南京信息工程大学
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NANJING UNIVERSITY OF INFORMATION SCIENCE & TECHNOLOGY

Characteristics of Stable Isotopic Composition in Lake Taihu and Stable Isotopic Mass Conservation to calculate the Water Evaporation

Reporter：Xu Jingzheng

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◆Outline

- Introduction
- Materials and Methods
- Results
  - Temporal and spatial variation of hydrogen and oxygen stable isotopes in Lake Taihu.
  - Analysis the influence of hydrogen and oxygen stable isotopes enrichment factors.
  - Lake evaporation
- Conclusions

◆Introduction

- Compositions of stable isotopes of lake water provide unique information on hydrological, meteorological and climatic processes.

- Taihu Lake Basin is one of the most economically developed and fastest growing areas in China. Over the past ten years, since the increasing demand for water in this basin, it is necessary to study the lake water balance. stable isotopes provide a unique perspective for this research.

- In hydrology studies, the temporal variation and spatial distribution of water hydrogen and oxygen isotopes can visually shows the situation of the evaporation and the flow direction of the lake, so as to provide reference for the water balance. Meanwhile, the evaporation computed by hydrogen and oxygen isotopes could provide reference for government to make decisions.

◆Research contents

- The temporal and spatial variation of HDO and $H_2^{18}O$：
  1）different time scale of HDO and $H_2^{18}O$ variation in MLW, including month/season/year scale ;
  2）seasonal variation of HDO and $H_2^{18}O$ in the whole lake；
  3）spatial variation of HDO and $H_2^{18}O$ in the whole lake.

- Find the factor that influence water isotope enrichment, and analysis their control mechanism for HDO and $H_2^{18}O$.

- Conclude the HDO and $H_2^{18}O$ content of evaporation by C-G mode. The stable isotopic method and Priestley-Taylor mode are used to calculate the water evaporation.

- Determine the water residence time by lake water evaporation and throughflow index.

◆Data

- **Flux**： CSAT 3（ Campbell Scientific Inc., Logan, UT)
  LI7500A (LiCor, Lincoln, NE)。

- **Water sampling and analysising** （Model DLT-100, Los Gatos Research, Mountain View, CA, USA）

- **Precipitation isotope**: Changshu station（31° 32‘56’‘N，120° 41’53‘’E）

◆C-G mode

- C-G mode (Craig and Gordon,1965)could conclude the isotope content of evaporation for open water:

$$\delta_E = \frac{\alpha_{eq}\delta_L - h\delta_a - \varepsilon_{eq} - (1-h)\varepsilon_k}{\left(1-h\right)+\left(1-h\right)\varepsilon_k \times 10^{-3}}$$

δ_E: Isotope composition of evaporation
δ_a: Isotope composition of vapor
δ_L: Isotope composition of lake water
h: Relative humidity as Tempreture of water surface
ε_{eq} /α_{eq} equilibrium fractionation factor, the function of water Tempreture （Majoube, 1971）
ε_k dynamic coefficient fractionation , the function of wind speed (Merlivat, 1979)

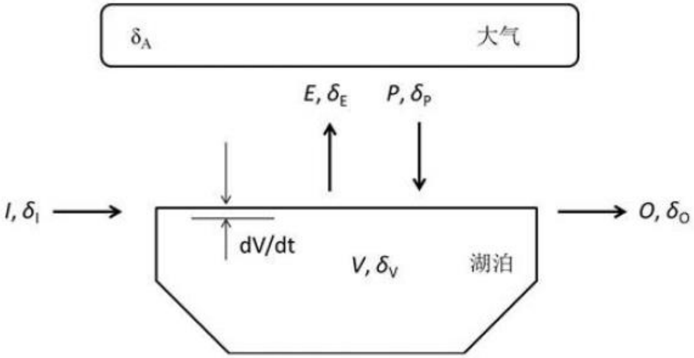
◆Isotopic mass balance equation

同位素质量守恒公式：

$$\delta_I I + \delta_P P = \delta_E E + \Delta(\delta_L V) + \delta_O O$$

由上述公式可得湖水蒸发量E:

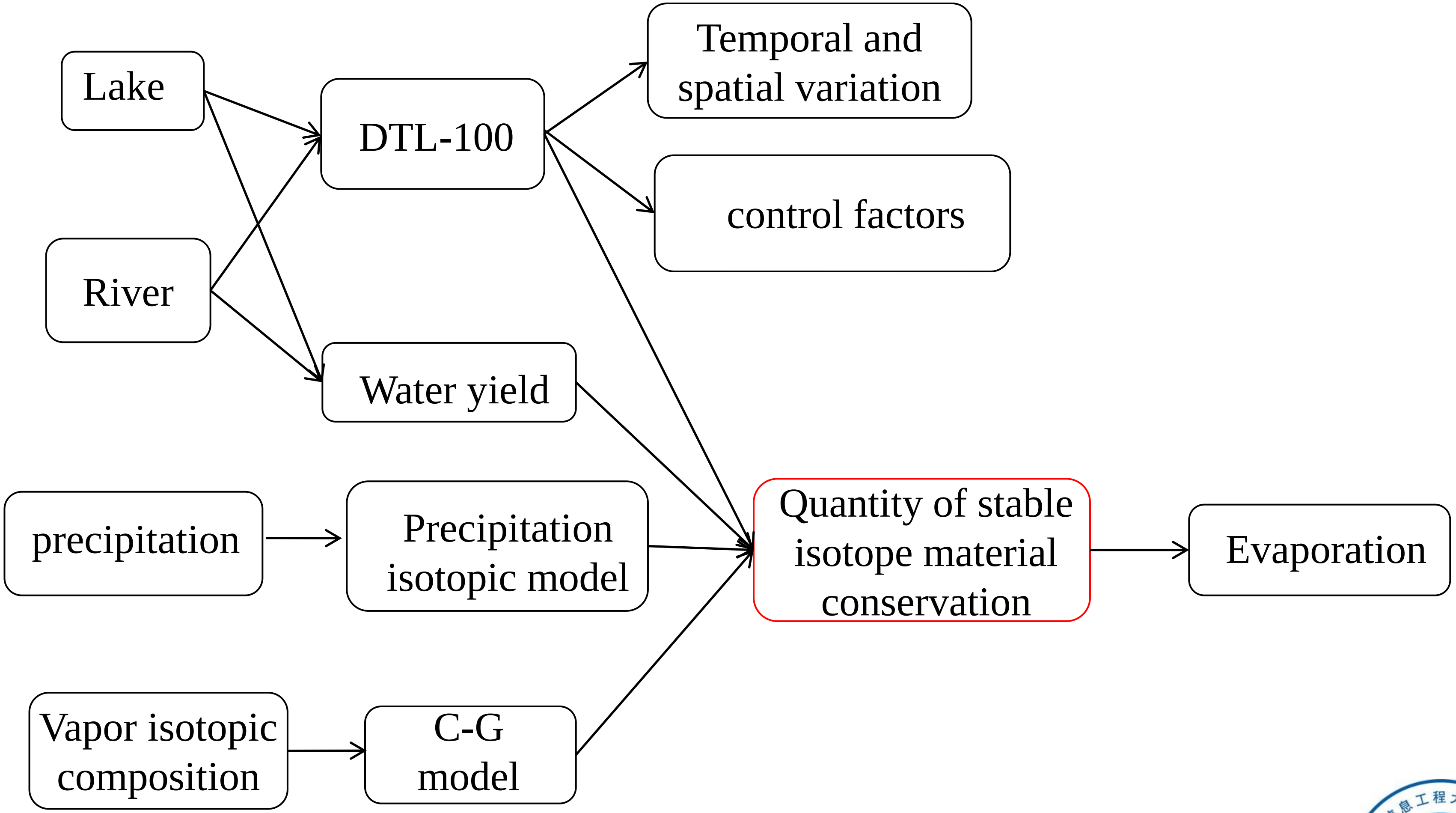
$$\mathrm{E} = \frac{\delta_I I + \delta_P P - \Delta(\delta_L V) - \delta_O O}{\delta_E}$$



将I= $E + \Delta V + O - P$带入湖水蒸发量E的方程，可将I消掉。

$$\mathrm{E} = \frac{\delta_I(\Delta V + O - P) + \delta_P P - \Delta(\delta_L V) - \delta_O O}{\delta_E - \delta_I}$$

◆structure



Lake

River

DTL-100

Water yield

Temporal and spatial variation

control factors

precipitation

Precipitation isotopic model

Vapor isotopic composition

C-G model

Quantity of stable isotope material conservation

Evaporation

Fig2 The technology roadmap

◆Sites

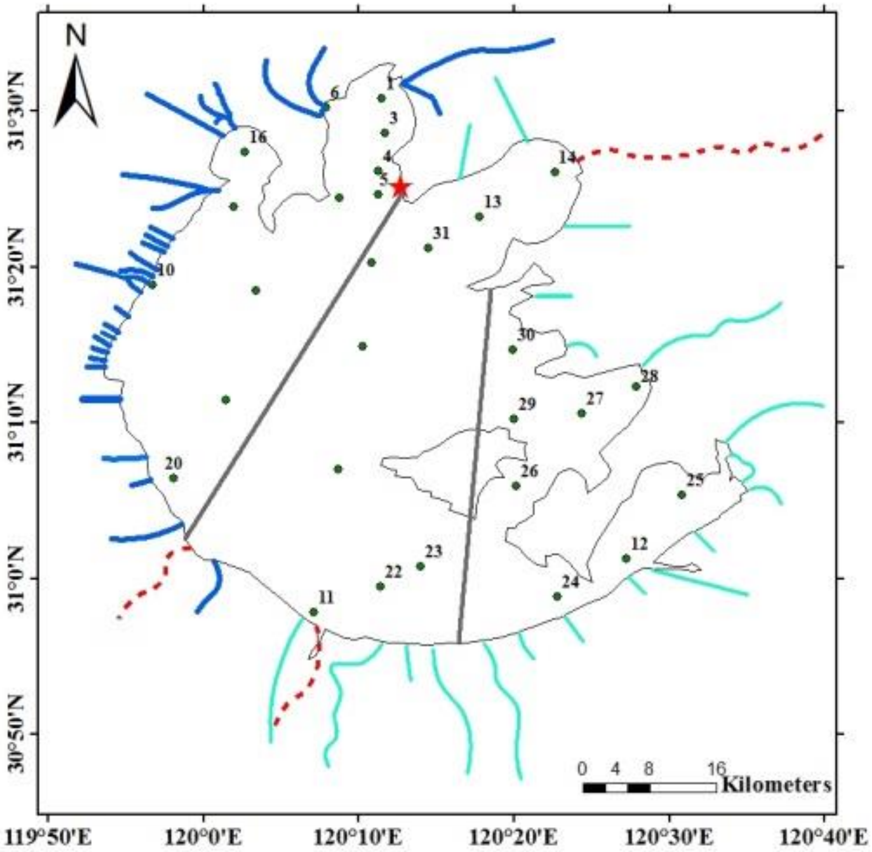


Fig3，Sampling points.

Star: the MLW site; dots: lake survey sites; thick blue lines: inflow rivers; thin green lines: outflow rivers; red dashed lines: inflow/outflow rivers ;Greylines mark approximate boundary of the inflow and outflow regions.

Temporal and spatial variation of hydrogen and oxygen stable isotopes in Lake Taihu.

The temporal and spatial variation of HDO and $H_2{}^{18}O$

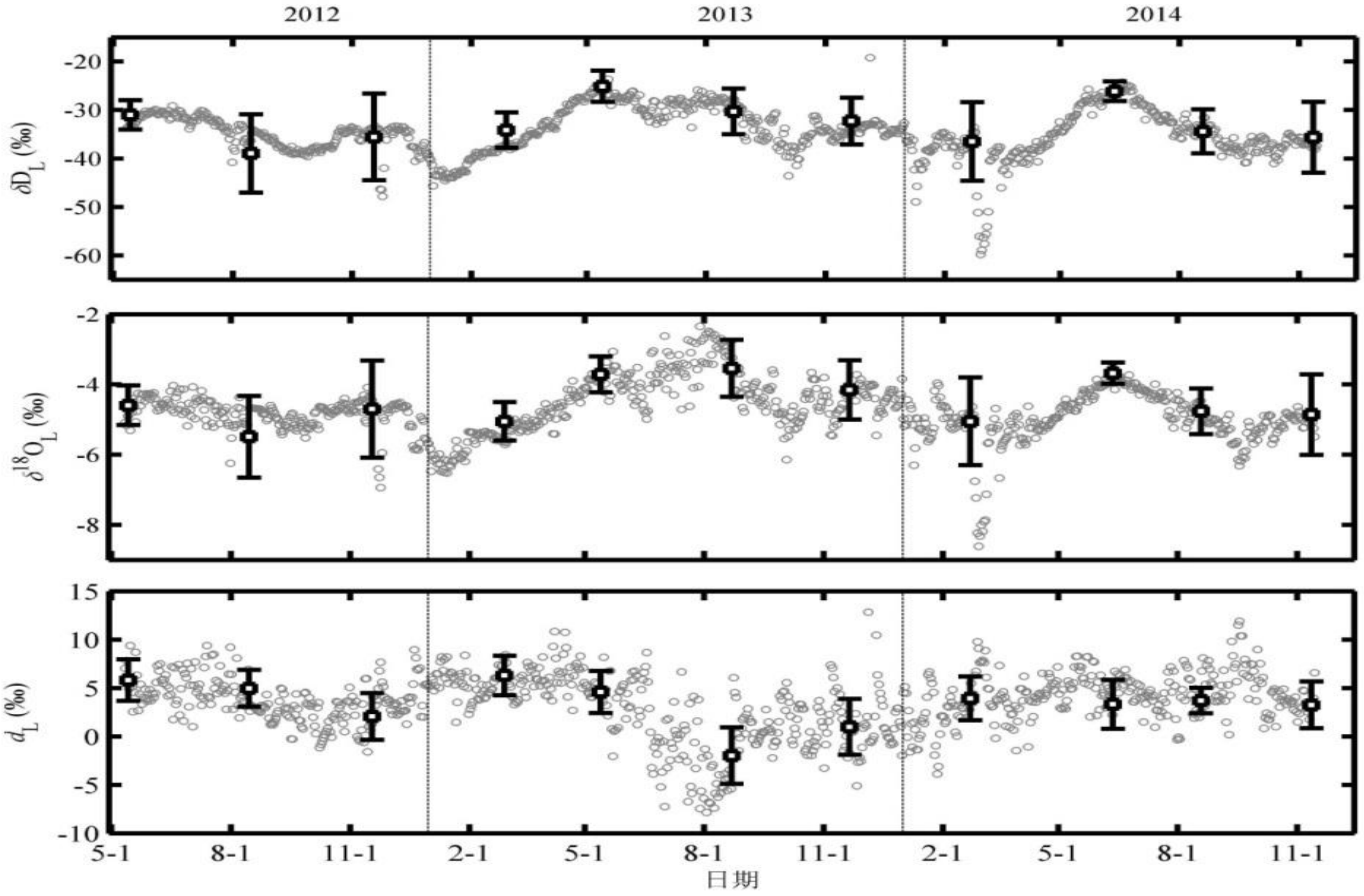


Fig4 The temporal variation of $\delta^{18}O_L$、δD_L and d_L in MWL

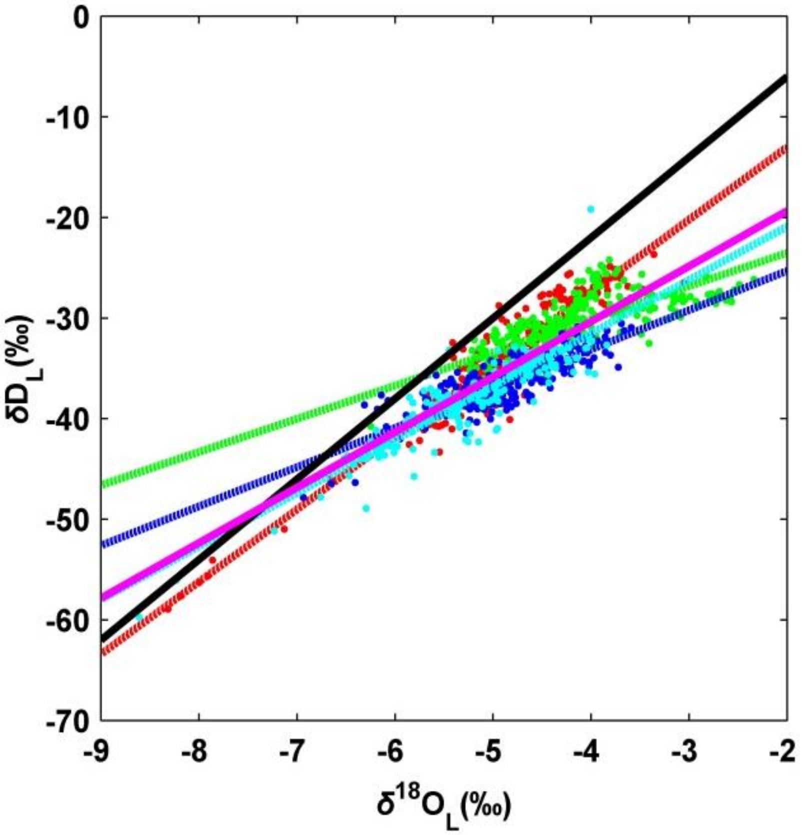


Fig 5 Comparison of the local evaporation lines of the whole year and that of each season.

Red line(Spring)：$\delta D_L = 7.24\delta^{18}O_L + 1.37$（$r = 0.94$，$p < 0.01$）；Green line(Summer)：$\delta D_L = 3.32\ O_L - 16.86$（$r = 0.75$，$p < 0.01$）；Blue line(Autumn)：$\delta D_L = 3.86\ O_L - 17.50$（$r = 0.82$，$p < 0.01$）；Baby blue(Winter)：$\delta D_L = 5.32\ O_L - 10.28$（$r = 0.9$，$p < 0.01$）；Pink line(average)：$\delta D_L = 5.5\ O_L - 8.34$ ($r = 0.87$，$p < 0.01$)；Black line: GMWL.

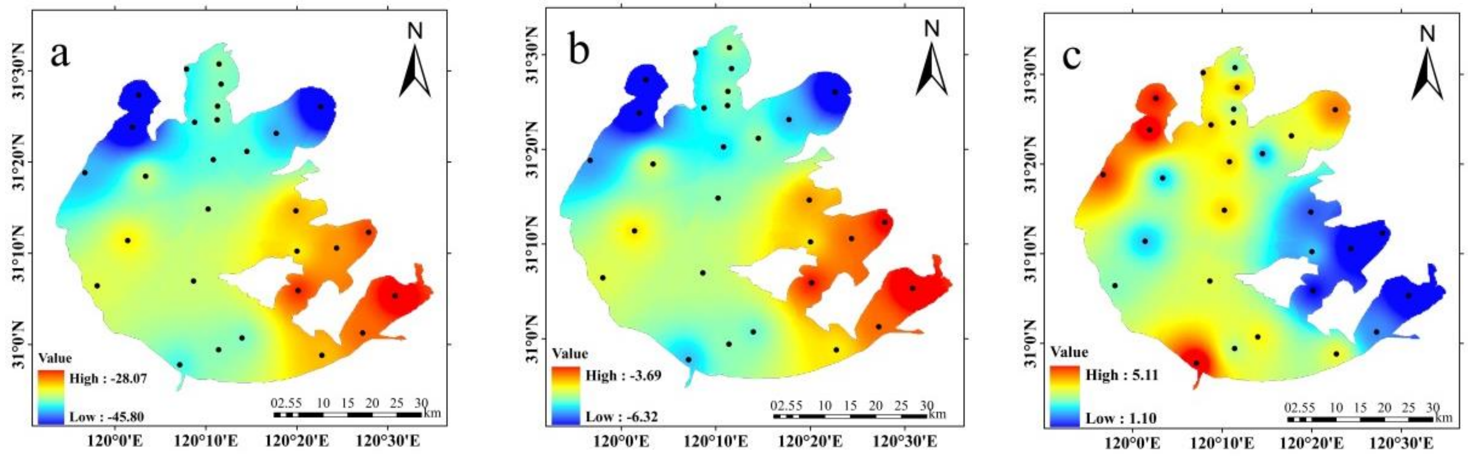


Fig6 Spatial patterns of the annual mean lake water isotope composition: a: HDO; b: $H_2{}^{18}O$; c: d-excess

1, spatial patterns of the lake isotopic composition were characterized with a gradual isotopic gradient from the northwest river inflow zone to the southeast river outflow zone.

2,The spatial patterns was controlled by the water flow pattern.

(Xiao et al., 2016)

$\delta^{18}O$

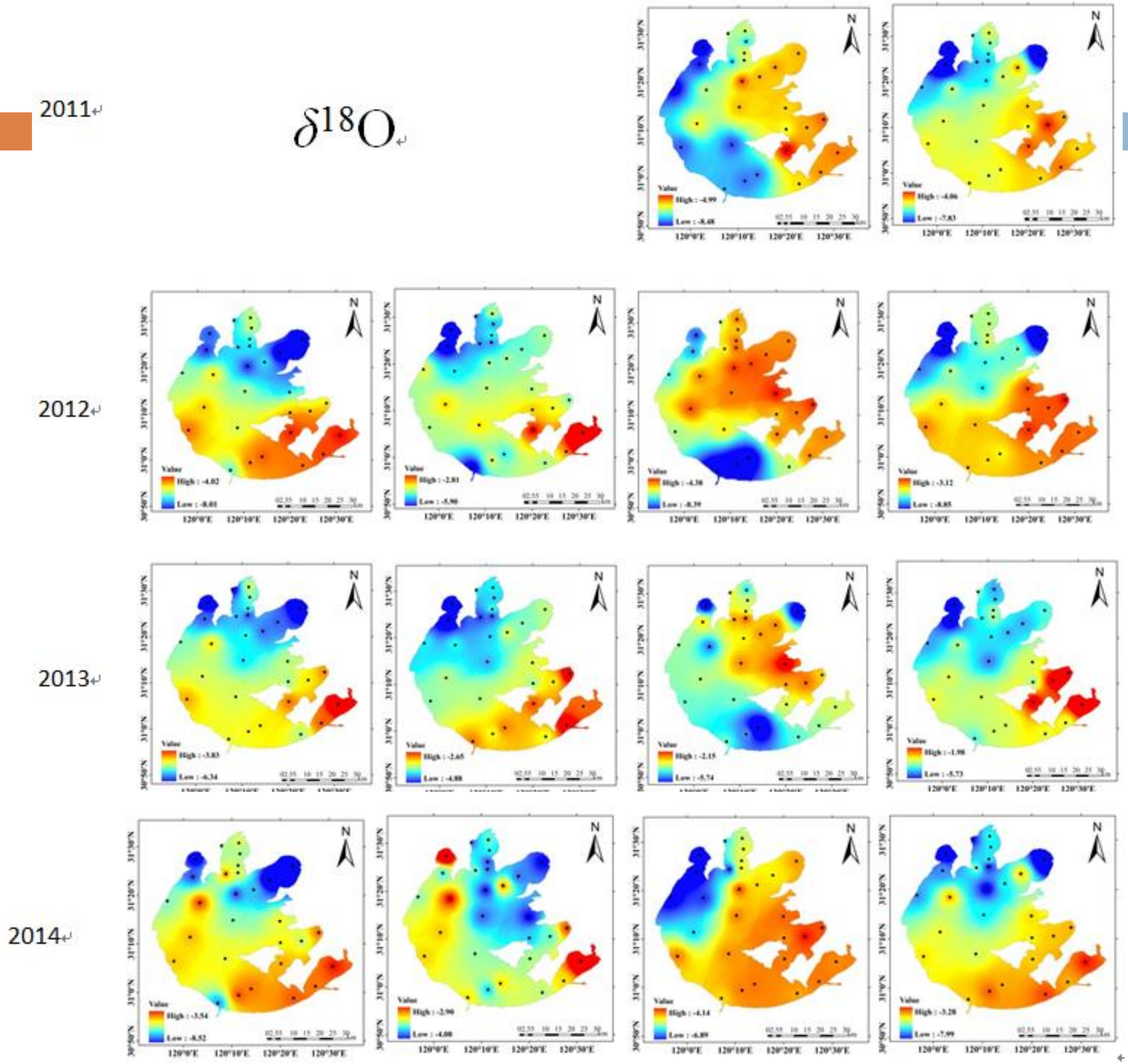
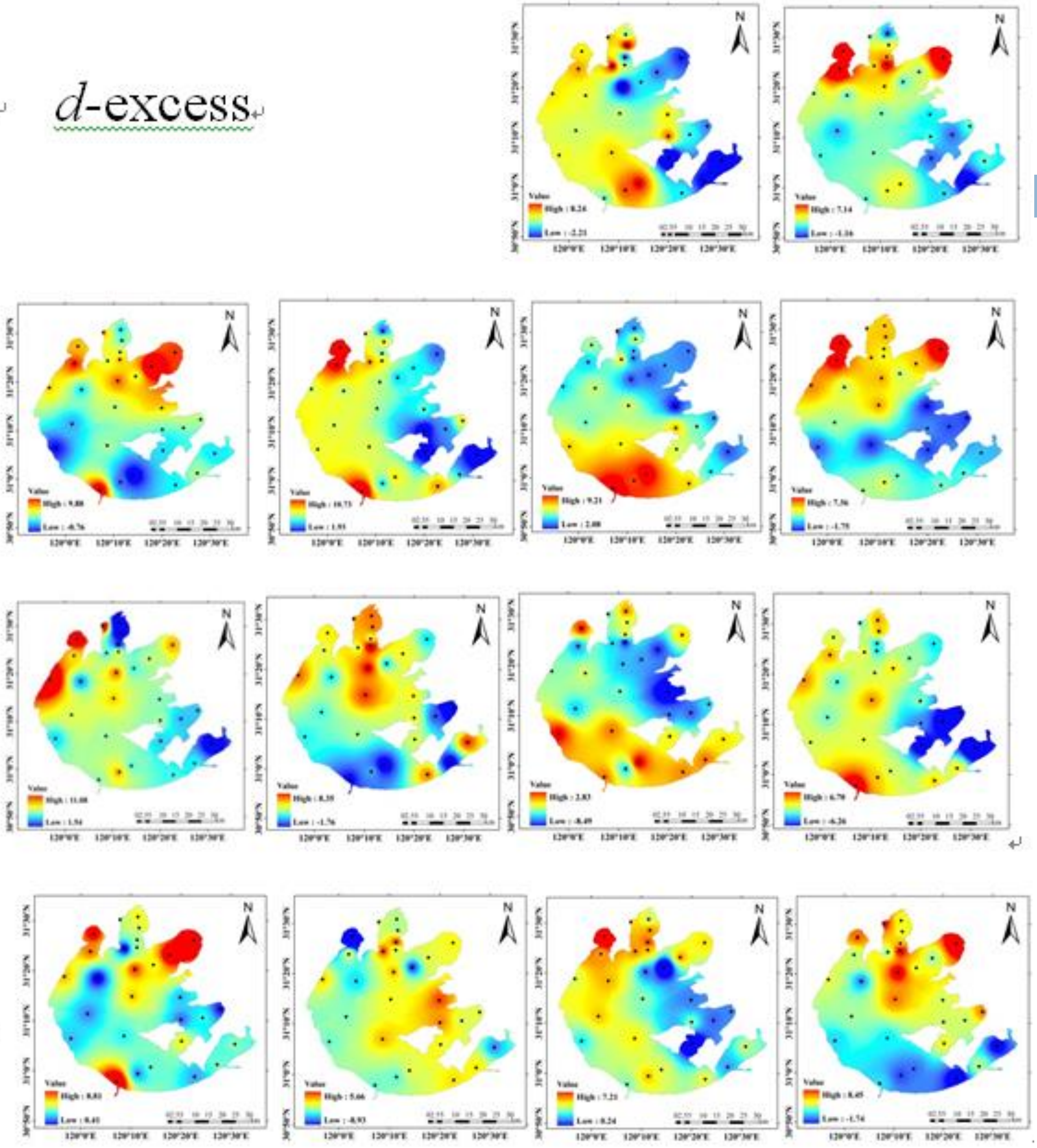


Fig7 Spatial distribution of $\delta^{18}O$ at each lake survey.

2011 *d*-excess



2012

2013

2014

Fig8 Spatial distribution of *d*-excess at each lake survey.

◆ Analysis the influence of hydrogen and oxygen stable isotopes enrichment factors.

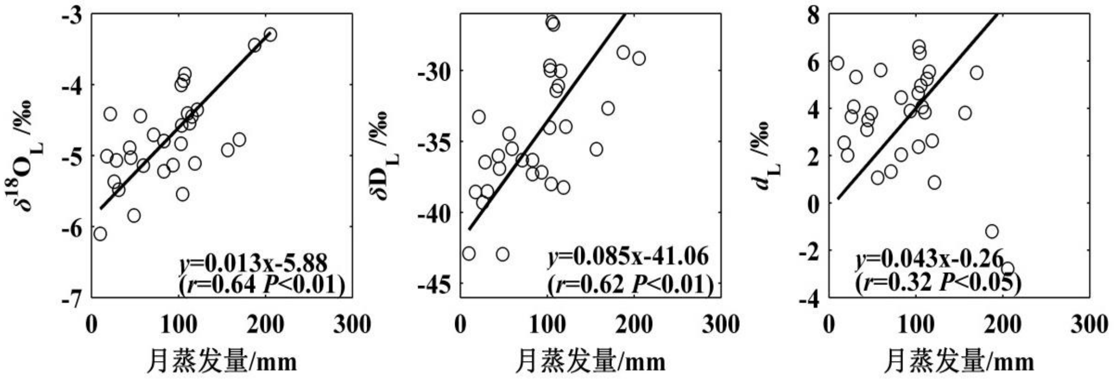


Fig9 Correlation between the monthly mean value of the isotopic composition of lake water and the monthly total lake evaporation.

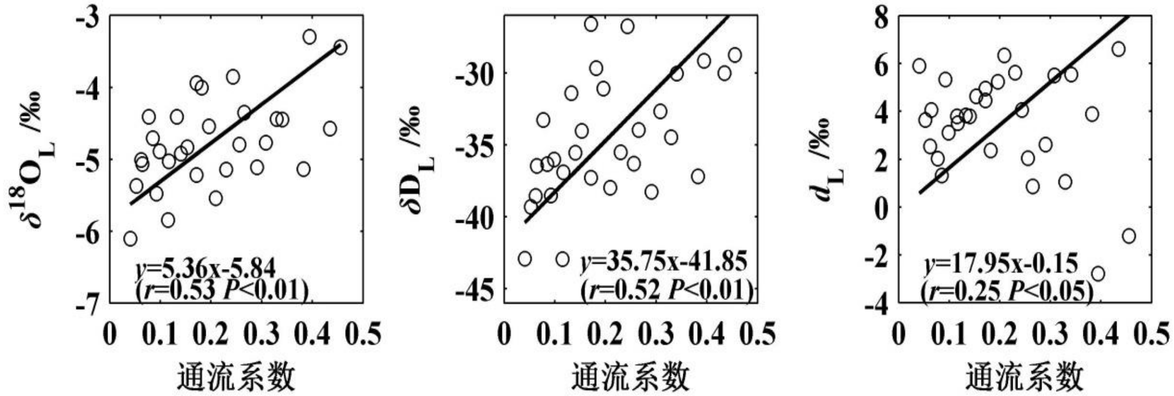


Fig10 Correlation between the isotopic composition of lake water and throughflow index.

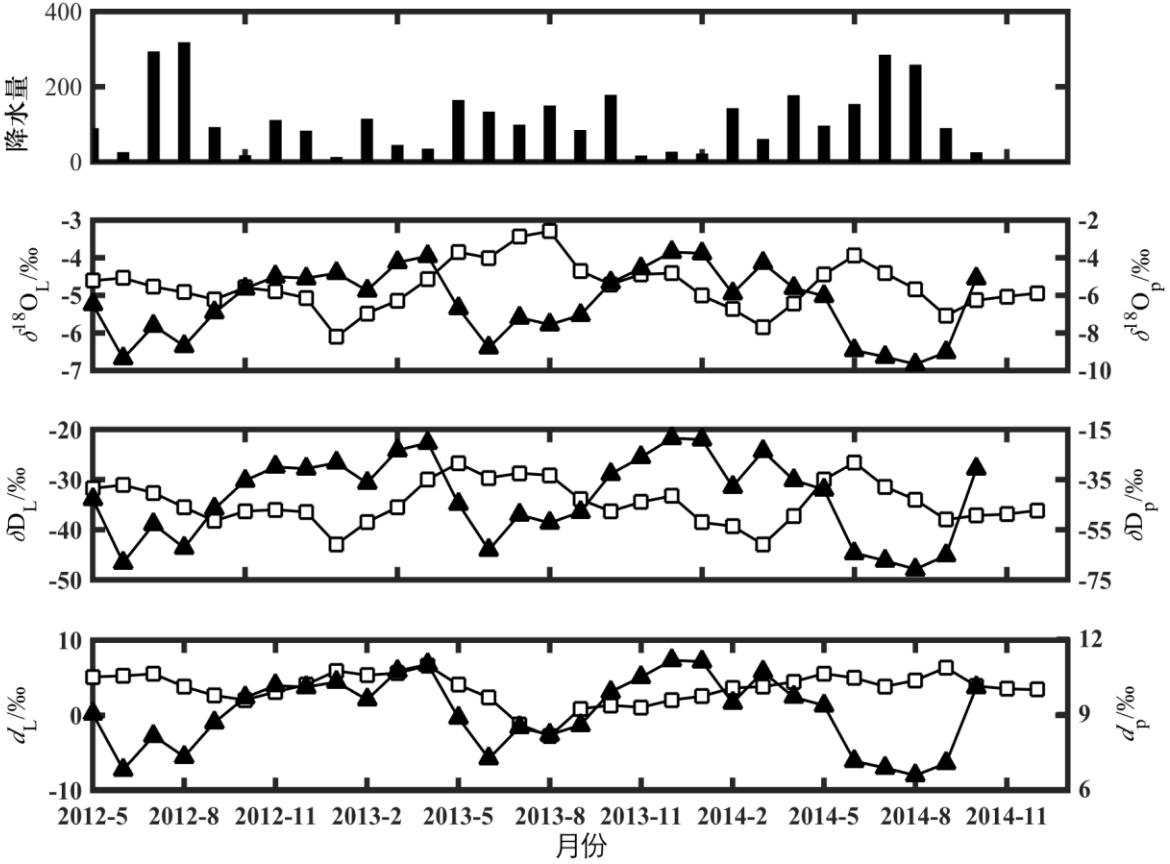


Fig11 Time series of precipitation and isotopic composition of rain water and lake water .

Bar： Monthly precipitation ；

Square：The composition of isotopes；

Triangle ： The composition of isotopes in precipitation。

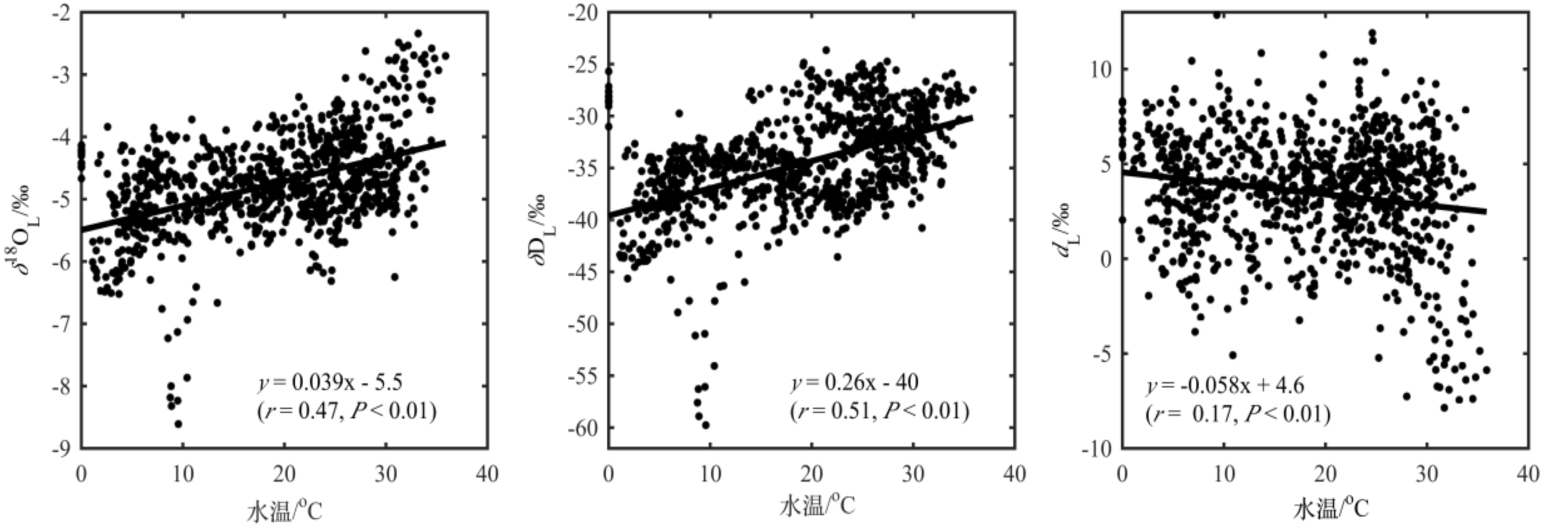
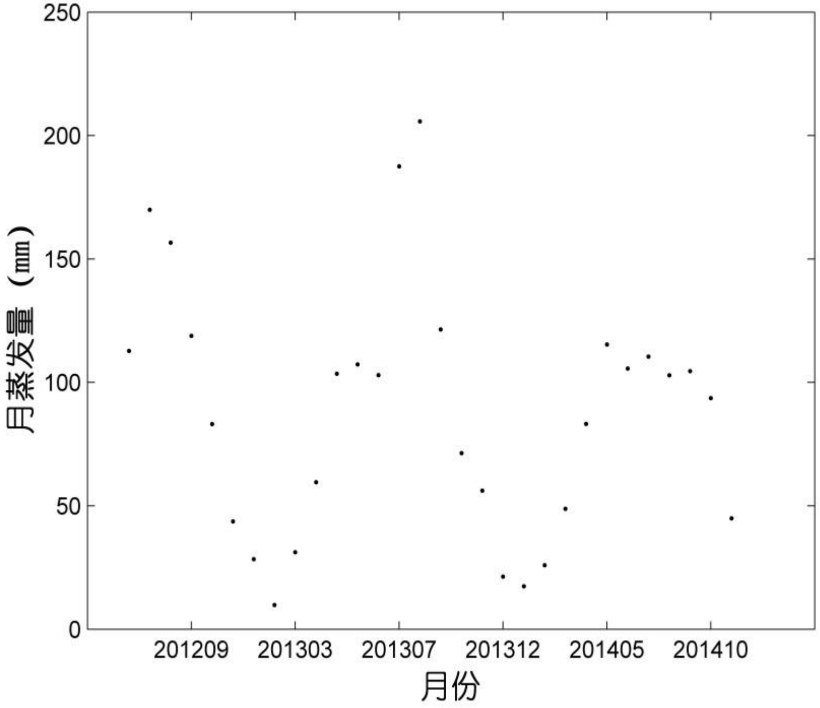


Fig12 Correlation between the isotopic composition of lake water and water temperature

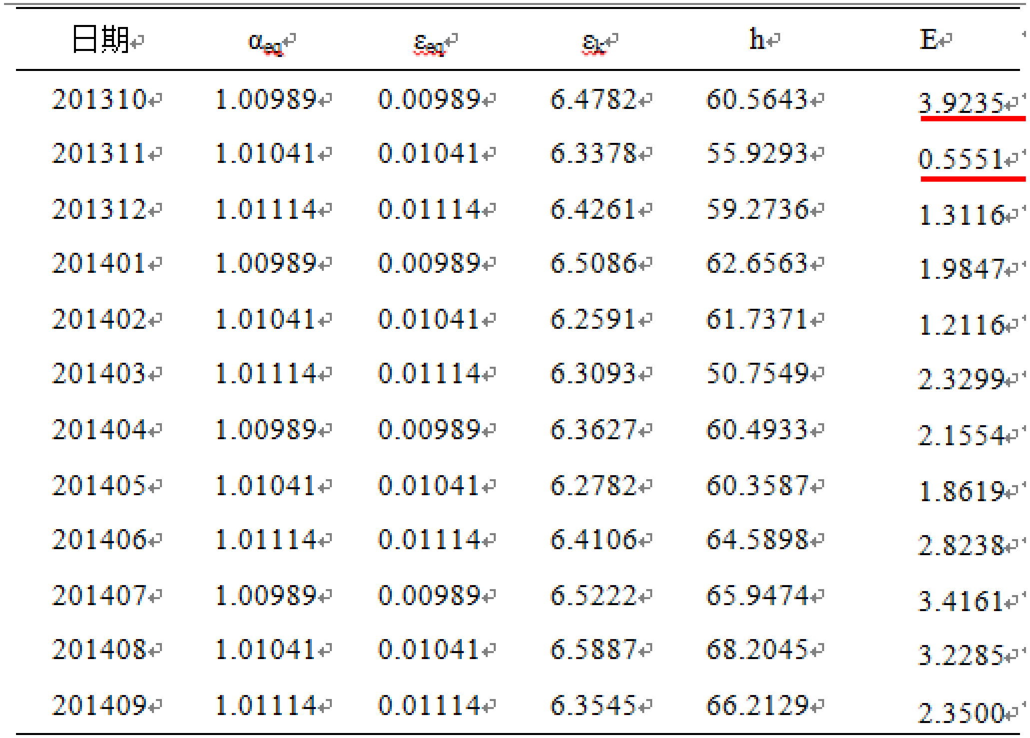
◆Lake evaporation



$$E = \alpha \frac{S}{S+\gamma} \frac{R_n - VQ}{\lambda \rho_w} \times 86.4 \times 10^6$$

Fig13 Priestley-Taylor model to calculate evaporation.

Table1 Isotopic content quality balance method to calculate the water evaporation fractionation



日期	α_{eq}	ε_{eq}	ε_k	h	E
201310	1.00989	0.00989	6.4782	60.5643	3.9235
201311	1.01041	0.01041	6.3378	55.9293	0.5551
201312	1.01114	0.01114	6.4261	59.2736	1.3116
201401	1.00989	0.00989	6.5086	62.6563	1.9847
201402	1.01041	0.01041	6.2591	61.7371	1.2116
201403	1.01114	0.01114	6.3093	50.7549	2.3299
201404	1.00989	0.00989	6.3627	60.4933	2.1554
201405	1.01041	0.01041	6.2782	60.3587	1.8619
201406	1.01114	0.01114	6.4106	64.5898	2.8238
201407	1.00989	0.00989	6.5222	65.9474	3.4161
201408	1.01041	0.01041	6.5887	68.2045	3.2285
201409	1.01114	0.01114	6.3545	66.2129	2.3500

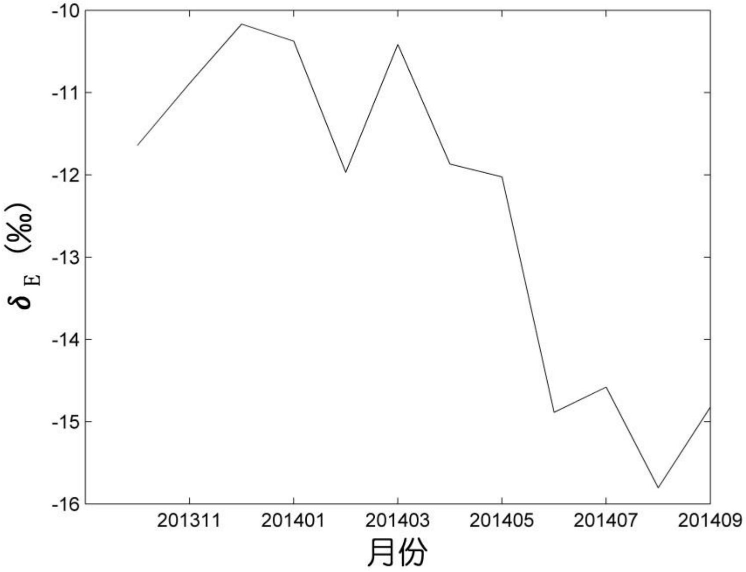


Fig14 The whole lake δ_E change tendency

E: $27.15 \times 10^8 m^3$

The lake water residence time τ： $\tau = xV/E$， x: throughflow index ; V: Water of the Lake Taihu; E: evaporation. MLW: The residence time was 42 ± 7 and 24 ± 7 days using HDO and $H_2^{18}O$ as tracer respectively 。

◆Conclusions

（1）① The isotopic composition of lake water in Taihu show a obvious seasonal variation ,which in summer is most high and winter the lowest, while most fluctuated in spring. ② Evaporation and throughflow index are controlled the isotopic enrichment in lake water. ③The difference isotope composition between precipitation and lake water showed that lake water isotopic enrichment isn’t controlled by precipitation. ④ Water temperature did not control the isotopic enrichment.

（2） The hydrogen and oxygen stable isotope of lake water have obvious spatial distribution. The stable isotope composition gradually increased from northwest and northeast Taihu where much river flow into lake to water flow-out region that is southeast of the lake.

（3）It is similar for the calculated evaporation by stable isotope methods and conventional methods. There are differences for calculated residence time by HDO and $H_2{}^{18}O$, however, both results could response the water age in different season.

Thank you

Any question is welcome！