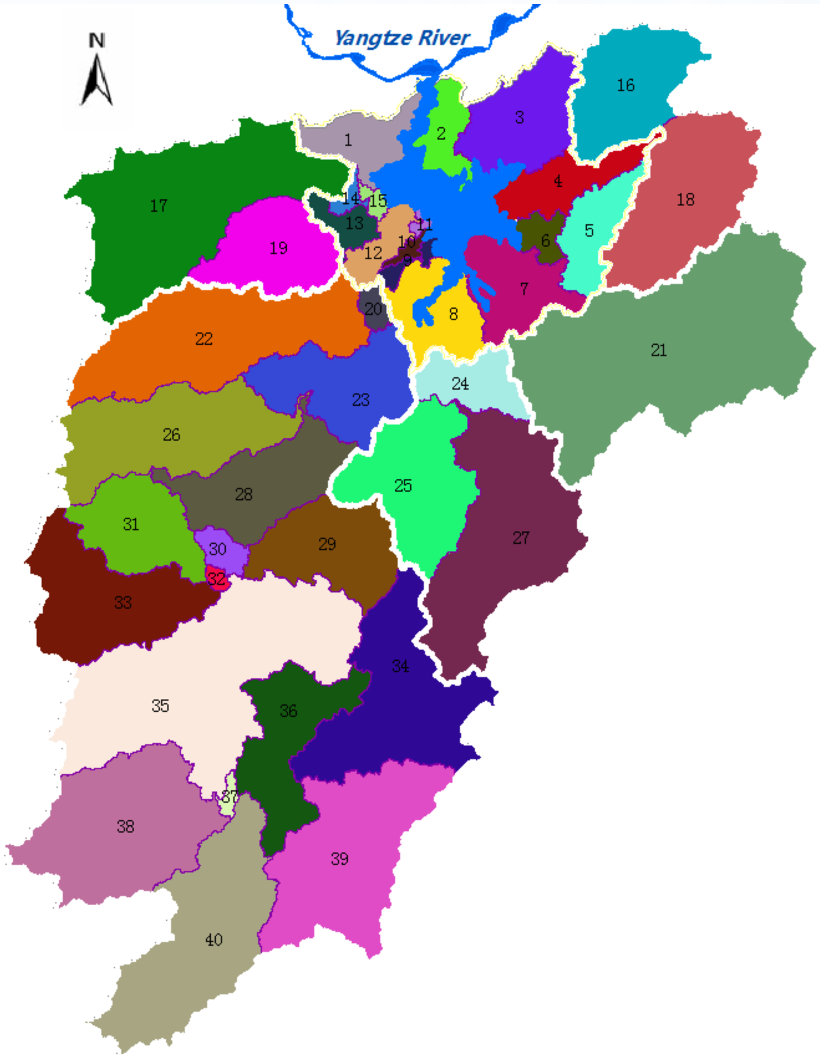
- The land use map was derived from Landsat TM/ETM+ (1990, 30m resolution) remote sensing images.
- Land uses classifications
  - Forest(*58.86%*)
  - Agricultural(*28.41%*)
  - Pasture(*10.96%*)
  - Bare land(*2.54%*)
  - Urban(*1.91%*)
  - Water(*1.70%*)
  - Wetland(*0.61%*)
- Forest is the main land use type with 58.86% of the whole areas, and agricultural land is the second, which are over 28.41 % of the area.



2.3 Hydrological Prediction: SWAT Model Setup for the Poyang Lake basin

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

- The Basin was divided into 40 sub-basins and 1197 HRUs by overlaying soil, land use and slope maps.



2.3 Hydrological Prediction: SWAT Model Setup for the Poyang Lake 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:*

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

- *Relative error index:*

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

2.3 Hydrological Prediction: SWAT Model Setup for the Poyang Lake basin

- Sensitivity analysis ,calibration and validation
  - Sensitivity analysis and calibration by data from 2000-2005

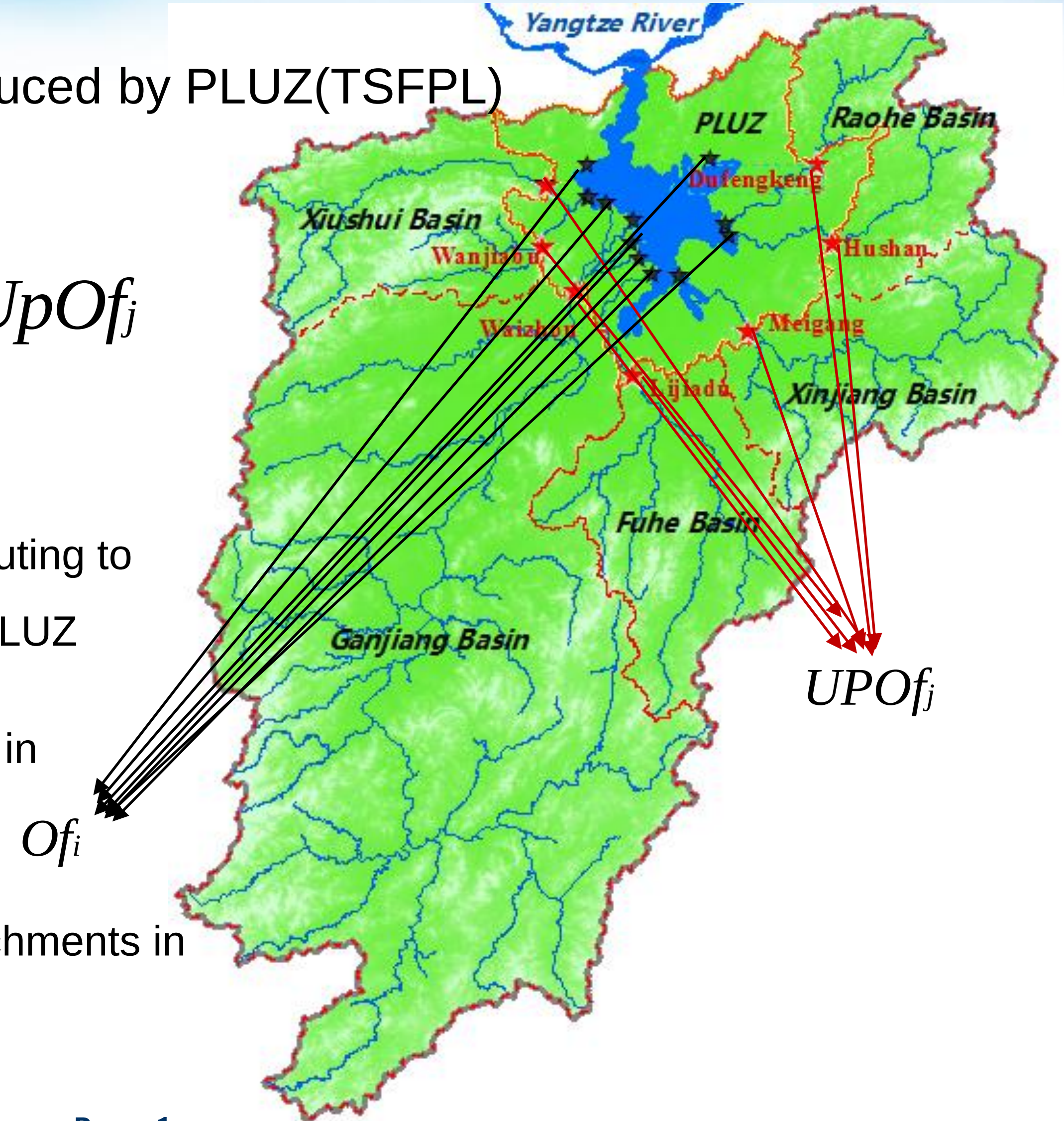
    Validation by data from 2006-2011
  - Parameters to calibrate(11)
    - CN2
    - GW_DELAY
    - CH_N2
    - SMFMN
    - TIMP
    - CANMX
    - CH_K2
    - OV_N
    - RCHRG_DP
    - GWQMN
    - ALPHA_BNK

2.3 Hydrological Prediction:
SWAT Model Setup for the Poyang Lake basin

- Calculate the streamflow produced by PLUZ(TSFPL)

$$TSfPLUZ = \sum_{i=1}^{n} Of_i - \sum_{j=1}^{m} UpOf_j$$

- $TSfPLUZ$ Total streamflow contributing to inflow of Poyang Lake produced by PLUZ
- Of_i outflow of each subcatchments in PLUZ
- $UPOf_j$ outflow of upstream subcatchments in PLUZ

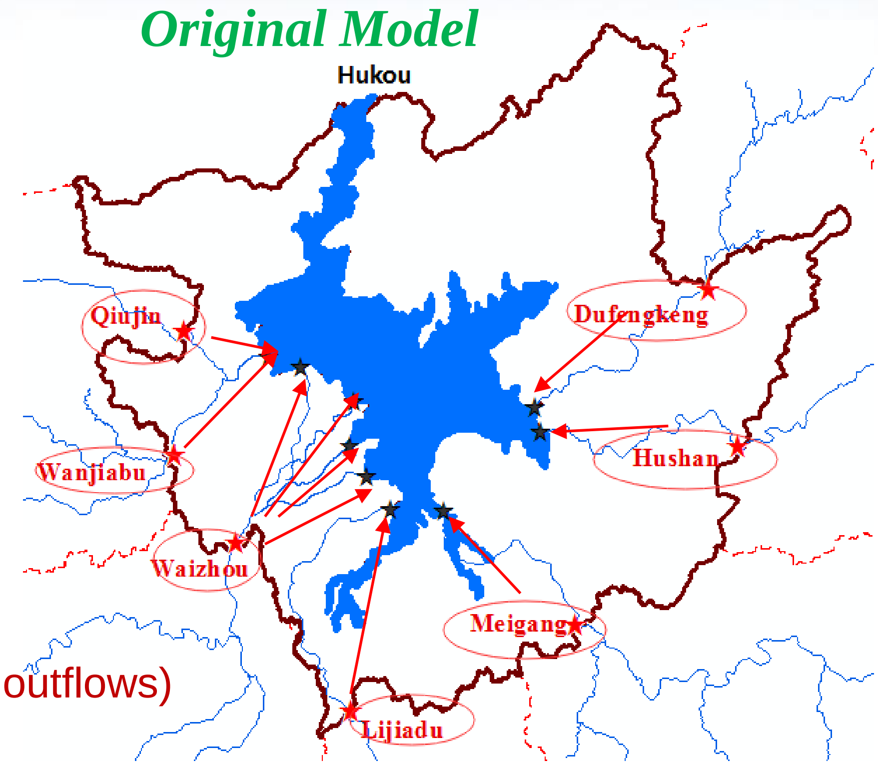


2.4 Further Validation by Hydrodynamic Model

- Hydrodynamic Model(Delft3D)

Delft3D has the ability to simulate water-level variation by inputting discharge at inlets and water level at the outlet.

- Input data
  - Lake topography(1990)
  - Lake shorelines(Modis Image in 1998)
  - Water level at Hukou (2001-2010)
  - Data series of inflow discharge (five rivers outflows)



- Output data

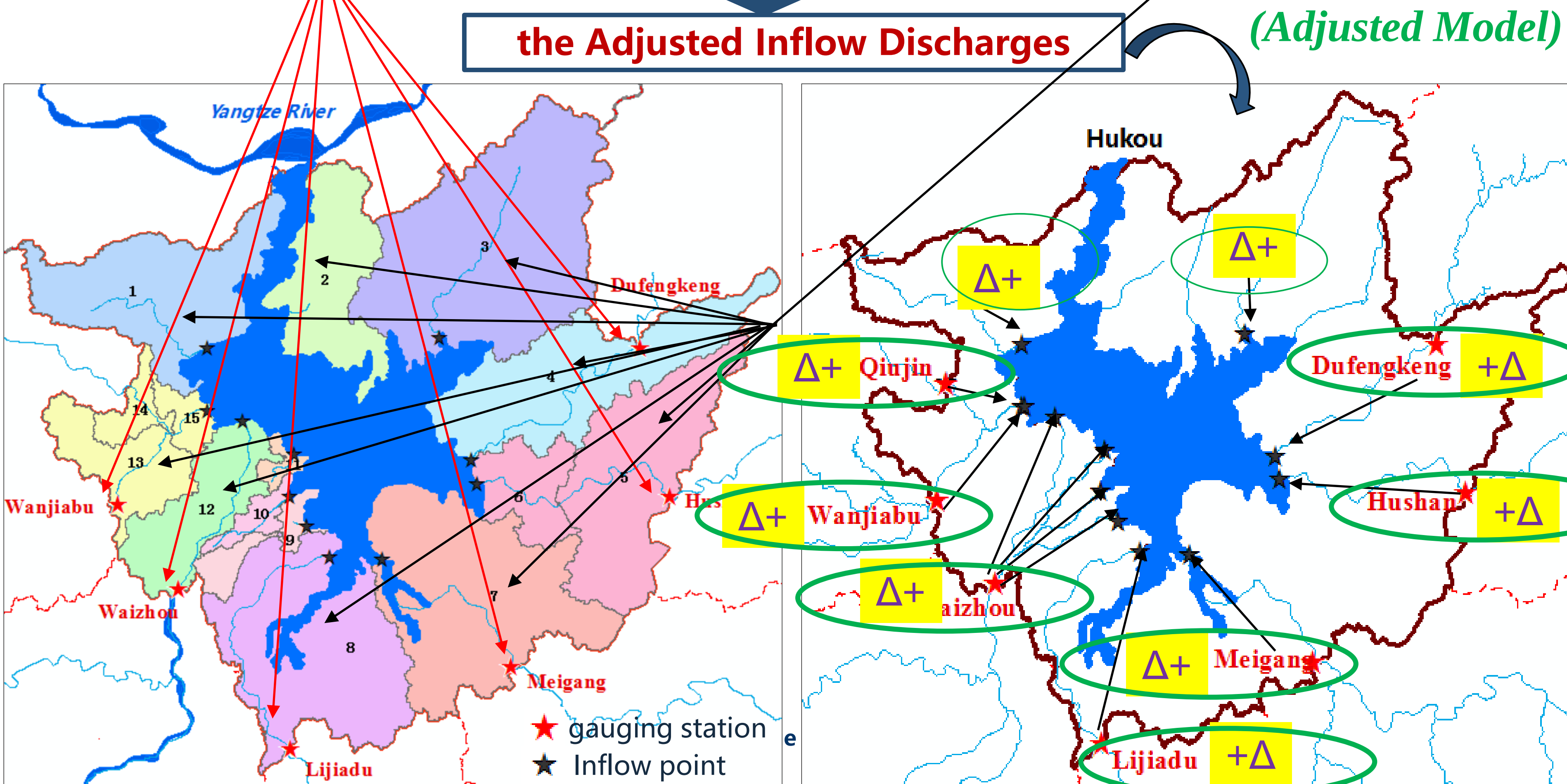
Instantaneous discharges at Hukou is much less than the observed because of the streamflow in PLUZ.

2.4 Further Validation by Hydrodynamic Model

- Adjust the inflow discharges by adding the streamflow of the PLUZ

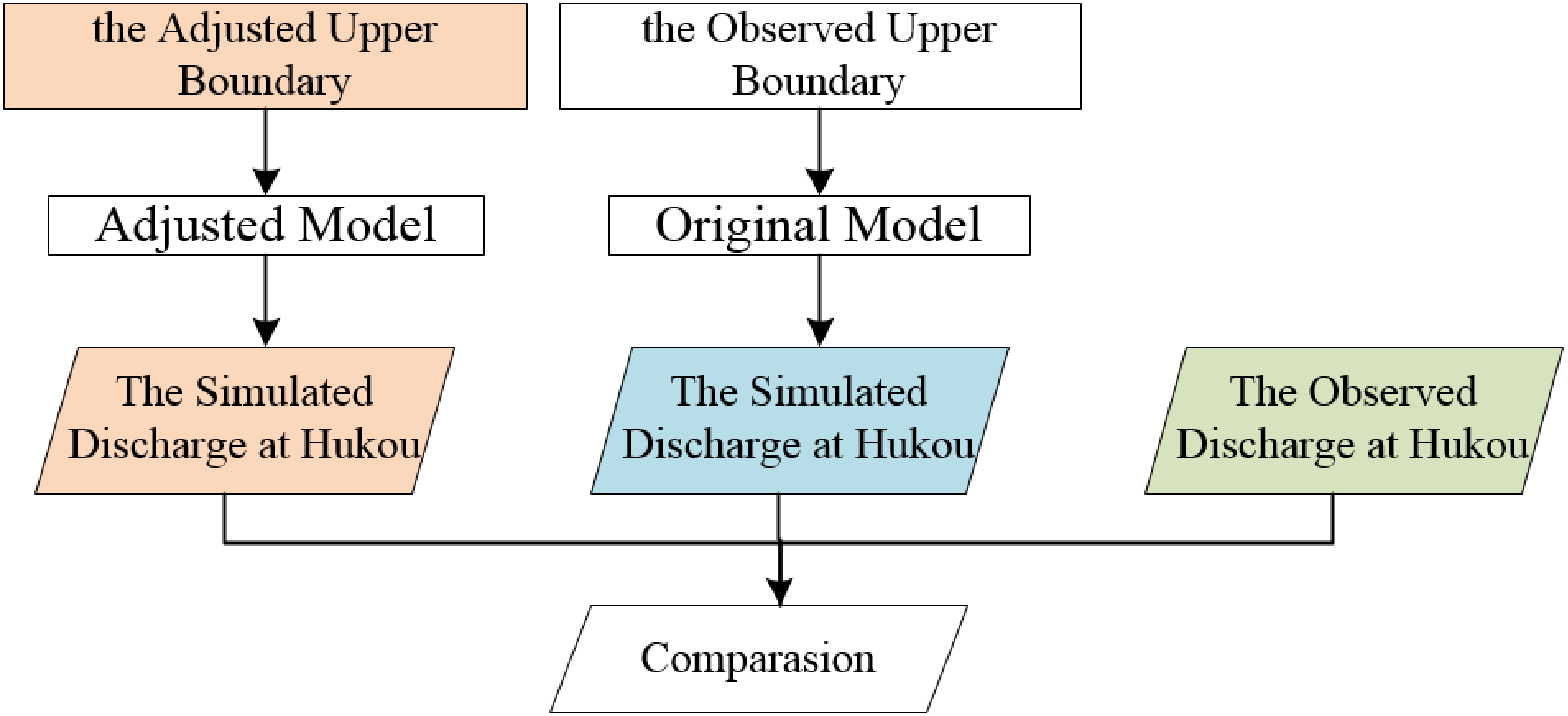
Discharges at 7 gauging stations + **Streamflow of the PLUZ(1-15sub-basins)**

the Adjusted Inflow Discharges



2.4 Further Validation by Hydrodynamic Model

- **Access the model performance with the adjusted discharge**



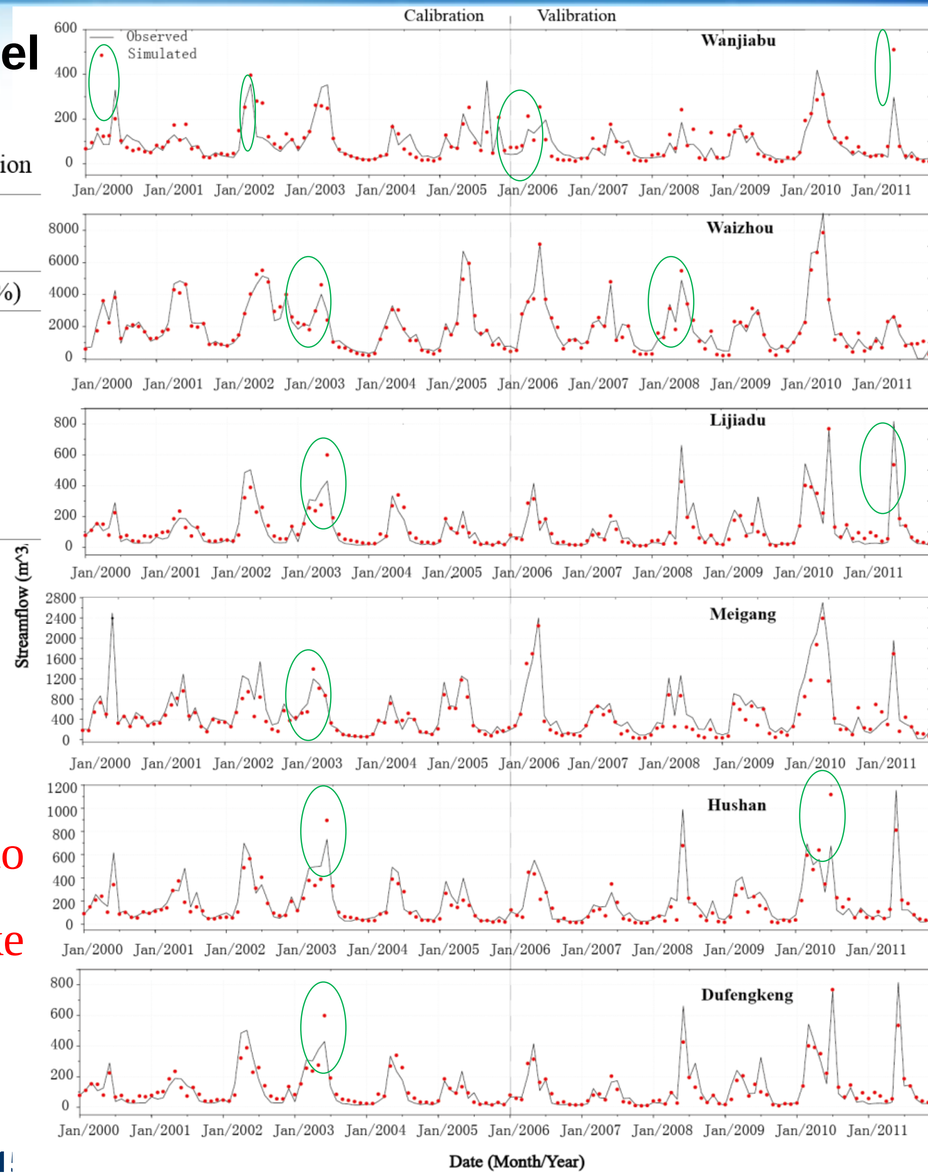
3 Results and discussion

■ Calibration and validation of SWAT Model

Table 1 Quantitative Assessment of Model Calibration and Validation for Streamflow Simulation

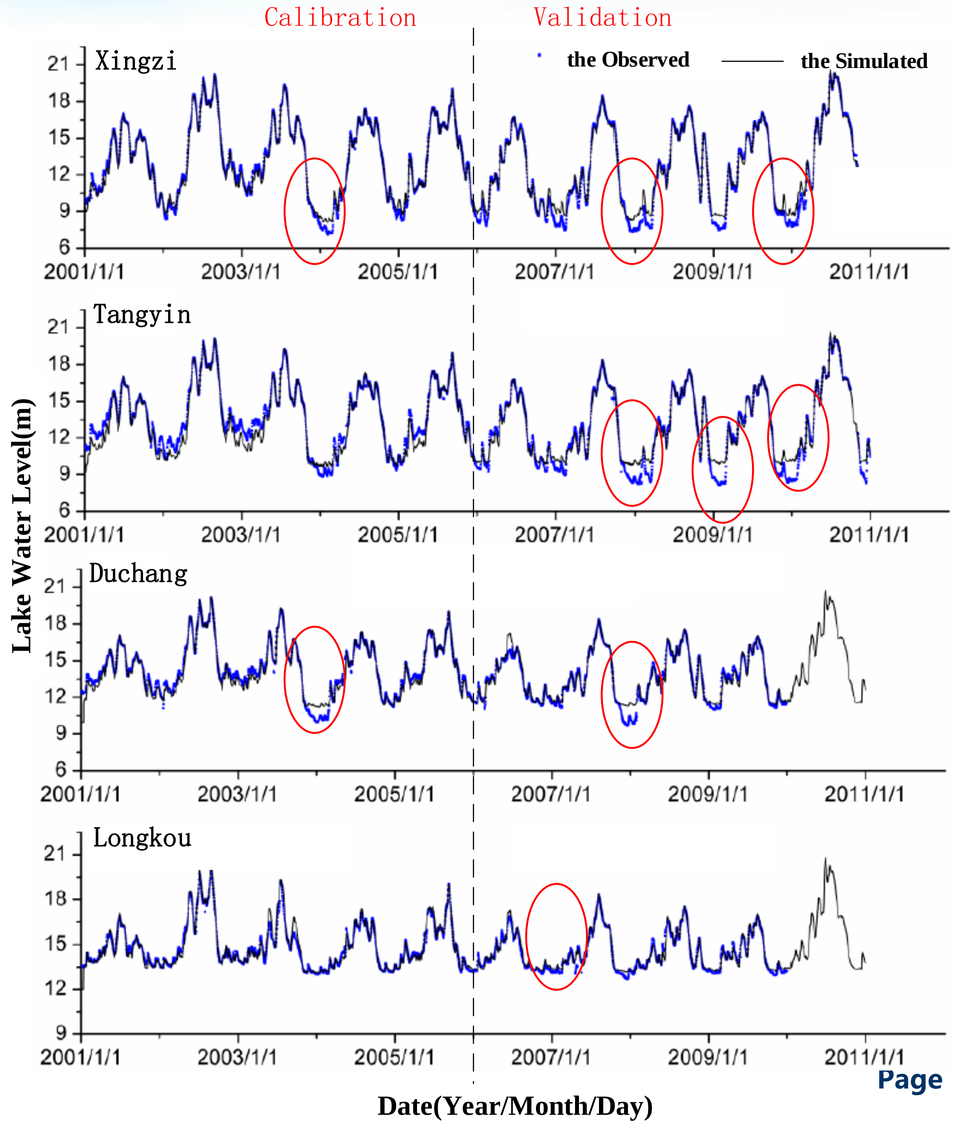
Gauging Station	River Sub-catchment	Calibration(Jan.2000-Dec.2005)			Validation(Jan.2006-Dec.2011)		
		R^2	Ens	PBIAS(%)	R^2	Ens	PBIAS(%)
Wanjiabu	Xiushui	0.63	0.61	-0.2	0.78	0.76	9.4
Waizhou	Ganjiang	0.94	0.93	3.2	0.95	0.93	6.5
Lijiadu	Fuhe	0.84	0.82	-9.4	0.88	0.85	-16.8
Meigang	Xinjiang	0.89	0.89	1.1	0.91	0.90	10.0
Hushan	Raohe	0.81	0.78	14.2	0.76	0.75	13.9
Dufengkeng	Raohe	0.80	0.80	-4.7	0.83	0.80	9.4

- the Peak Discharge(not accurately simulated)
- Wanjiabu Gauging Station(0.63,0.61)
- The model was also proved to be effective to simulate catchment discharge in Poyang Lake Basin, with R^2, Ens > 0.75, |PBIAS| < 17% .



3 Results and discussion

Calibration and Validation of Deflt3D Model (the Original Model)

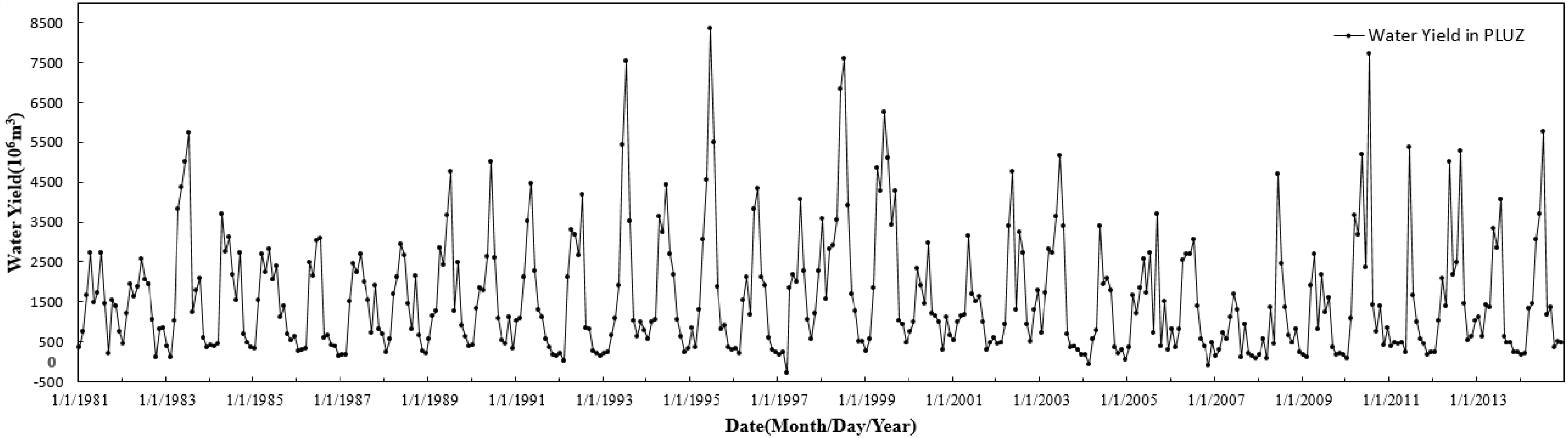


- High value of R^2 (0.953 ~ 0.978) and low value of |PBAIS| (1.14%~3.99%) indicates a satisfactory agreement between the observed and the simulated lake water levels .
- Both amplitude and phase are reasonably represented.
- The main discrepancies between the simulated and observed lake water levels occurred during periods of low water levels. (<1.5m)
- In general, Delft3D Model has the ability to simulate the outflow of the lake.

3 Results and discussion

Hydrological Prediction in PLUZ

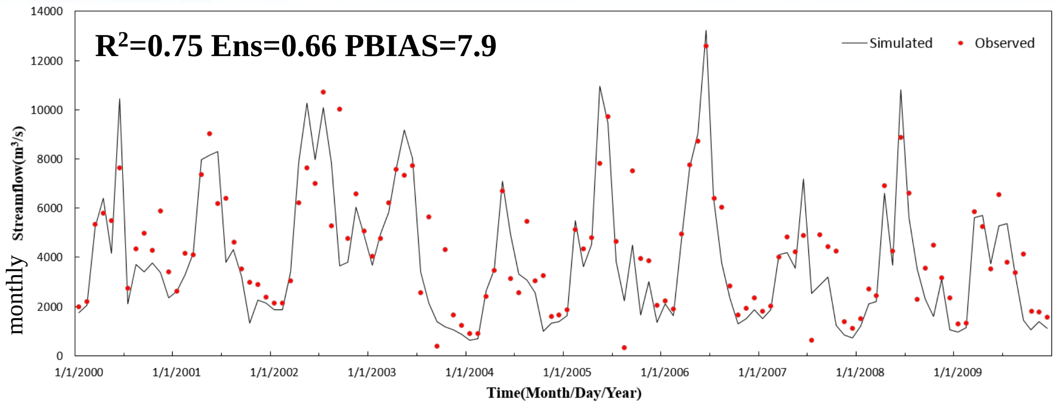
Monthly water yield in PLUZ from 1981 to 2014

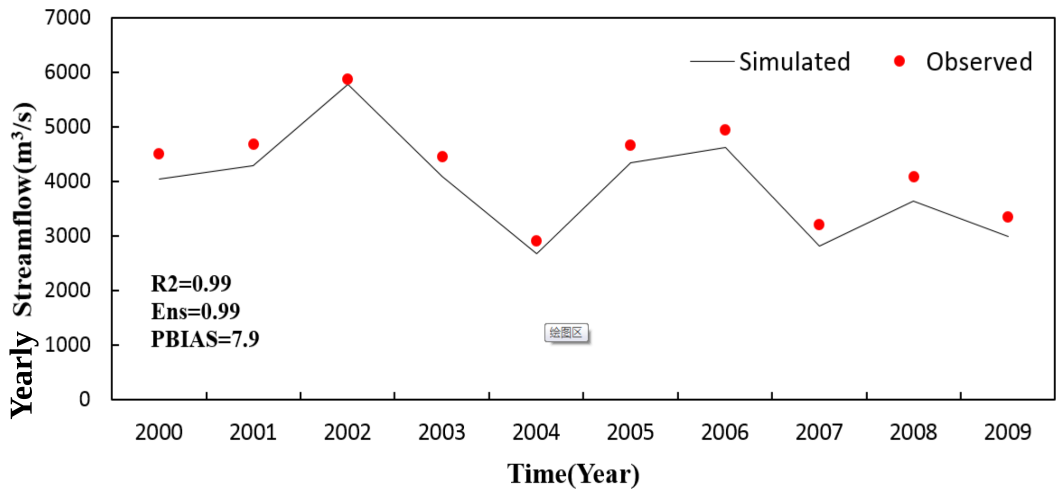


- Monthly water yield from 1981 to 2014 revealed significant seasonality.
- Extreme Flood and Severe Drought Event .
- The cumulative annual water yield in PLUZ totals 15.2KM^3(11.4% of that from whole Poyang Lake Basin) averagely.

3 Results and discussion

Hydrological Prediction in PLUZ





Comparison of the simulated (the sum of the simulated streamflow in PLUZ and observed streamflow from the five major subbasins) and the observed at Hukou

- **Comparison of Monthly Streamflow**

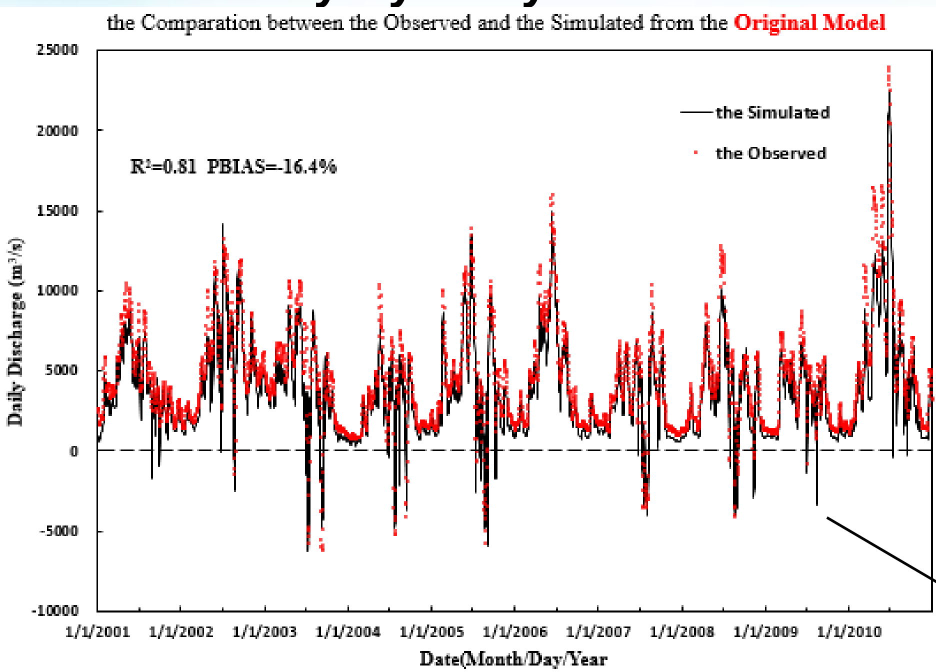
The relationship between the simulated and the observed at Hukou is not good (**R^2=0.75 Ens=0.66 PBIAS=7.9**) because of Poyang Lake's role in storing water at high flow period and contributing water at low flow period.

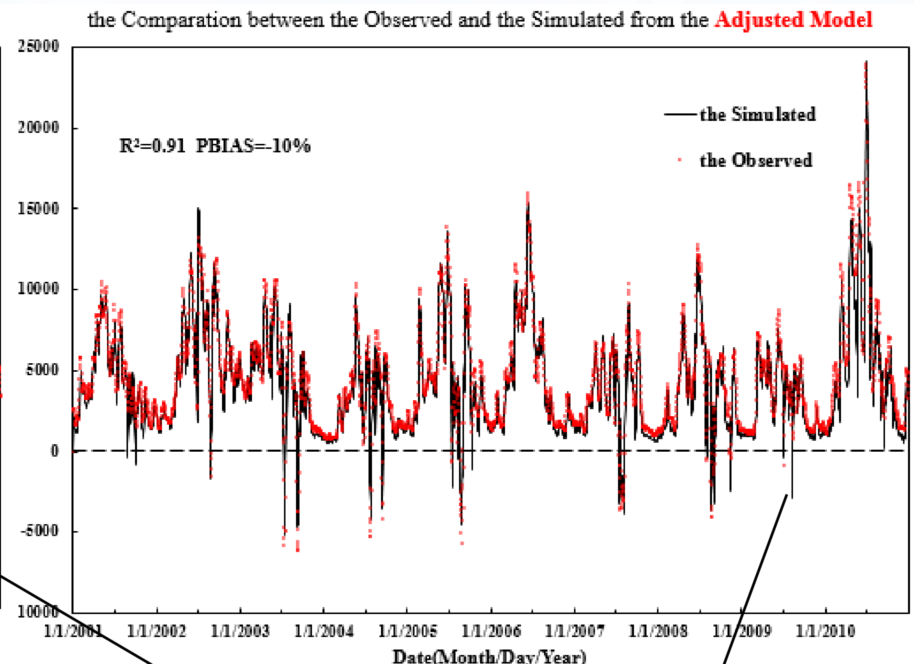
- **Comparison of Yearly Streamflow**

The relationship between the simulated and the observed at Hukou shows a close agreement (**R^2=0.99 Ens=0.99 PBIAS=7.9**) because that storage capacity of Poyang Lake stays constant in terms of inter-annual variation.

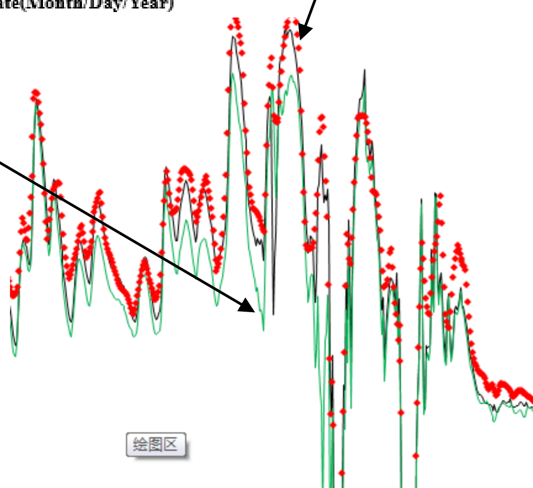
3 Results and discussion

Validation by Hydrodynamic Model





- The blocking effect of Yangtze River is observed in the both figure. However, discrepancies between the observed and simulated in original model is large than that in the adjusted model.
- The accuracy of lake discharges was improved in the Adjusted Model when the inflows from PLUZ was taken into consideration (R^2 = 0.91 and PBIAS =-10% **VS** R^2 = 0.81 and PBIAS = -16.4% when inflow from PLUZ is neglected).
- The improved result demonstrate that the simulated streamflow in PLUZ by the SWAT Model is reasonable.



Conclusions

- The cumulative annual water yield in PLUZ totals 15.2KM^3, occupying 11.4% of that in the whole Poyang Lake Basin averagely, a great contribution, which has a great influence on drought/flood in the Poyang Lake basin.
- And using the SWAT Model to simulate streamflow in PLUZ is reasonable.
- In general, the study is aimed at predicting the streamflow from the ungauged area using SWAT model and validating the result by hydrodynamic model. The outcome of the paper will benefit hydrological engineers and scientists to study the extreme droughts and floods in the Poyang Lake basin.

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Thank you !

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