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Variation of Hydrologic Process and Ecologic Evolution of Wetland in Poyang Lake under Changing Environment

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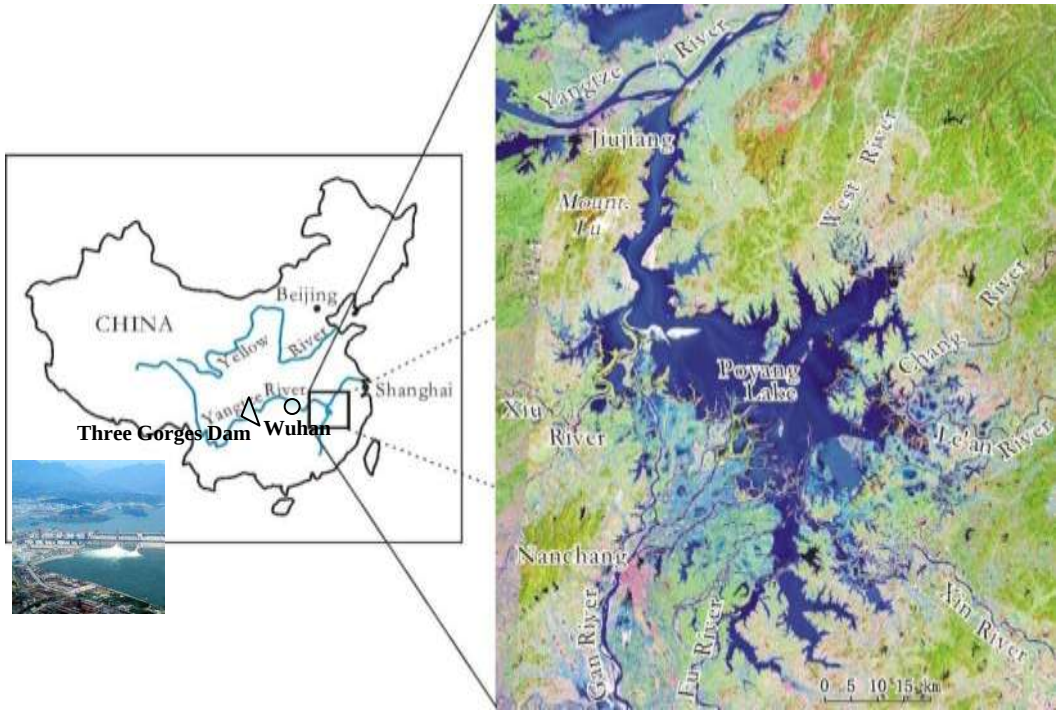
Outline

- **Introduction on Poyang Lake**
- **The Variation of Hydrologic Process**
- **Eco-hydrologic Variation in Wetland and its Response to the Building of the Gate**
- **Conclusions**

1. Introduction on Poyang Lake

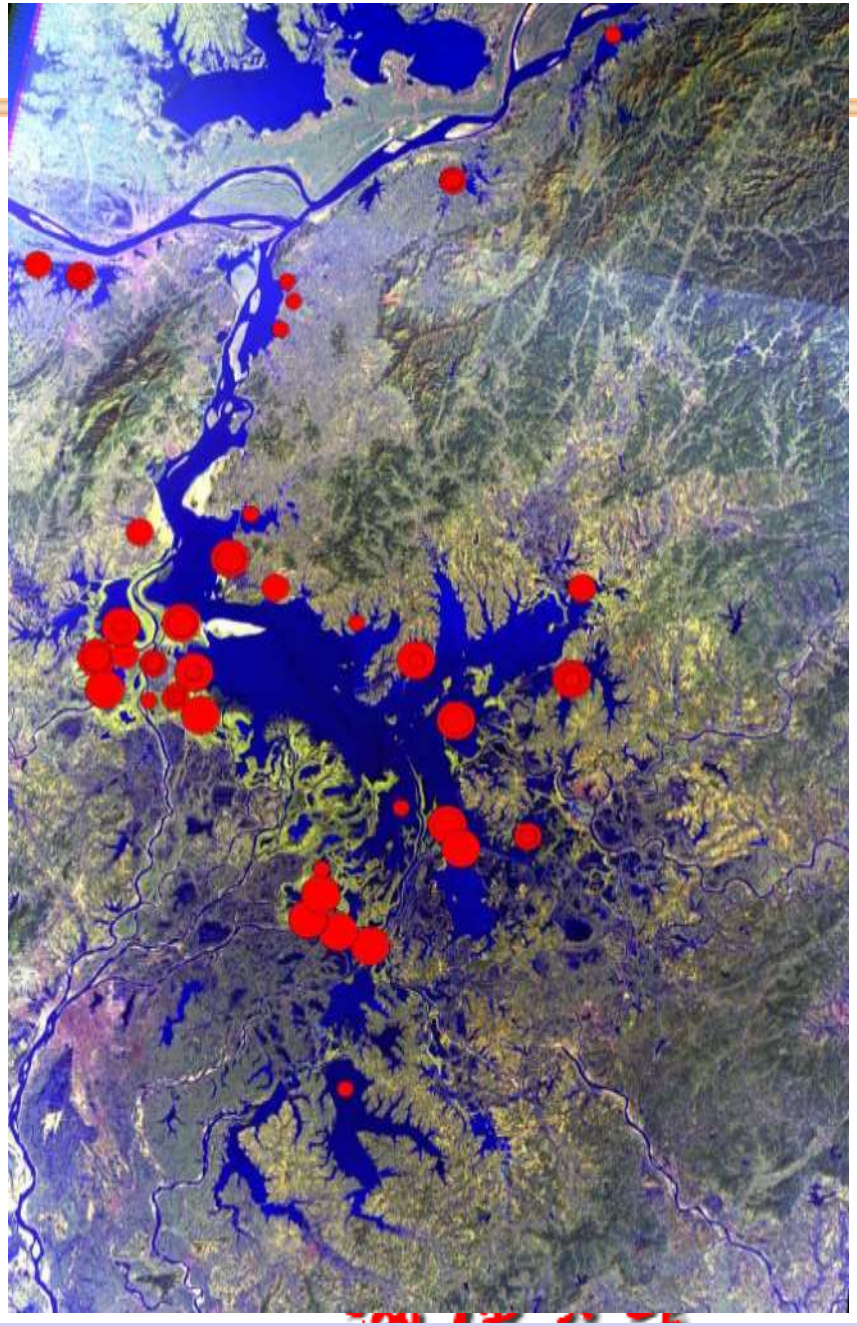


- **Poyang Lake, the largest freshwater lake in China, is located in the south bank of middle branch of Yangtze River and the north of Jiangxi province.**

- **Poyang Lake receives streamflow mainly from five rivers: Xiu R.(Xiushui), Gan R.(Ganjiang), Fu R.(Fuhe), Xin R.(XinJiang) and Rao R.(Raohe), and exchanges streamflow with Yangtze River. The total area of the catchments is 16.22×10^4 km^2, occupying the 97.3% of Jiangxi Province.**

1. Introduction on Poyang Lake

- **The area of the lake grows up to 4000 km^2 during rainy season while during dry season the area of the lake shrinks to less than 1000 km^2.**
- **Poyang Lake is one of the most important wetlands in the world, where the Poyang Lake National Nature Reserving Region and Nanjishan National Natural Reserveing Region locate. The wetland provides a habitat for many endangered species.**



Distribution of white crane in the wetland

1. Introduction on Poyang Lake

High frequency of Flood and Drought disaster due to climate change

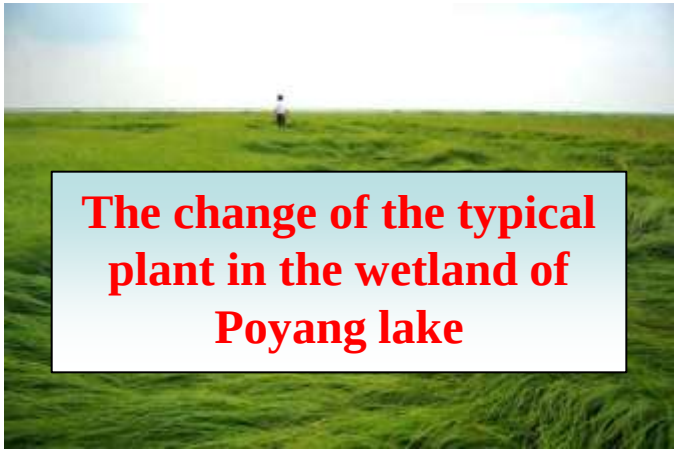
The serious degradation of ecological system because of the low water level and drought disaster.

Climate Change and Human Activities

Complicated relationship between the lake and Yangtze river due to human activities

Deterioration of water quality due to the emission of water pollutants caused by the high speed development of society and economy

1. Introduction on Poyang Lake



The change of the typical plant in the wetland of Poyang lake

The impactions of low water level

- The discharge into Yangtze river from the lake increases , especially during the dry season. The low water level of lake appears early and lasts longer time than before. The Drought-Flood Abrupt Alternation takes place more frequently.
- On Jan. 6th, 2012, the water level observed at Duchang gauging station is 7.95m which is the lowest level since 1952。 Since 1980, because of the building of dykes to reclaim land from marshes and the artificial control of lake branch, the area of Poyang lake body connecting to the Yangtze river was greatly compressed, this caused the degradation of ecologic system and environment of wetland.

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2. The Variation of Hydrologic Process

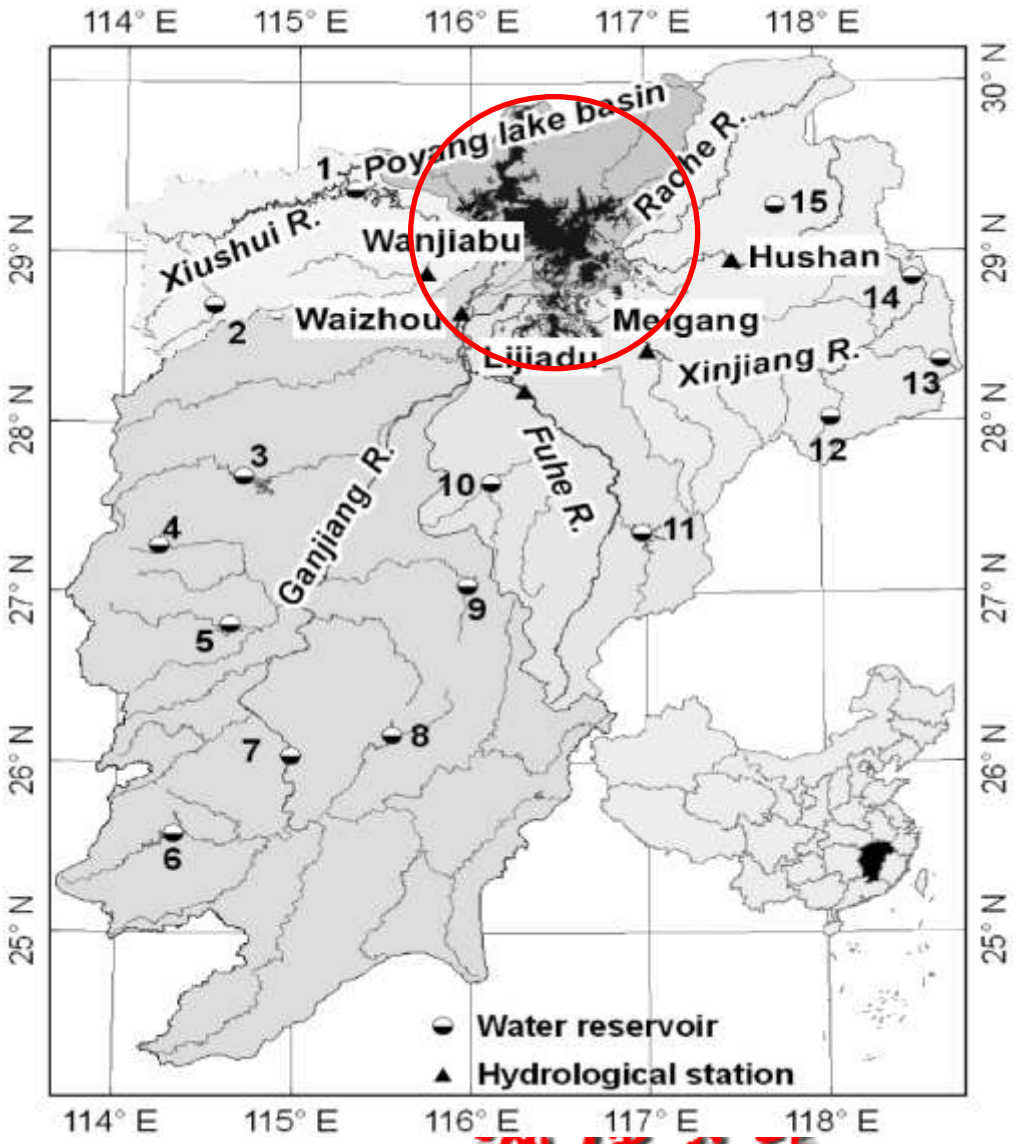
2、The variation of hydrologic process

- **Total Runoff Into Poyang Lake**

  The Total Runoff Into Poyang Lake includes the runoff of the five main rivers entering the lake and the region surrounding the lake which is between the gaging station of the five main rivers and the lake.

- **Data**

  Daily average total runoff entering into Poyang Lake from 1959 to 2009 .



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2、The variation of hydrologic process

- **Methods**

-Statistic values of annual, monthly average and seasonal average total runoff into Poyang Lake

- Mann-Kendall rank correlation test

statistic value: $U = \dfrac{\tau}{[D(\tau)]^{1/2}}$, **where** $\tau = \dfrac{4k}{n(n-1)} - 1 \quad D(\tau) = \dfrac{2(2n+5)}{9n(n-1)}$

- Moving average $y_t = \dfrac{1}{2k+1} \sum_{i=-k}^{k} x_{t+i}$

- Continuous wavelet transform analysis $W_f(a,b) = |a|^{-1/2} \int_{t=-\infty}^{\infty} f(t) \overline{\varphi(\dfrac{t-b}{a})} dt$

where $\varphi(a,b) = |a|^{-1/2} \varphi(\dfrac{t-b}{a})$ **wavelet base function**

we choose the Morlet wavelet base function:

$$\varphi(t) = e^{i\omega_0 t} \cdot e^{-t^2/2}$$

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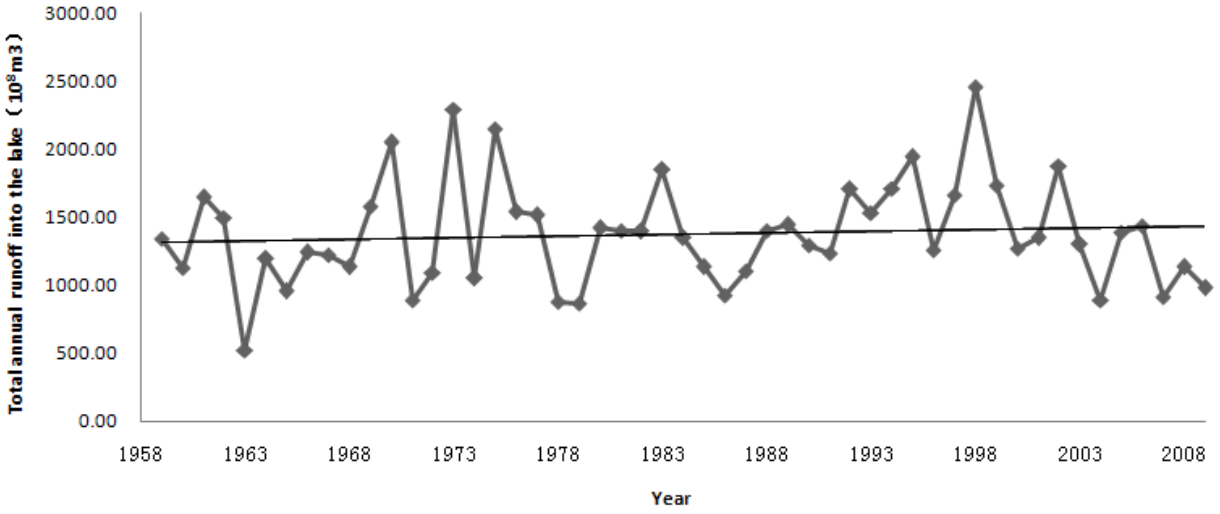
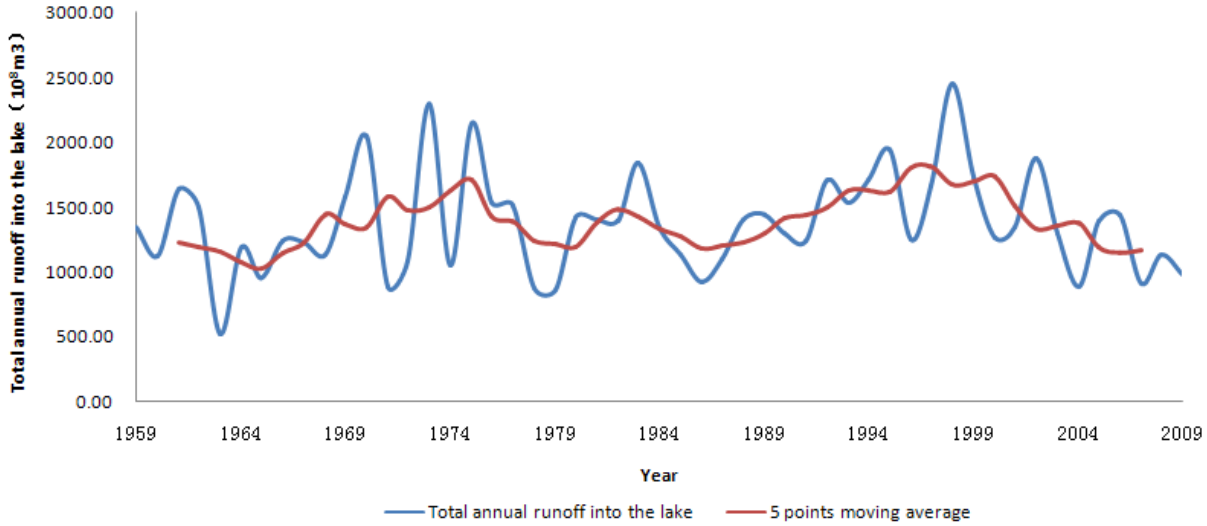
2、The variation of hydrologic process

- **The trend analysis of total annual runoff into Poyang Lake**



Mann-Kendall rank correlation test : U=0.6741，$U<U_{\alpha/2}=1.96$（α=0.05），the assuming test show that the trend is not obvious.



Five points moving averaging analysis

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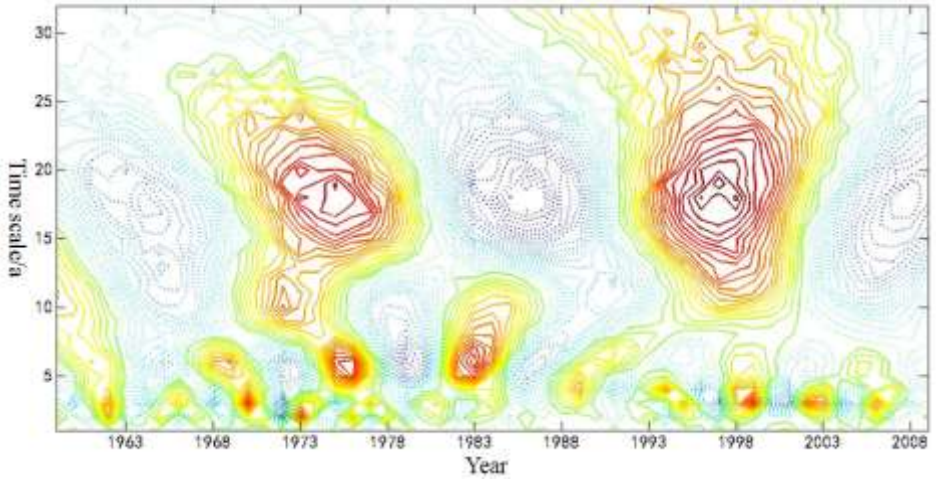
2、The variation of hydrologic process

Total annual runoff into Poyang Lake decadal anomaly during 1959-2009

Time	Anomaly/10^8m^3	Anomaly percentage%
1960s	-166.65	-12.10
1970s	53.94	3.92
1980s	-36.28	-2.63
1990s	276.15	20.05
The early 21st century	-123.65	-8.98

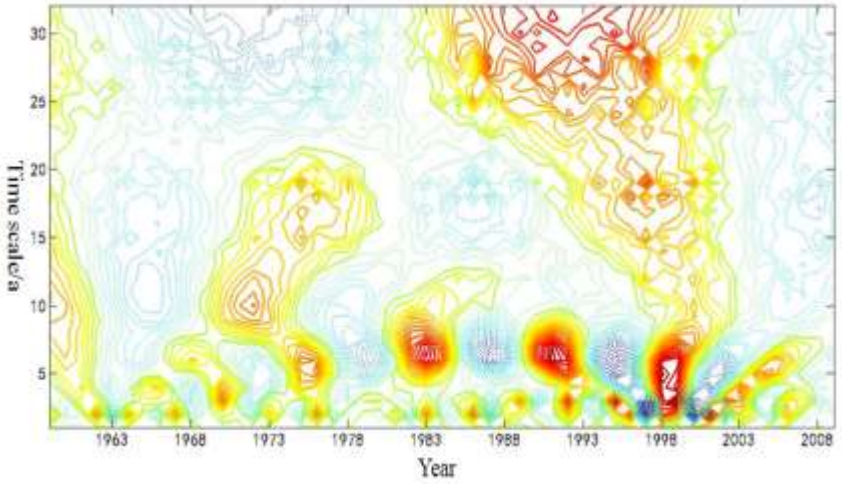


The wavelet transform of total annual runoff into Poyang Lake anomaly series from 1959 to 2009

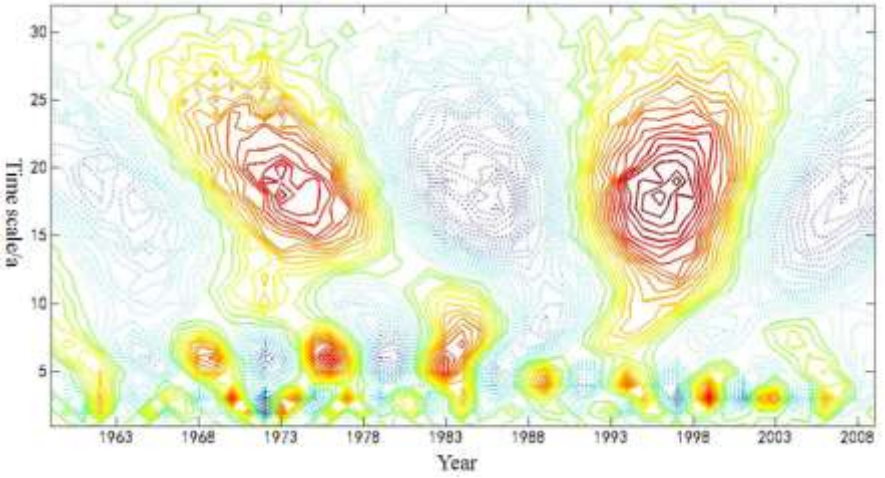
As can be seen from the left Fig.， there are obvious periodic oscillation of 14-25a and central time scale for 19a， during which the total runoff into the lake experienced less-more-less-more-less cyclic process. contour is not closed in 2009， so it is predicted that total runoff into Poyang Lake will be less than the multi-annually averaging value in the next few years。There are also obvious periodic oscillation of 3-6a and central time scale for 4a,there are more cyclic-alternating-patterns that total runoff into the lake is less and more than normal period.

2、The variation of hydrologic process

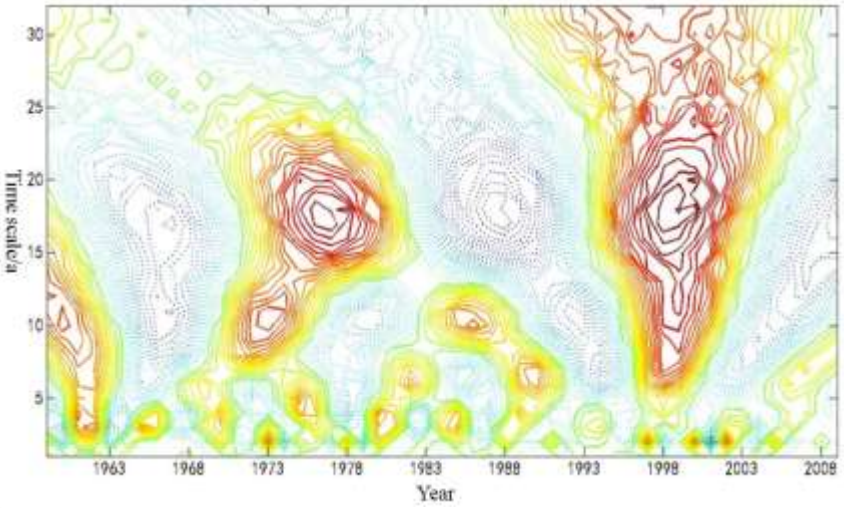
- **The seasonal variation characteristics of total runoff into Poyang Lake**



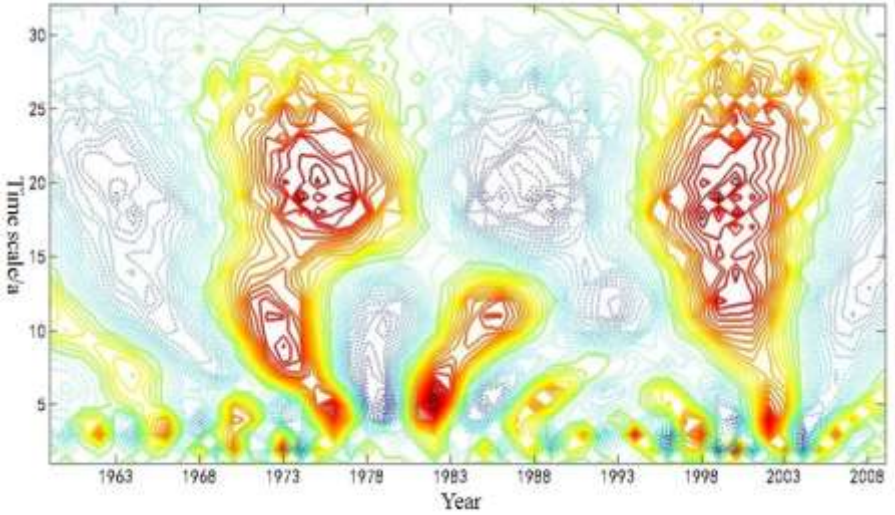
The wavelet transform of total runoff into the lake anomalies series during Jan-.Mar.



The wavelet transform of total runoff into the lake anomalies series during Apr.-Jun.

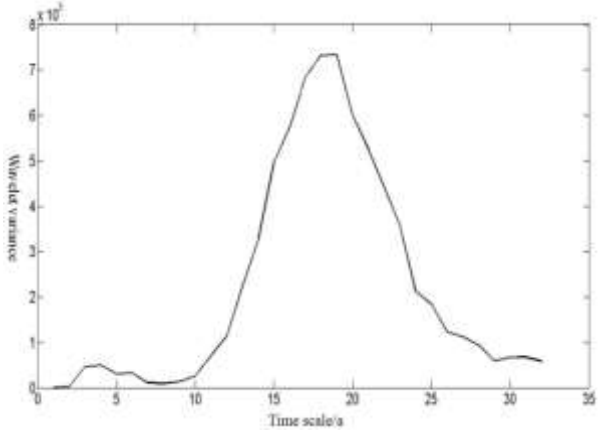


The wavelet transform of total runoff into the lake anomalies series during Jul.-Sep.

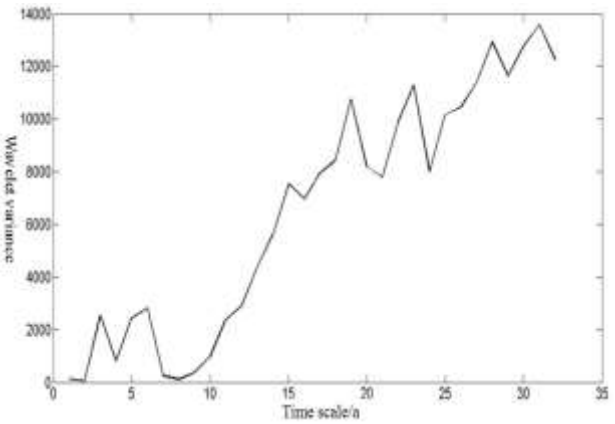


The wavelet transform of total runoff into the lake anomalies series during Oct.-Dec.

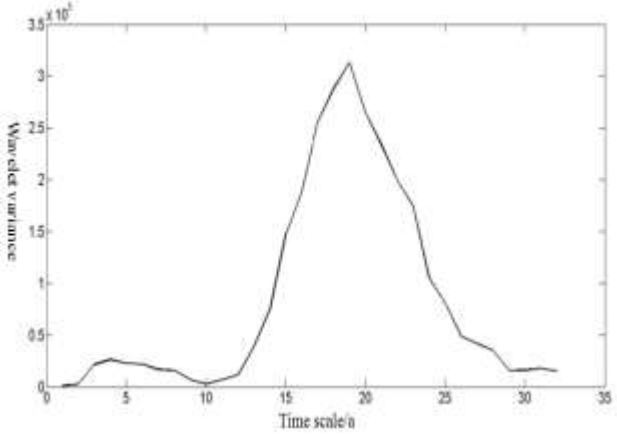
2、The variation of hydrologic process



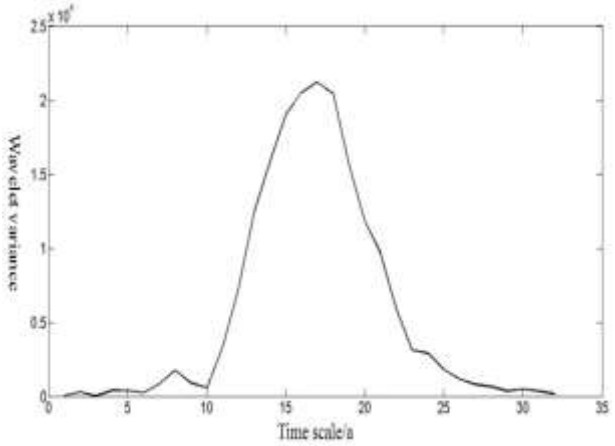
(a)



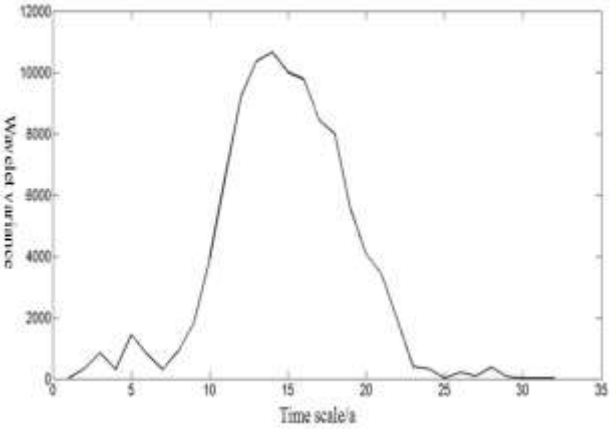
(b)



(c)



(d)



(e)

(a)The wavelet variance of the total annual runoff into the lake anomalies series;(b)The wavelet variance of the total runoff into the lake for the first period (Jan-Mar);(c) The wavelet variance of the total runoff into the lake for the second period(Apr-Jun); (d) The wavelet variance of the total runoff into the lake for the third period(Jul-Sep); (e) The wavelet variance of the total runoff into the lake for the fourth period(Oct-Dec).

2、The variation of hydrologic process

- **The phenomenon of Drought-Flood Abrupt Alternation**
  - **The difference between the total runoff entering into Poyang lake from Apr. to May and from Jun to Jul is obvious due to the analysis of data.**
  - **The periodic-alternating-processes that the total runoff entering into the lake is less and more than normal year's values of Apr.-May and Jun-Jul show the phenomenon of alternation from "Drought to Flood" or from "Flood to Drought".**
  - **Either "Drought to Flood" or "Flood to Drought" both cause a certain extent impact on the Poyang Lake water system and human society, especial the abrupt alternation phenomenon changing from Drought to Flood.**

2、The variation of hydrologic process

- **For example:**
  - **the total amount of water entering Poyang Lake from five rivers is 42.2 × $10^8 m^3$ in Apr. 2011, which is 75% less than average annual value at the same period, and is the smallest at the same period in history(46.59× $10^8 m^3$ in 1963);**
  - **And in May 2011, it is 79.39× $10^8 m^3$ which is 62% less than average annual value at the same period, and is also the smallest at the same period in history. Severe drought occurred in Poyang lake catchment.**
  - **But into Jun, the continuous heavy rain caused water level at Jiujiang gauging station from 10.61m on Jun 4th to 17.57m on Jun 22nd, the water level rose 6.93m in 18d, meaning that water level rose by 0.385m/per day, it is very rare rising speed in history. The Xingzi water level station also appeared the highest water level of 17.42m on Jun 22nd since 2011.**

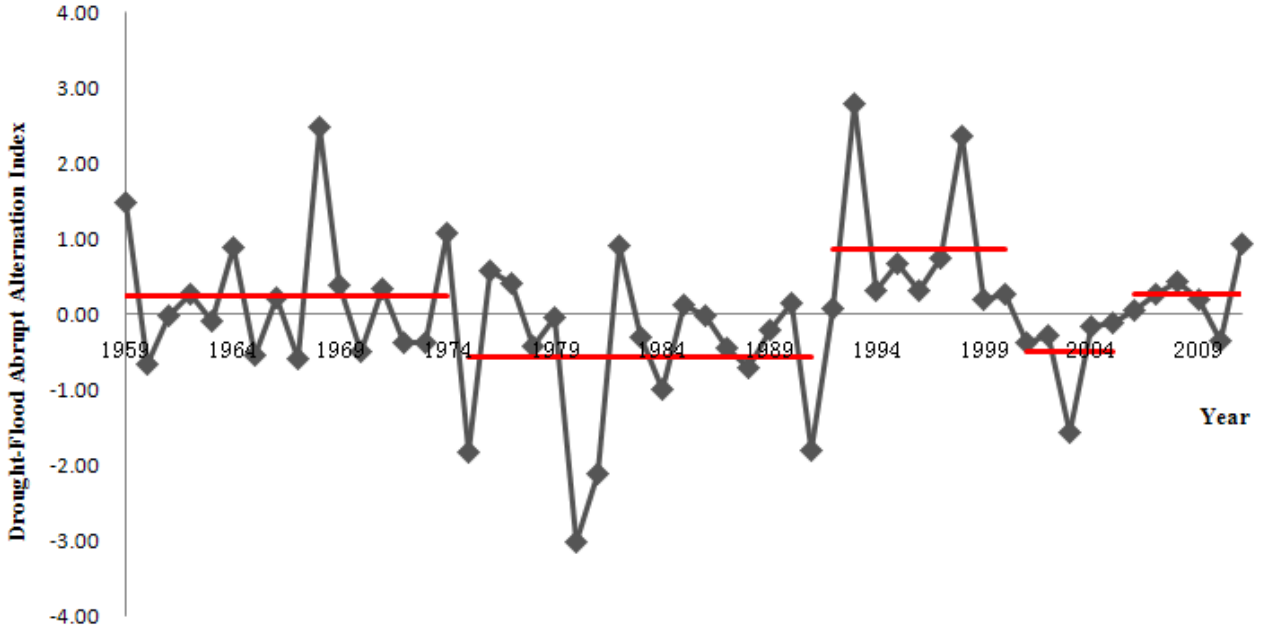
2、The variation of hydrologic process

Long-cycle Drought-Flood Abrupt Alternation Index(LDFAI)

$$LDFAI = (W_{6-7} - W_{45}) \cdot (|W_{4-5}| + |W_{6-7}|) \cdot 1.8^{-|W_{4-5}+W_{6-7}|}$$

W_{6-7} is the total amount of runoff entering lake during Jun and Jul

W_{4-5} is the total amount of runoff entering lake during Apr. and May



As can be seen from the figure, "Drought-Flood" mainly occurred in 1959~1974, 1992~2000 and 2006~2011. On the contrary, "Flood-Drought" mainly occurred in 1975~1991 and 2001~2005. According to above period analysis, we can further find that the period of transition between "Drought-Flood" and "Flood-Drought" has became shorter and shorter, demonstrating that the alternation of drought and flood recently took place more frequently.

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3. Eco-hydrologic Variation in Wetland and its Response to the Building of the Gate

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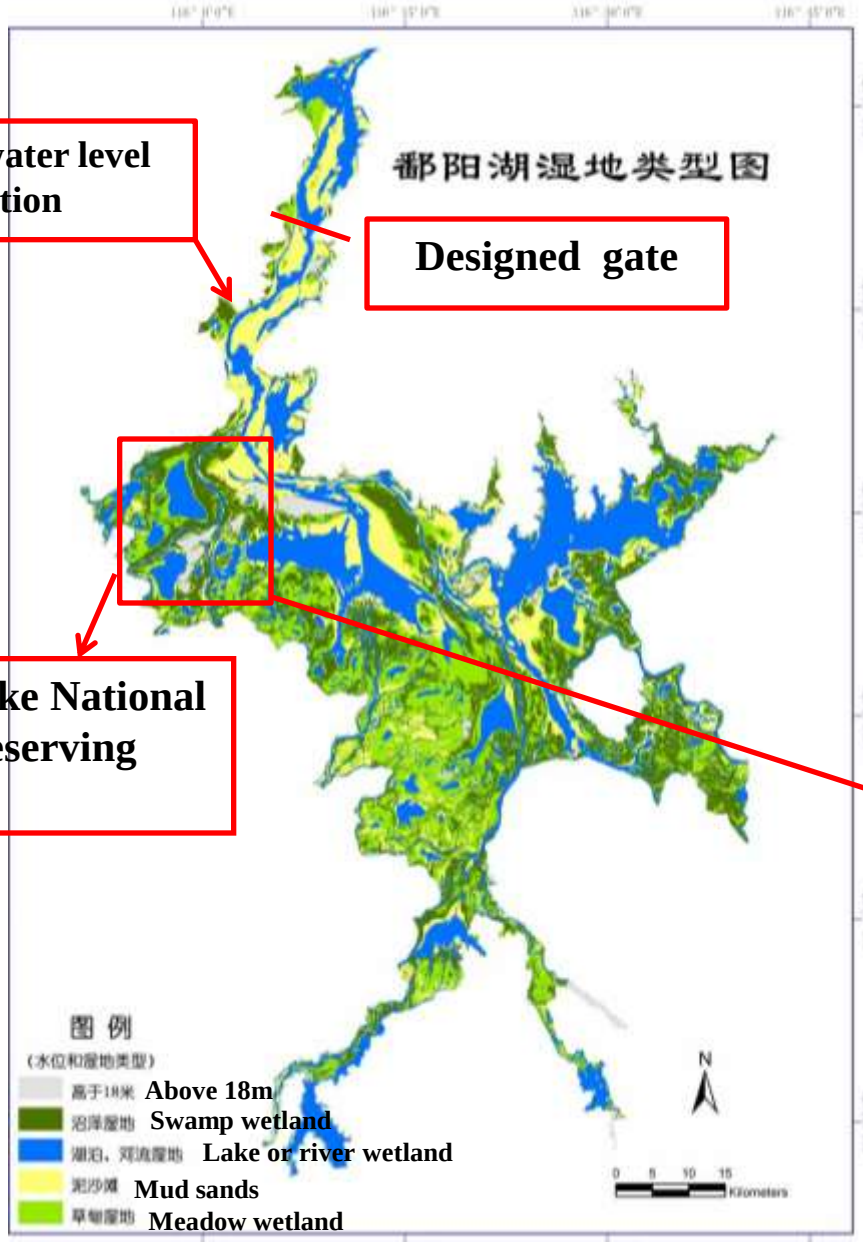
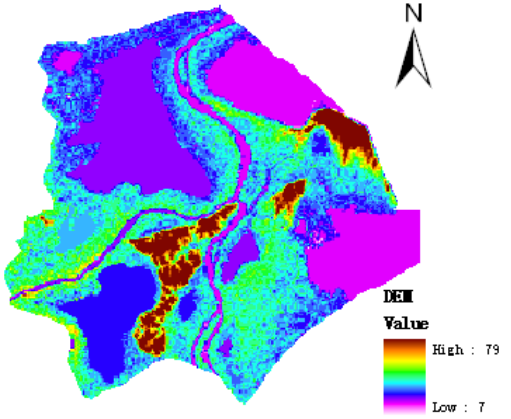
3. Eco-hydrologic Variation in Wetland and its Response to the Building of the Gate



Carex tristachya



Area: 22,400ha

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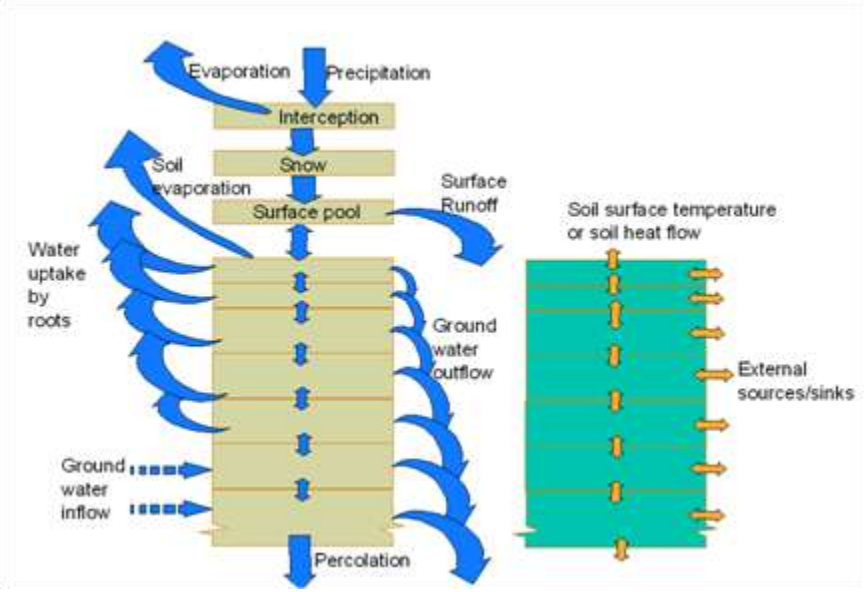
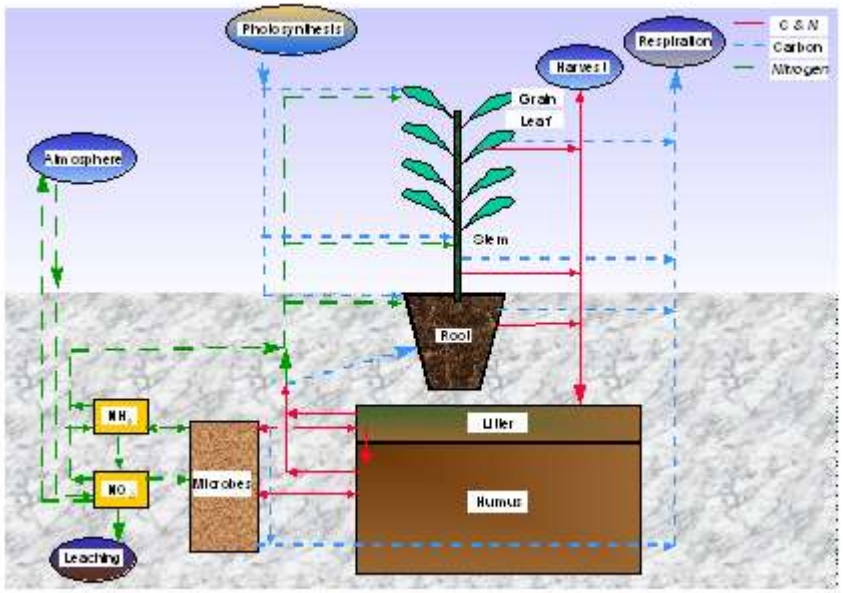
Researching route:

- The eco-hydrologic model, Coup-Model, is applied to simulate the wetland plant respiration, which reflects the variation of the wetland biomass and reveals the evolution and succession of wetland;
- To establish the relationship between water level of Xingzi station and wetland plant respiration by ANN;
- Assuming the scenarios of the changes of the water level of Xingzi station caused by the designed gate, and according to the relationship between the wetland plant respiration and water level of Xingzi, the changes of wetland plant respiration are deduced. Then the response of evolution and succession of wetland to the building of the gate is analyzed.

Coup-Model:

The CoupModel is a new updated version of the previous WinSoil model (Jansson, 1998). It is developed to quantify and increase the understanding concerning basic hydrological and biological processes in the soil-plant-atmosphere system.





Mass balance(left) and heat balance(right)of the abiotic part of model

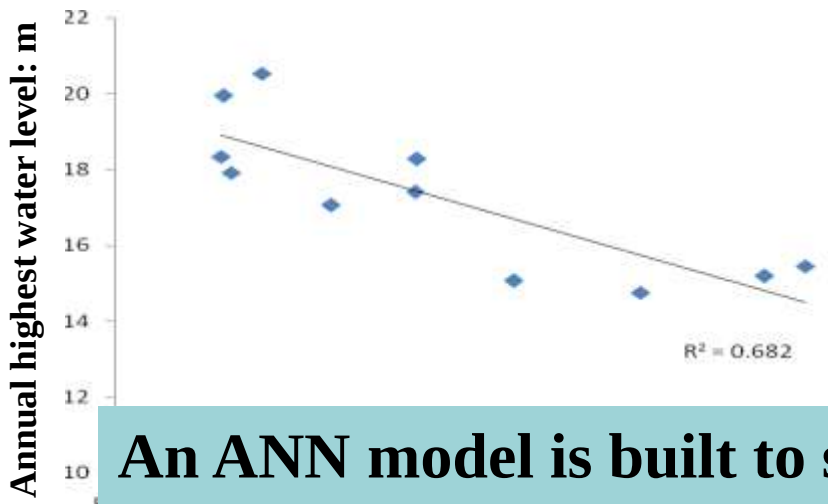
Schematic scheme of carbon, nitrogen and biomass flows (in one dimension) and storage. The soil is divided into layers and plant biomass can be divided into pools of annual and perennial tissues (Eckersten et al., 1998).

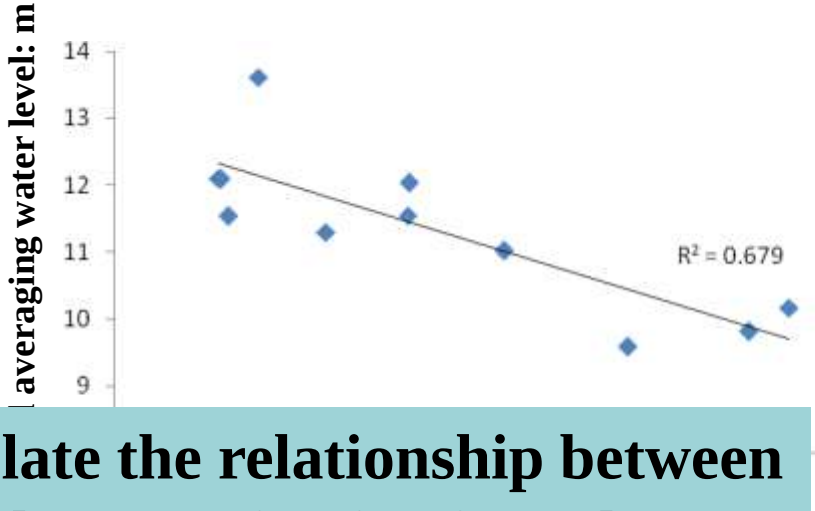
- **Three kinds of the data are needed. They are respectively**
  - Weather data
  - Plants data
  - Soil data
- **The simulation time is from 1990 to 2009. we use the weather data at seven stations（Boyang、Huangshi, Jingdezheng,Lushan, Nanchang, Nancheng, Xiushui）**
- **Carex tristachya is selected as the typical plant of wetland in Poyang National natural Reserving Area in order to explore the impaction of the change of lake water level on the evolution of wetland ecological process.**
- **According to Carex tristachya's seasonal growing periods and its surrounding environmental structure, the initial parameters related to the plants and soils are determined.**

Carex tristachya's seasonal growing periods

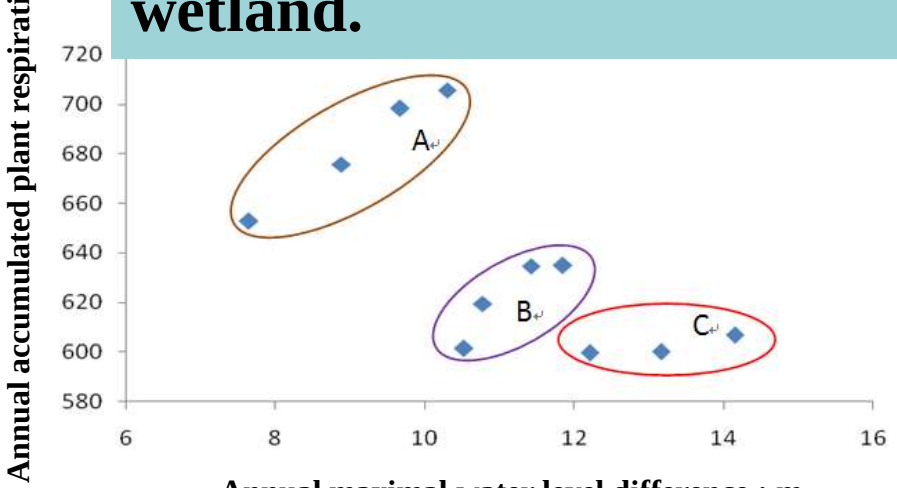
month	Average annual temperature (℃)	Average annual water level (m)	Growing of Carex tristachya	month	Average annual temperature (℃)	Average annual water level (m)	Growing of Carex tristachya
1	3.9	7.395	Winter buds overwintering period	7	28.6	19.054	Summer buds oversummering period
2	5.5	7.868	Winter buds germination period	8	28.8	15.119	Summer buds oversummering period
3	9.7	9.35	Slow growth period	9	24.6	13.975	Summer buds germination and high-speed growth period
4	11.8	10.853	High-speed growth period	10	18.7	11.575	Summer buds germination and high-speed growth period
5	22.3	12.324	High-speed growth period	11	13.2	9.479	Slow growth period
6	22.5	14.013		12	5.4	7.773	

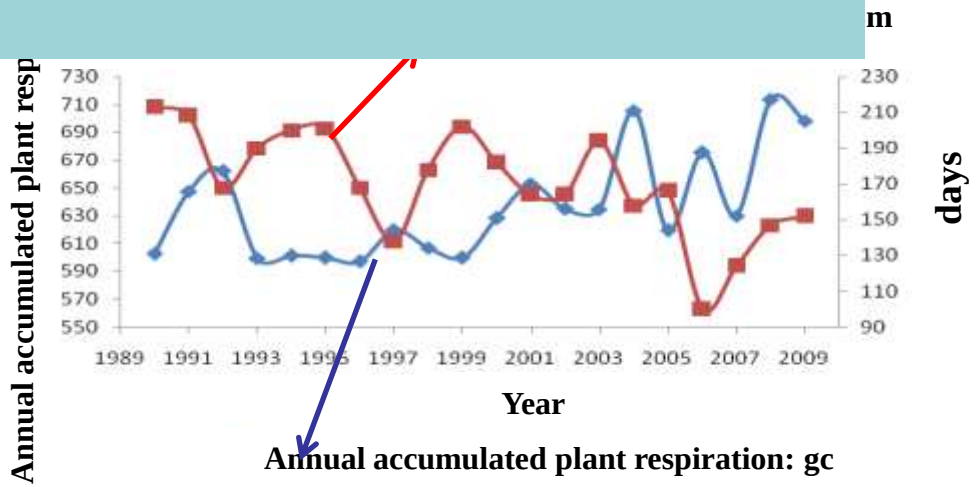
3. Eco-hydrologic Variation in Wetland and its Response to the Building of the Gate





An ANN model is built to simulate the relationship between daily average water level and plant respiration in order to explore the impactions of water level change on the wetland.





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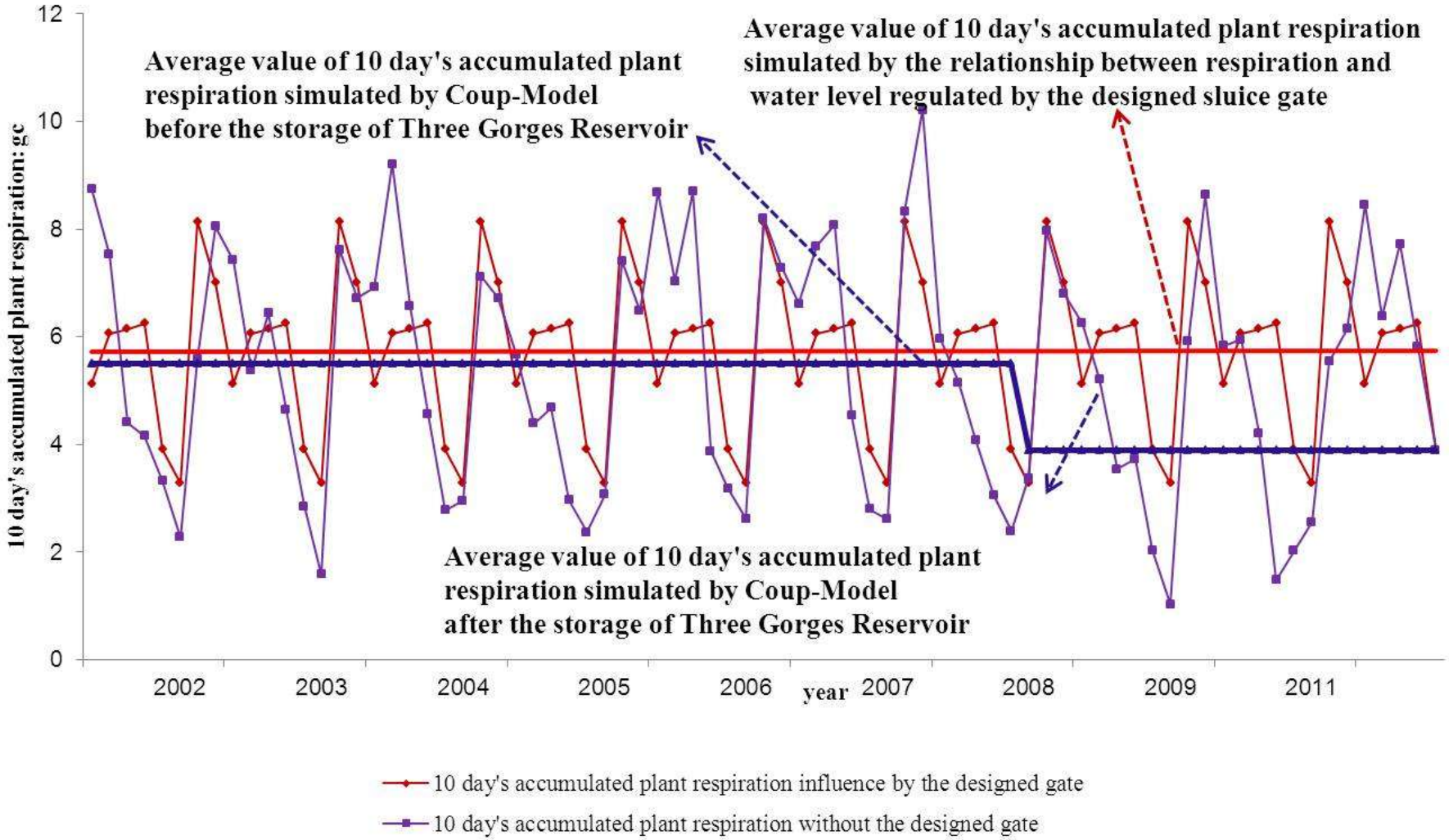

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4. Conclusions

- **Although the variation of total runoff entering the lake doesn't show the simplified increasing or decreasing trend, the alternation of drought and flood takes place more frequently. This means that the extreme hydrologic events will appear more frequently than before.**

- **Due to the development of water resources in the catchments surrounding the lake and in the upstream branch of Yangtze river, the obvious variety of hydrologic and ecological process is happening in Poyang lake. The low water level of lake appears early and lasts longer time than before. This has begun to change the ecological system of wetland in the lake due to the analysis of plant respiration before and after Three Gorges Dam's storage.**

- **The simulation of the impaction of the designed sluice gate on the plant respiration of wetland shows that the proposed sluice gate regulating the relationship between lake and Yangtze river can play efficient role in the wetland eco-restoration.**

Thank you ！