The lower Yangtze basin: Environment-human activity-climate interactions

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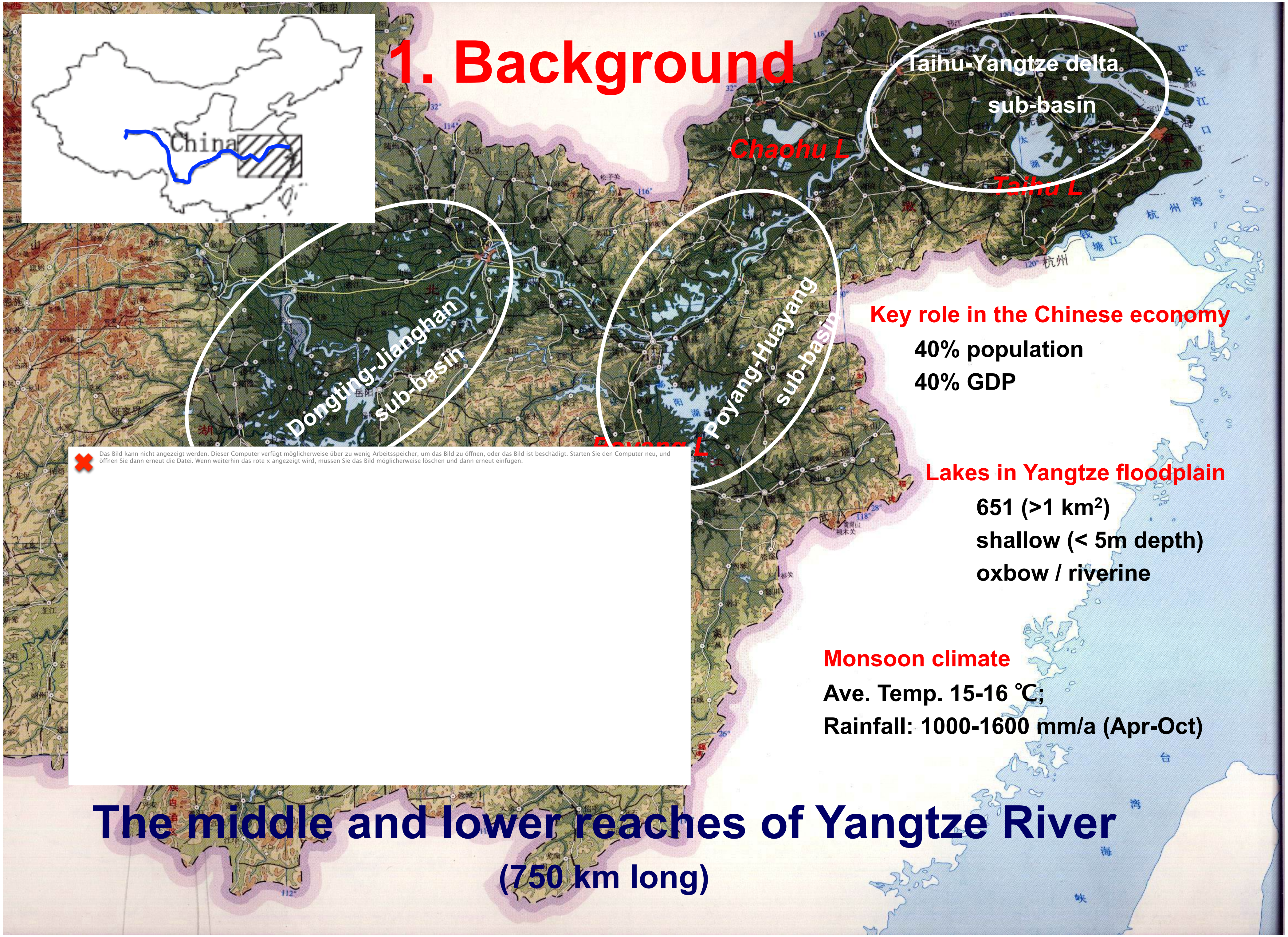
1. Background



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Key role in the Chinese economy

- 40% population
- 40% GDP

Lakes in Yangtze floodplain

- 651 (>1 km^2)
- shallow (< 5m depth)
- oxbow / riverine

Monsoon climate

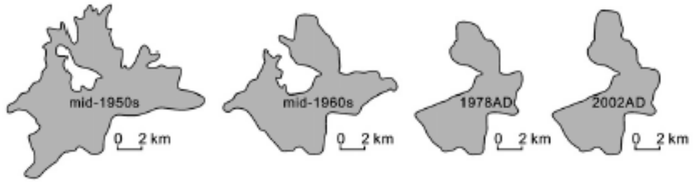
Ave. Temp. 15-16 ℃;

Rainfall: 1000-1600 mm/a (Apr-Oct)

The middle and lower reaches of Yangtze River

(750 km long)

Key environment problems



Changes of Taibai Lake area in the past 50 yrs

(Liu et al., 2007)

The long history of human disturbance, combined with monsoon climate, has had considerable influence on the lake catchment ecosystems and the hydro- and nutrient dynamics

Frequencies of flood disasters in Yangtze River

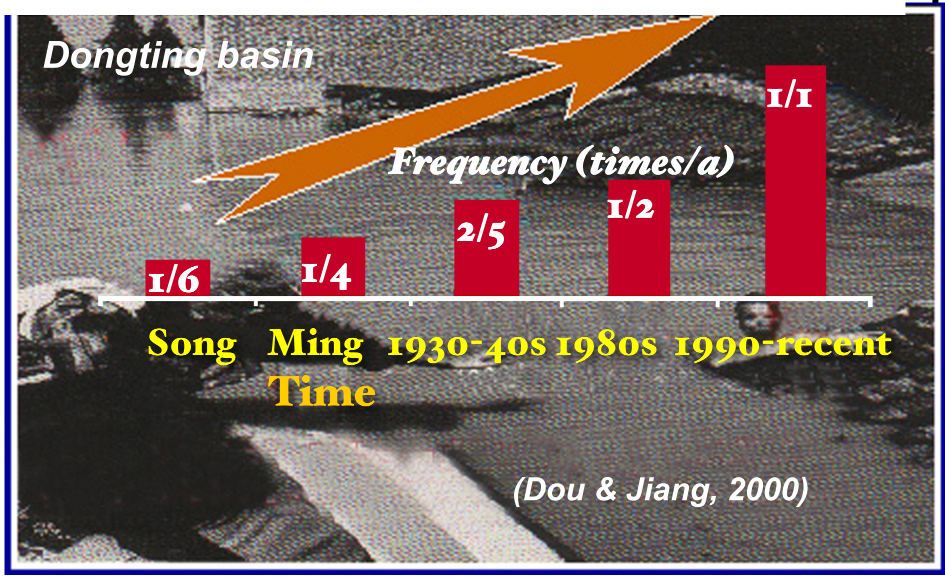
Dynasty or century	Total years	Average interval between floods (year)
Han Dynasty to Yuan Dynasty	1553	11
Ming Dynasty	276	9
Qing Dynasty	267	5
1950s	10	10
1960s	10	5
1970s	10	3.3
1980s	10	3.3
1990s	10	2.5

(Yin & Li, 2001)

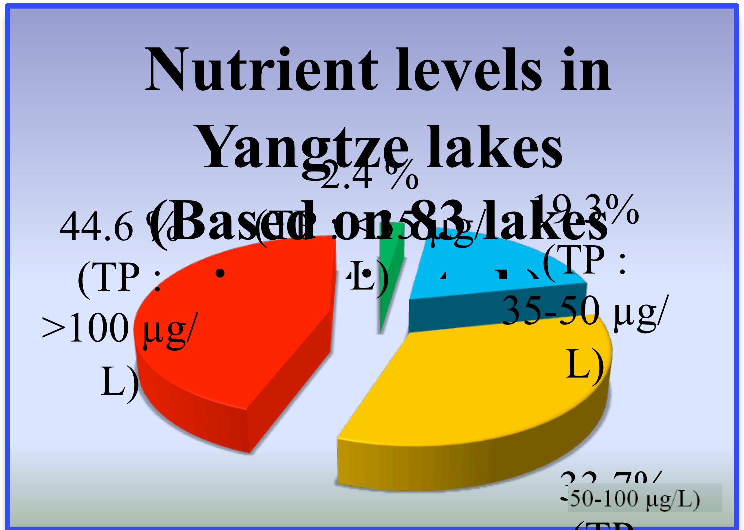
(Area: km²) ***(Wang & Dou, 1998)***

Lakes	Area (pre-1950s)	Areas (today)
Dongting L.	4700	2623
Poyang L.	5340	3900
Longgan L.	579	316
Chaohu L.	1170	770
Taihu L.	2500	2425
Taibei L.	69	25
Gucheng L.	65	24.5

Acceleration of lake shrinking



Flooding frequency increasing



Most lakes have high nutrient loading

2. Review on previous studies in lower Yangtze basin

(1)Historical documents

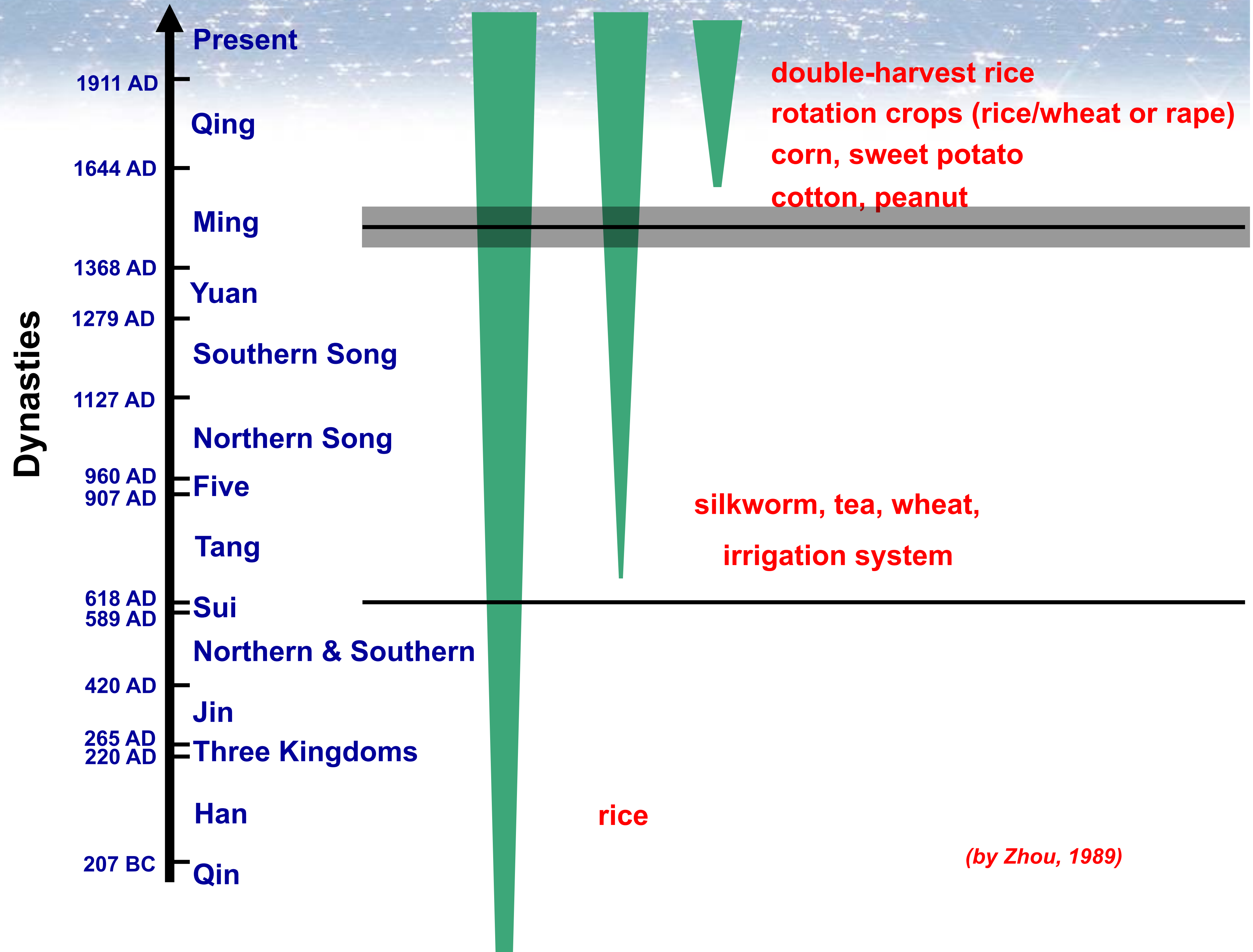
(2)Environmental archaeology

(3)Monsoonal climate reconstruction

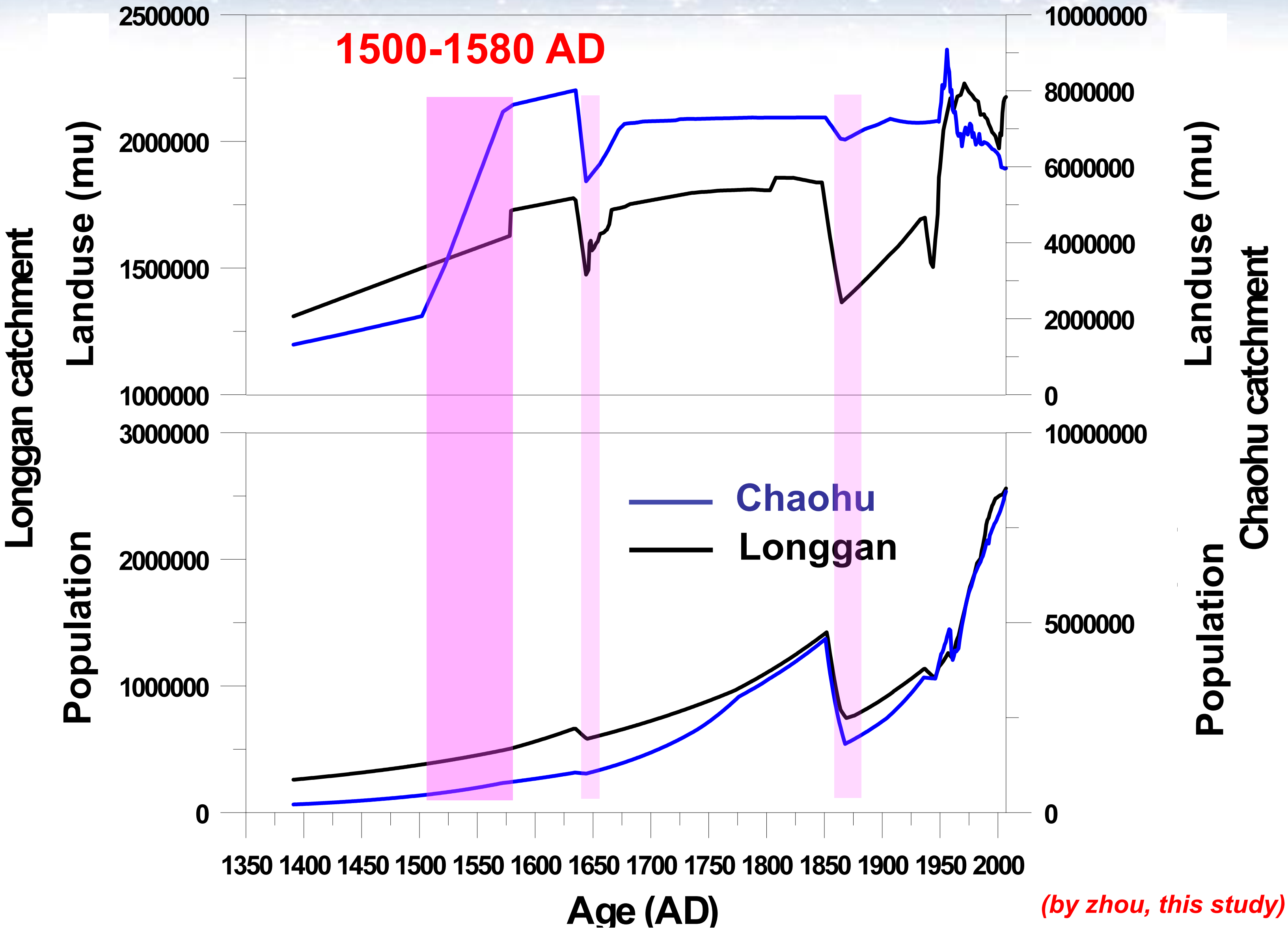
(4)Paleolimnology

(5)Modelling Water quality in Yangtze lake catchments

Crop cultivation & introduction in Yangtze floodplain



Population and land-use in two lake catchments



(by zhou, this study)

Historical human activity and soil erosion in Yangtze floodplain

Before 2100 BC: Fishing & hunting

2100 BC---200 BC: settlement for primary farming

Early Han Dynasty (207 BC): First population immigration

Sui-Tang Dynasty (589-907 AD): Clearance for farming & commerce activities,
weak soil erosion

Song Dynasty (after 960 AD): immigration, enhanced soil erosion,

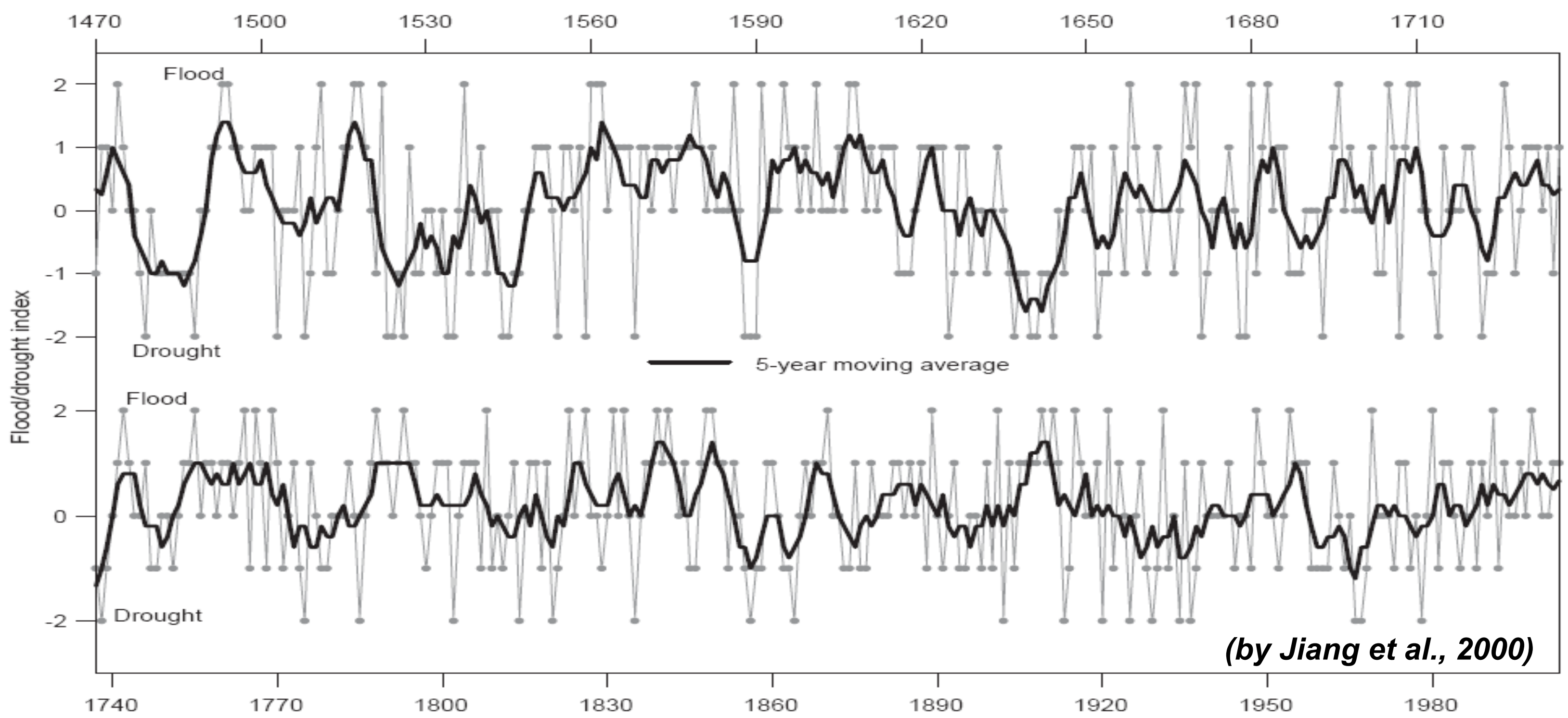
Ming &Qing Dynasty (1644 AD): rapid increase of population, serious soil erosion
introduction dry-land crops (corn/sweet potato/potato……)

1950-80s: continuous strong soil erosion

Recent 20 yrs: soil erosion slew down slightly

(by Shi, 2000)

Reconstructed flood/drought index (1470-1950 AD) in Yangtze floodplain



Index (category)	Description
2	Severe flood
1	Flood
0	Normal (without event or missing records)
−1	Drought
−2	Severe drought

Spectral analysis: the flood/drought cycle has periods of 16.69, 5.09 and 10.47 years

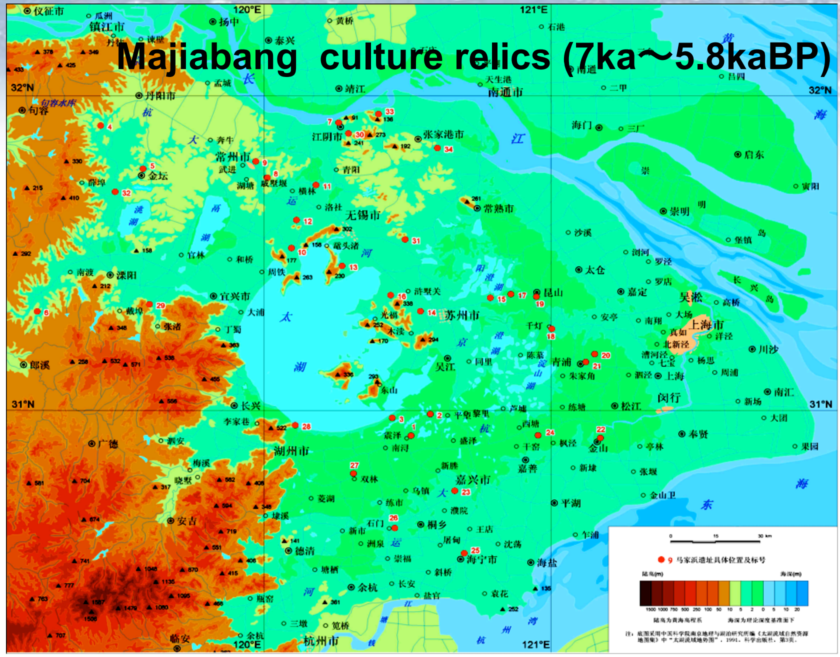
The relationship between ENSO index and flood/drought index indicates El Niño has a close relation with flood events and La Niña correlates with drought events

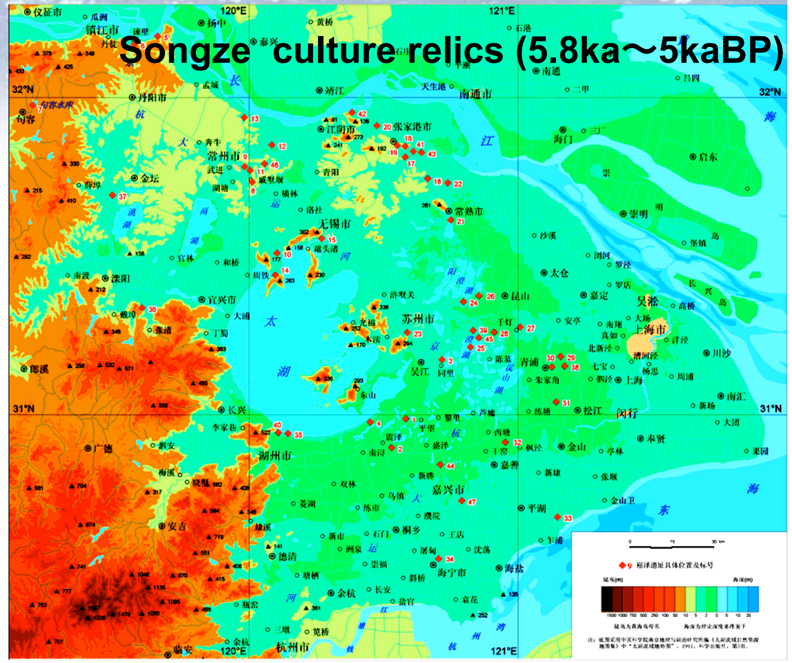
(2) Environmental archaeology

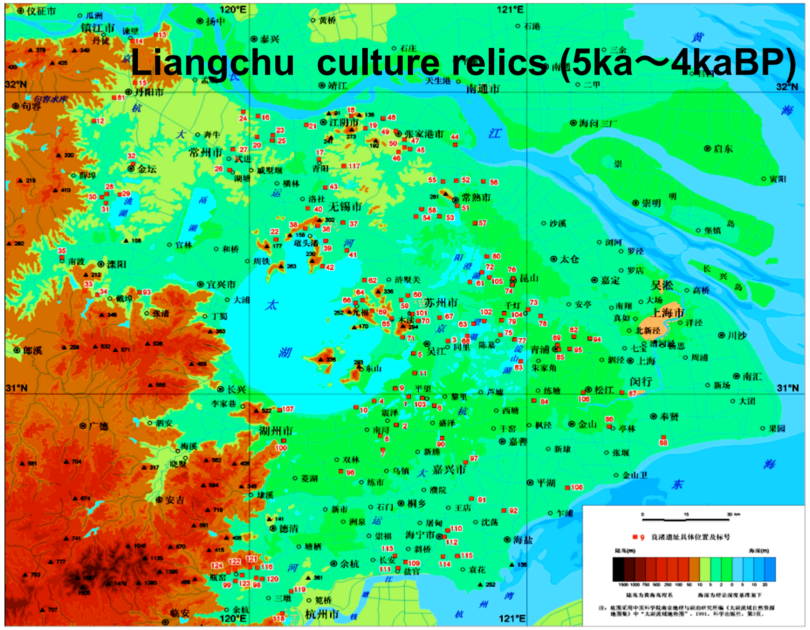
Neolithic Age (8-4 kaBP, 3 culture periods)

Bronze Age (after 4 kaBP, Dynasty Xia, Shang & Zhou)

Distributions of Neolithic relics in Taihu-Yangtze delta plain



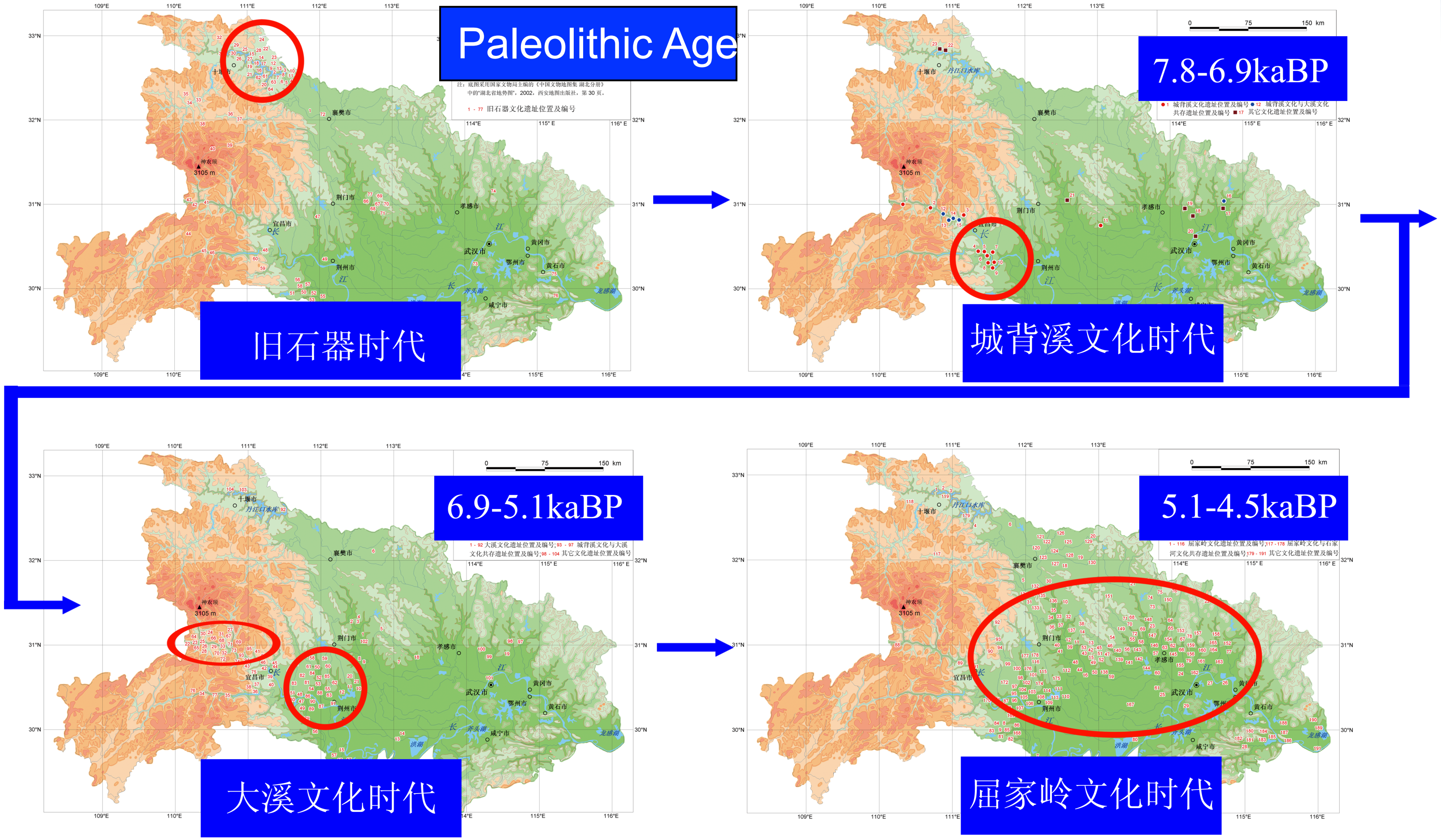




The distributions of relics sites with the different period indicate the quick expansion of human activity, corresponding to the retreat of the sea water in Taihu-Yangtze delta plain since 5.8 ka BP.

(Zhu et al., 2003)

Distributions of Paleolithic to Neolithic relics in Dongting-Jianghan basin

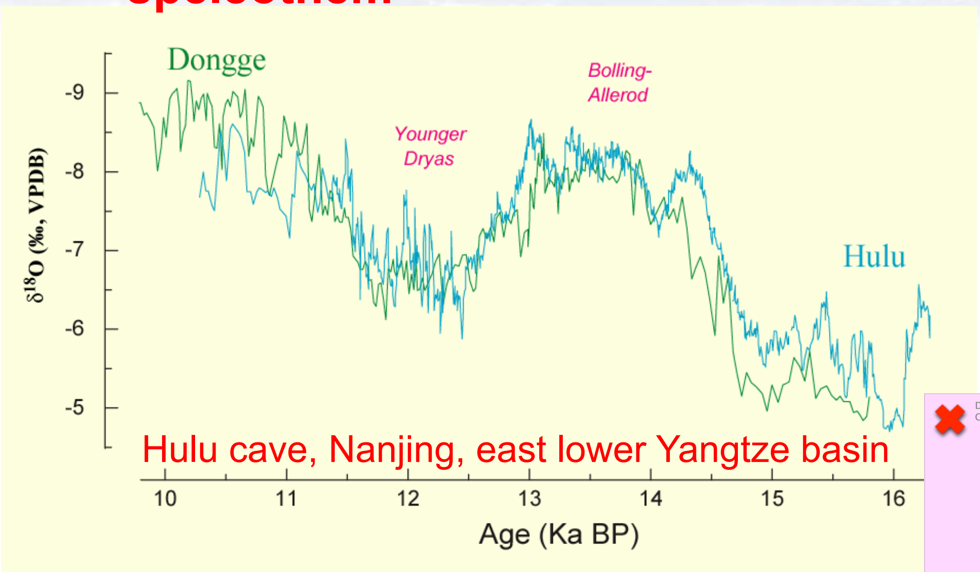


In the upper part of Yangtze basin, the distributions and the number of relics with different period suggest the early human adaptation to environment change controlled by climate

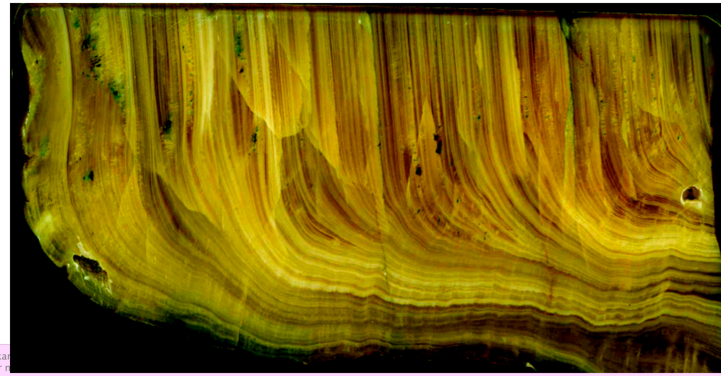
(Zhu et al., 2007)

(3) Monsoonal climate reconstruction

speleothem



Cave speleothem records in the low Yangtze basin

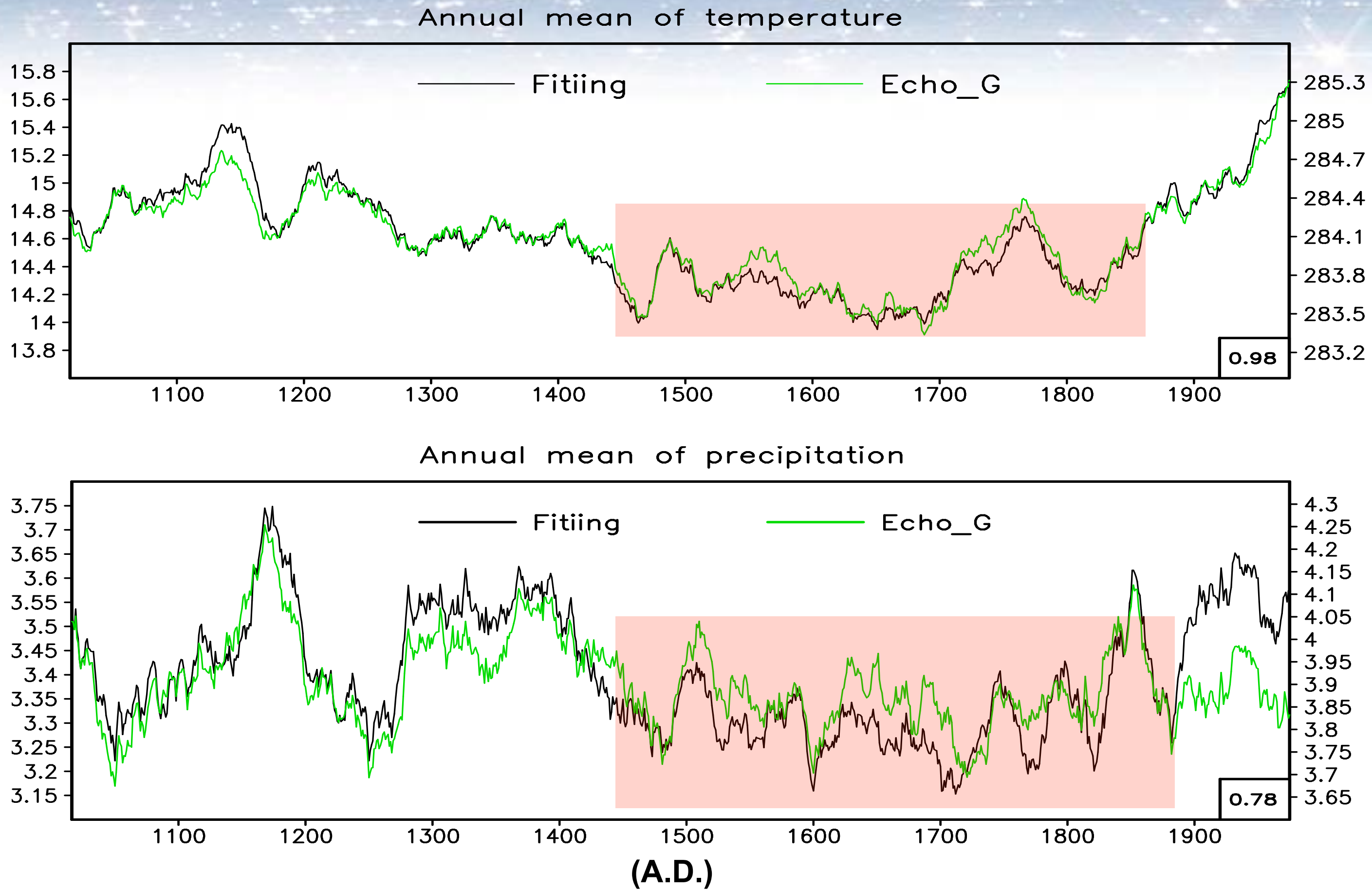


(Wang et al., 2005; 2008)

Sanbao & Heshang caves, west margin of YF

The changes in spelethem $\delta^{18}O$ is considered as a good indicator of East Asian Summer Monsoon, although there are some arguments on its signal source (monsoon intensity, precipitation, or temperature?)

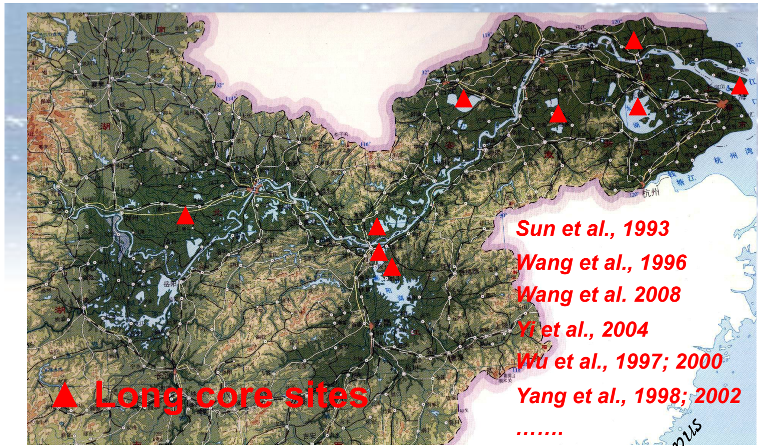
ECHO-G model



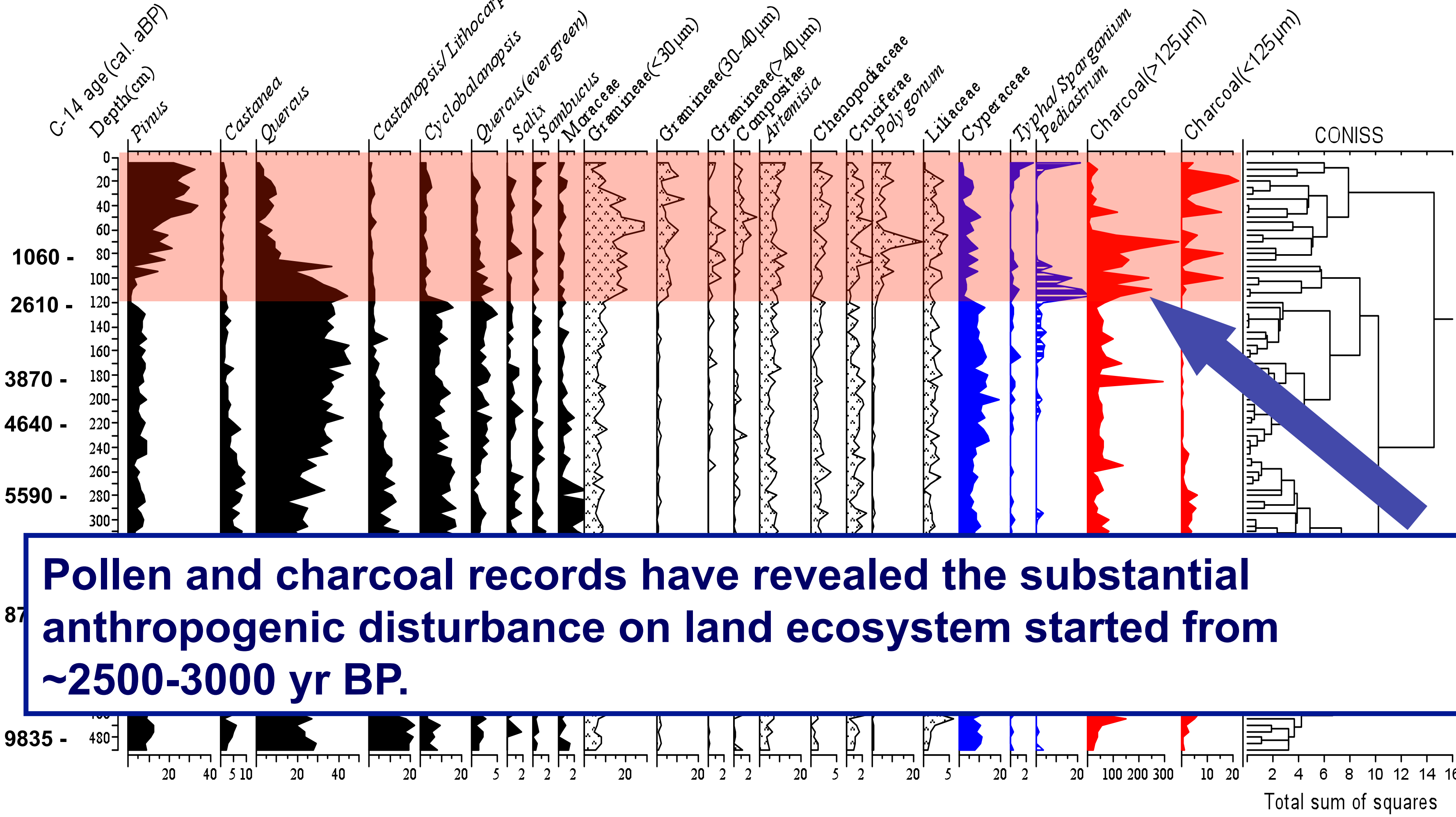
(Liu et al., 2005; 2009)

ECHO-G model has being applied to reconstruct the past millennium climate changes for eastern China (calibrated by the instrument data, speleothem and tree ring data)

(4) Paleolimnology in Yangtze floodplain

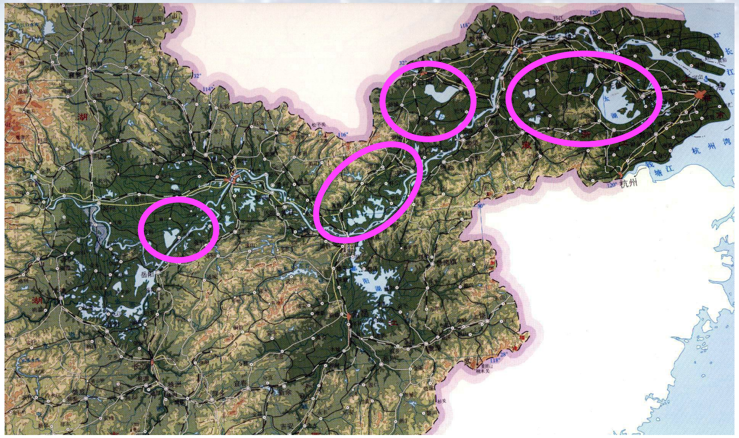


● Holocene lacustrine sediment records



Pollen and charcoal records have revealed the substantial anthropogenic disturbance on land ecosystem started from ~2500-3000 yr BP.

● Environment changes over past centuries



Indicators:

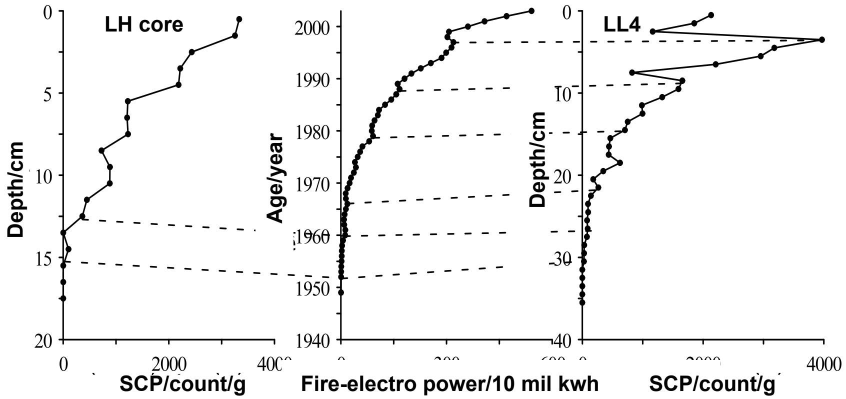
Physical: magnetism, particle size, SCP

Geochemical & bio-geochemical: trace metals, C/N/P,

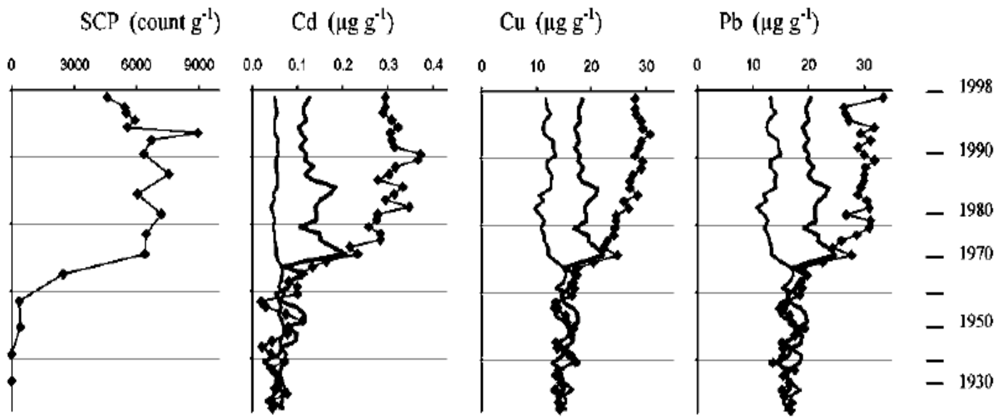
$\delta^{15}N$, $\delta^{13}C$, pigments, N-alkanes

Biological: diatom, chironomid, pollen, charcoal,

Pollution recorded in shallow Yangtze lakes

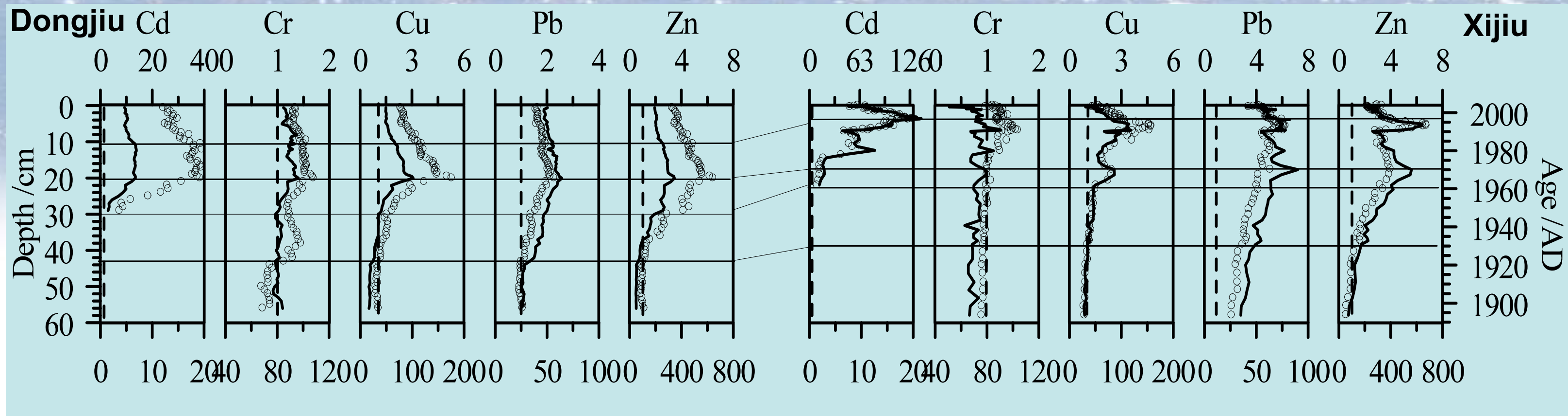


Longgan *(Wu et al., 2005)*



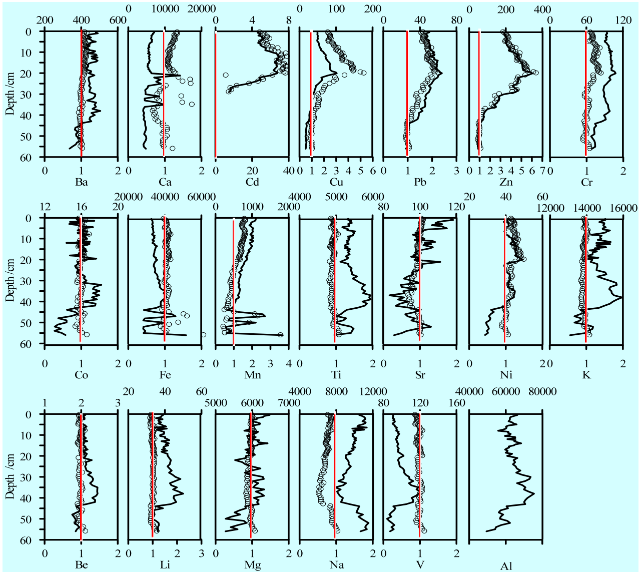
Taihu *(Rose et al., 2004)*

Pollution and sediment nutrient enrichment in most lakes has become increasing since the last 40-50 years.

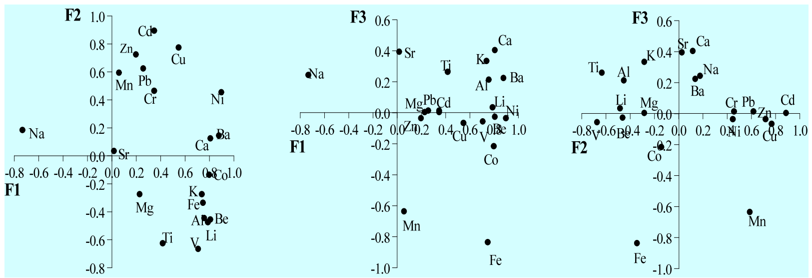


Heavy metals accumulation in DJ-5 core and XJ-1 core

Heavy metal pullution in Dongjiu & Xijiu, west Taihu



Enrichment factor of metals (*EFs*)

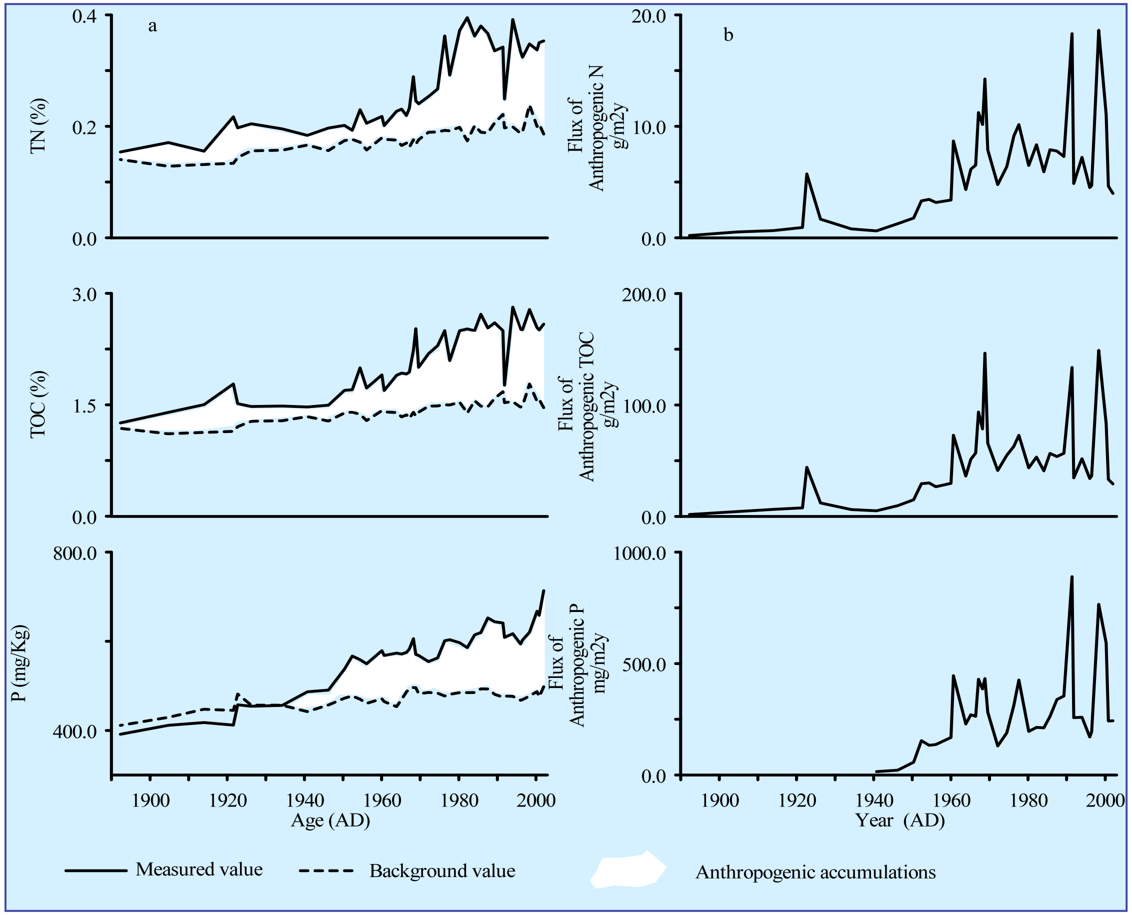


Statistical methods

Determine the source of metals

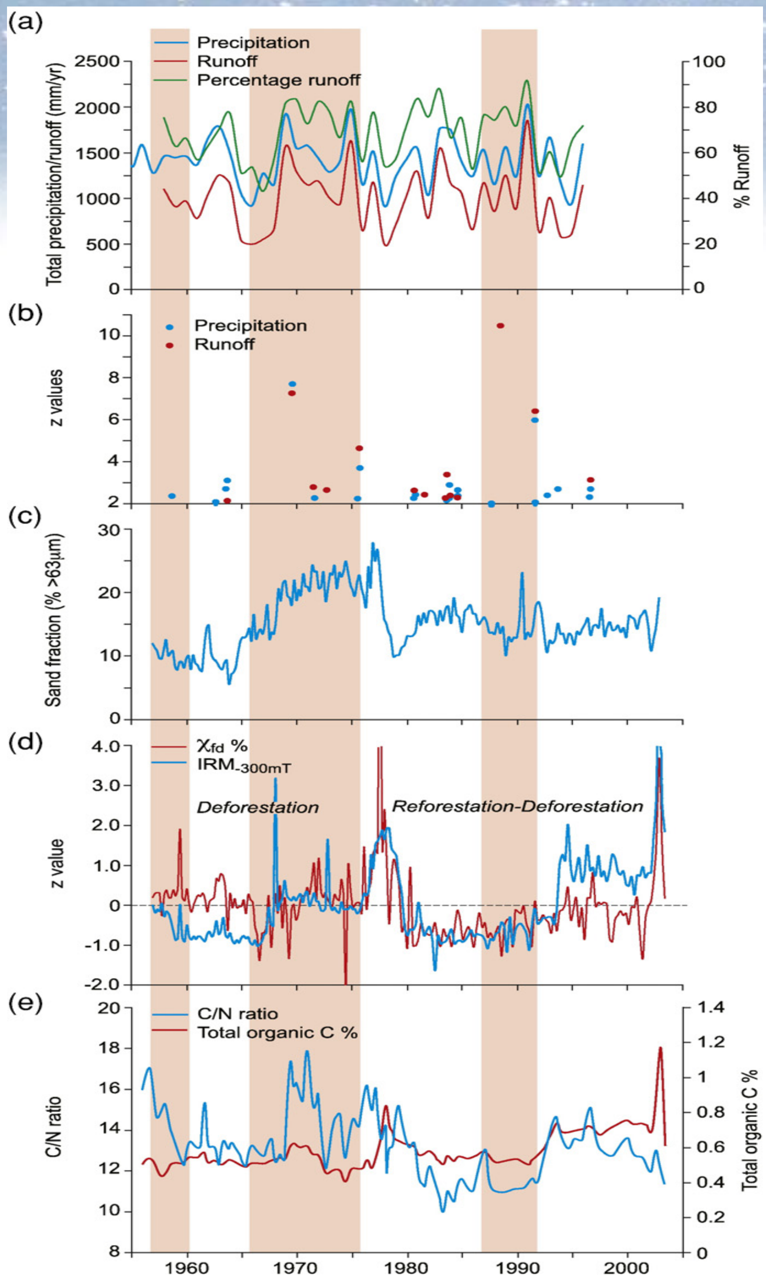
(Wu et al., 2009)

Nutrient enrichment in Longgan sediment and human impacts



Based on the measurement of the reference elements in the catchment, the background of sediment organic carbon(OC), nitrogen (N) and phosphorus (P) were estimated. Human-induced nutrient accumulation rates (OC, N and P) were distinguished over the last century.

(Wu et al., 2008)



Compilation of instrument, document and multi-proxies in sediment

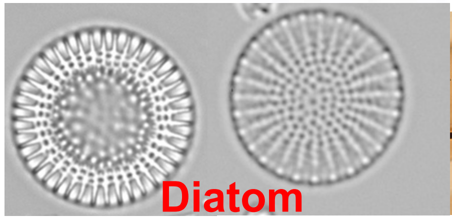
An integrated analysis on climate–human–environment interactions from a reservoir in Chaohu catchment (1958–2003)

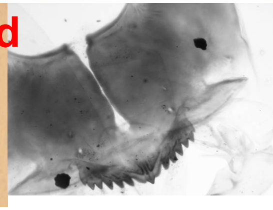
a) annual precipitation, annual runoff,and annual runoff as percentage of annual precipitation;
b) extreme monthly precipitation and runoff (z score values N 2);
c) reservoir sediment sand fraction as proxy for sediment accumulation rate;
d) reservoir sediment magnetic proxies for catchment substrates (IRM) and surface soil erosion (χ_{FD}), with timings of catchment deforestation and reforestation;
e) reservoir sediment C/N ratio and percentage TOC.

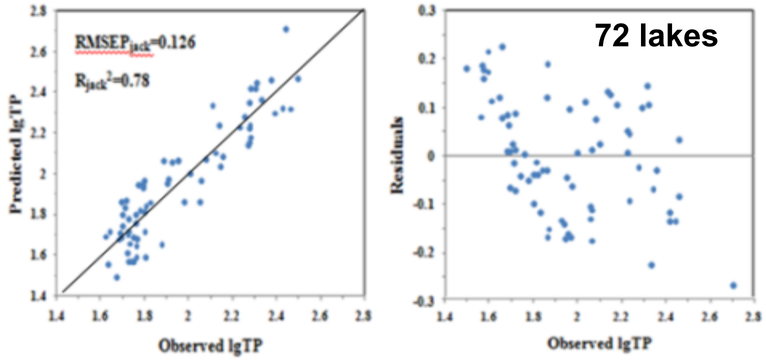
The three vertical bars indicate periods of Great Leap Forward (1958–1960), the Great Cultural Revolution (1966–1976) and check dam construction (late 1980s/early 1990s).

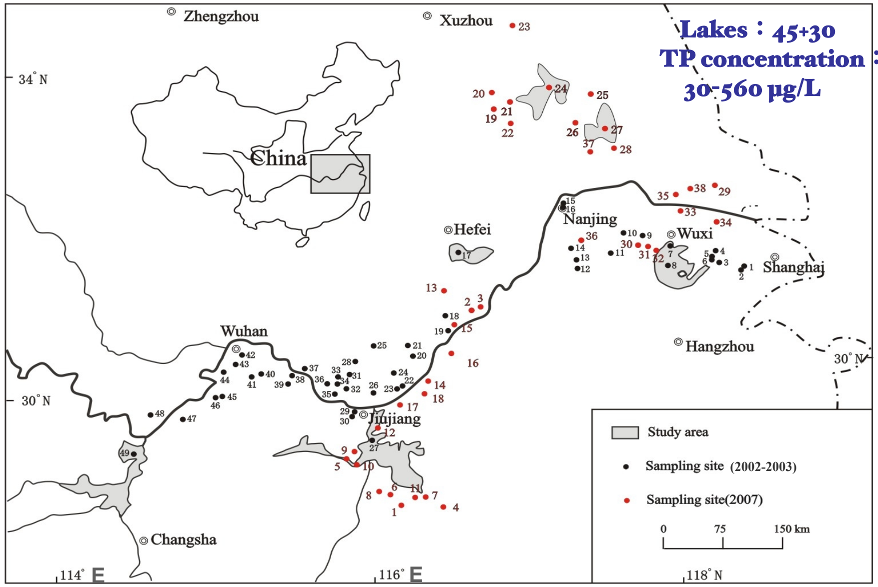
(Dai et al., 2009)

Past water phosphorous reconstruction (transfer function)





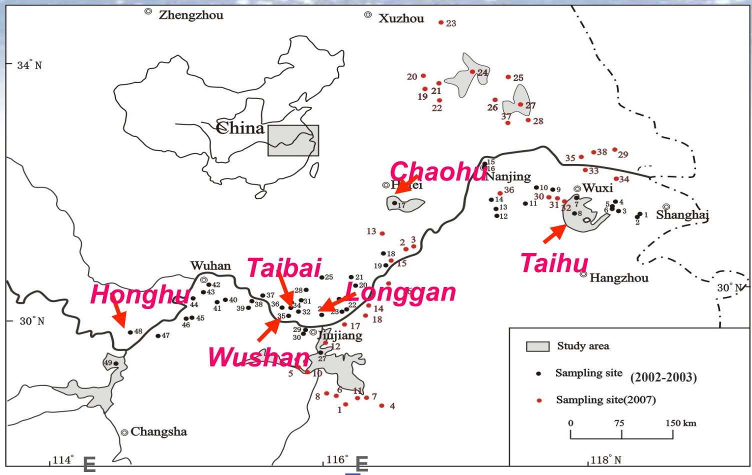


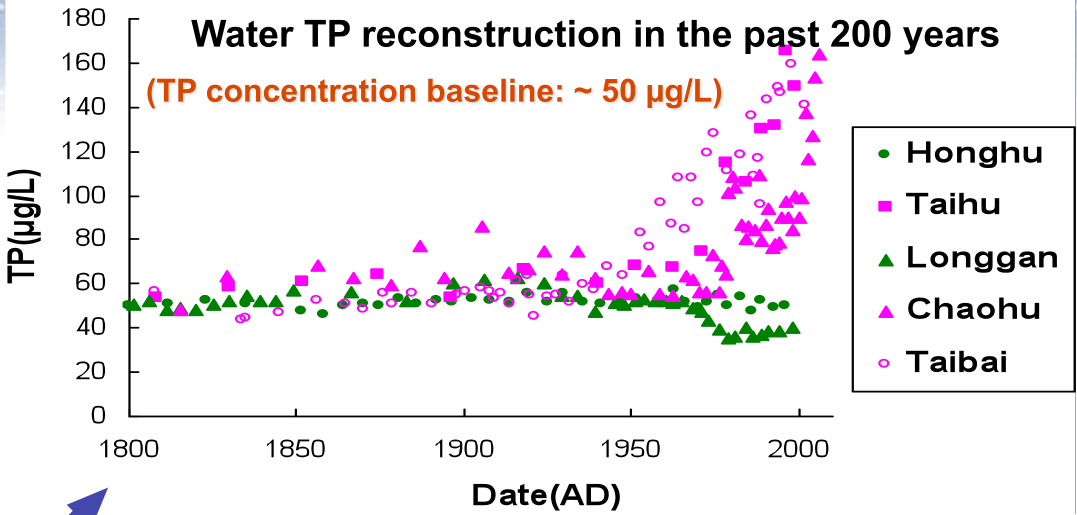


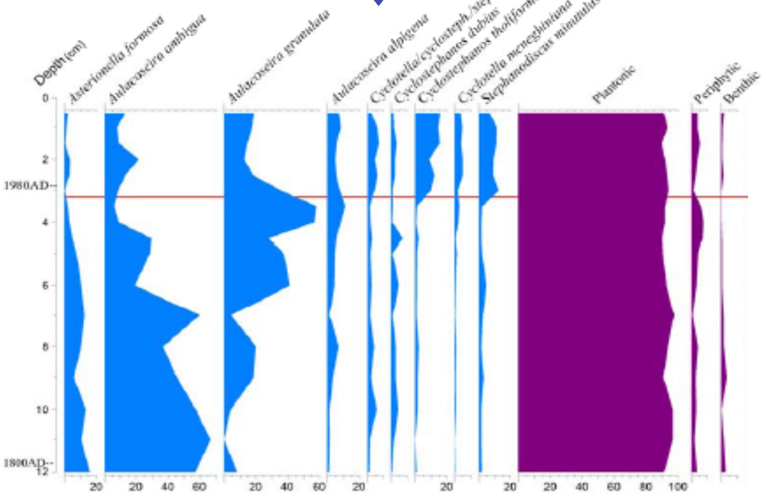
Diatom-and Chironomid based TP transfer function for Yangtze lakes using the inverse WA model

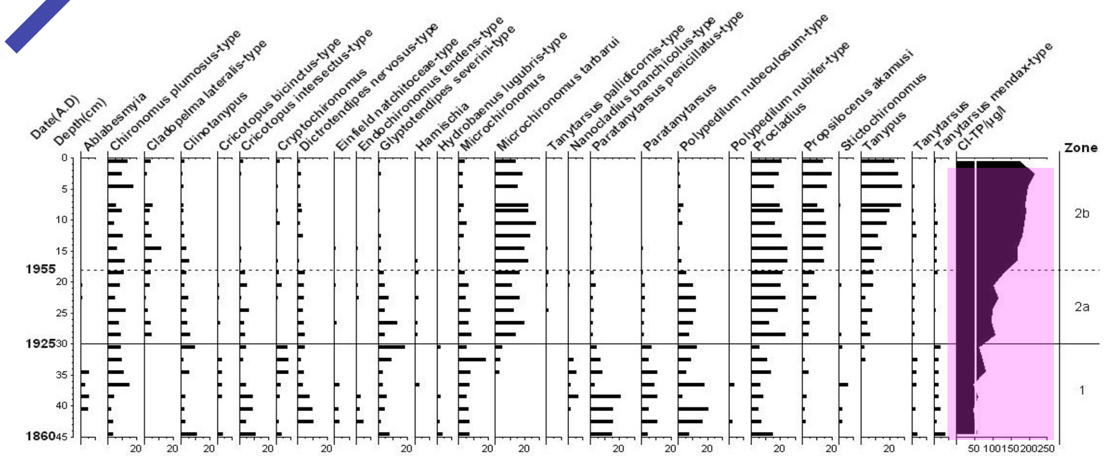
(Yang et al., 2005; 2008)

The established TP transfer functions using 72 lake data-set provides high predictive ability (R^2) and low error (RMSEP), robust enough for past water TP reconstruction.









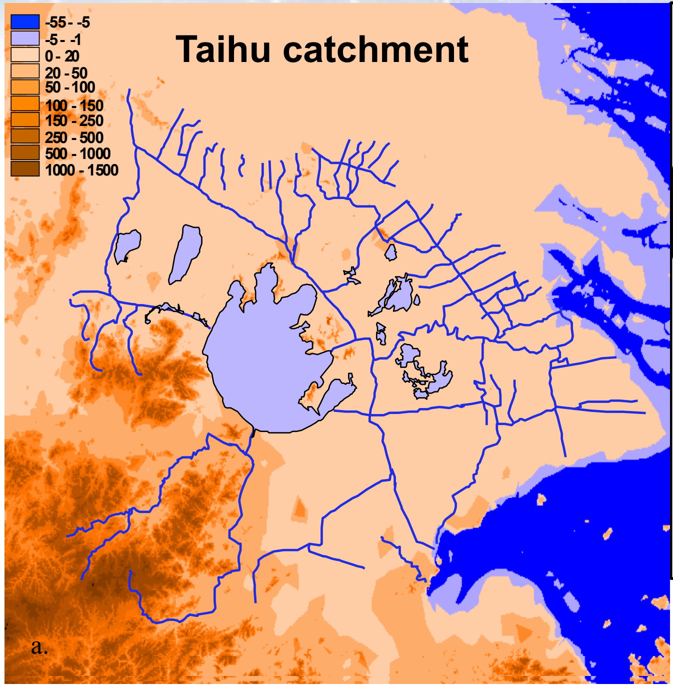
Fossil diatom in lake sediment

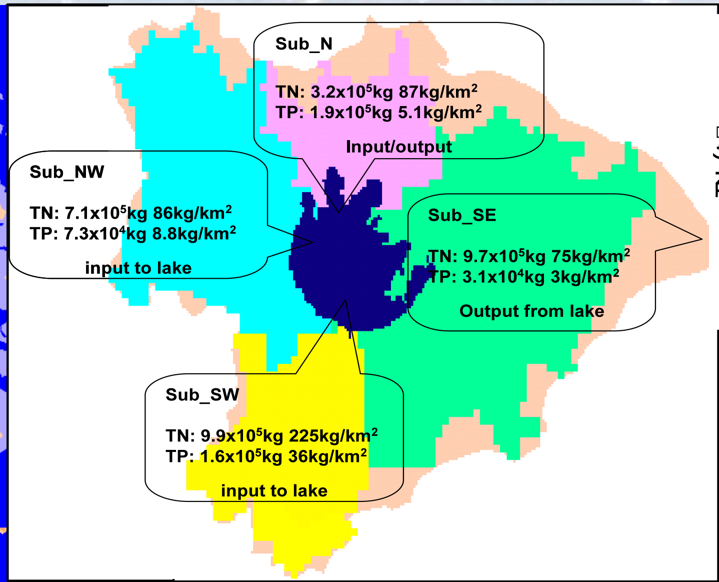
(Yang et al., 2009; Dong et al., 2008)

Water TP reconstruction based on chironomid record in Wushan lake

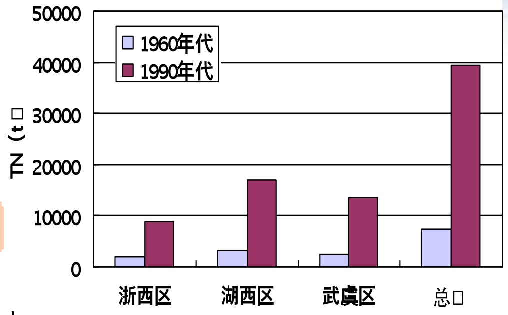
(Zhang et al., 2010)

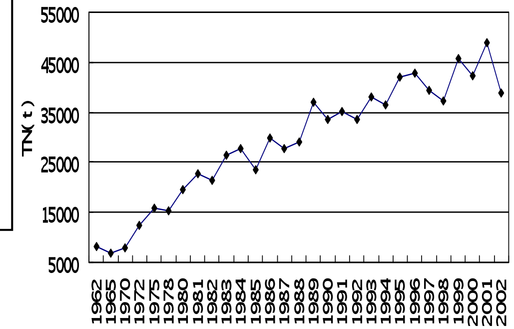
(5) Modelling historical nutrient inputs using SWAT





(Lai et al. 2006; Yu et al. 2007; Yu et al., 2008)



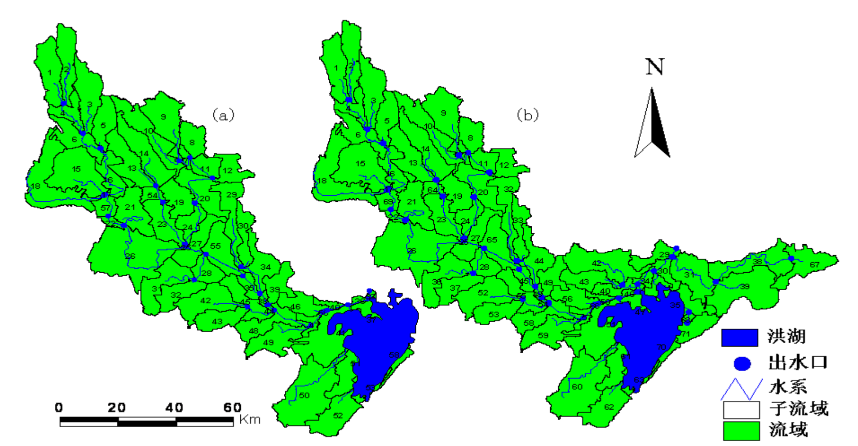


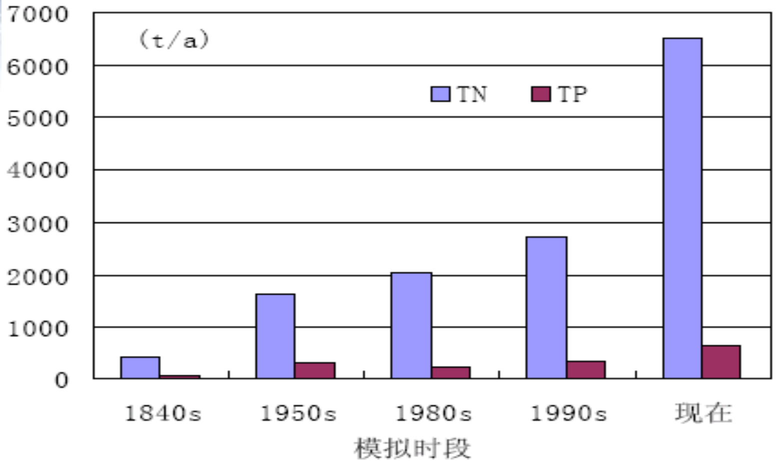
Modeling TN and TP production changes in a natural farm basin can be compared with pre-100 year sediment records in a broad scale: TP was simulated 1860t/a and TP 240t/a; Comparing to 1990s, the farming basin contributes 7% TN and 13% TP of modern levels from catchment to lake.

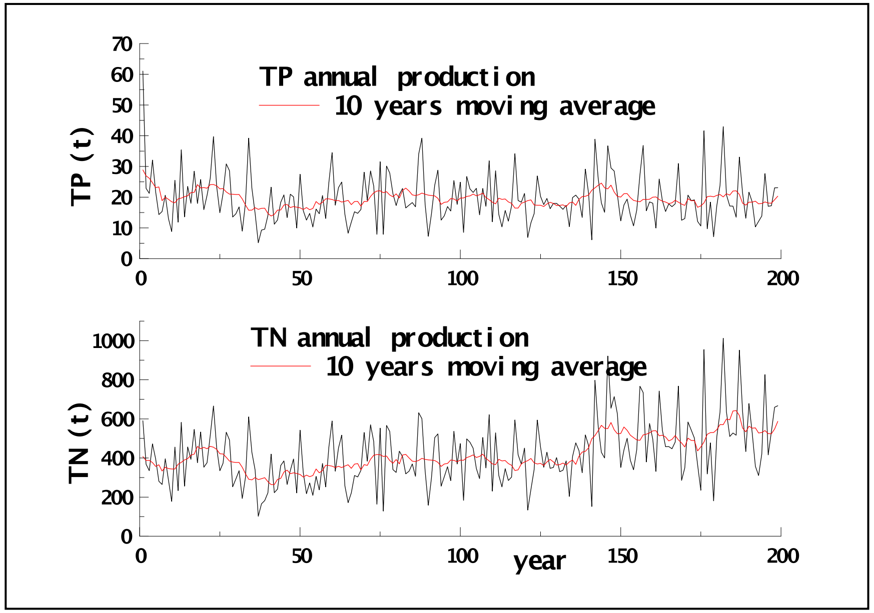
Sensitive experiments from 1960s to 1990s found that increase TN from 11% to 45% and TP from 14% to 30% was contributed by industry factor (fertilizer and pollution discharge), while urban development (population and sewage) increased TP 38 to 47%, and agricultural factors (soil, vegetation and livestock discharge) change TN and TP from 33 to 12%.

Comparisons with present (1960-90s), the future (+100 yrs) TN will increase 5-8% and TP increase 5-10%; this would increase pressures for Taihu Basin.

Honghu catchment: modelling nutrient inputs over the past 200 years







In the past 200 years, TN increased from 420t/a to 6522 t/a; and TP from 78 t/a to 665t/a.

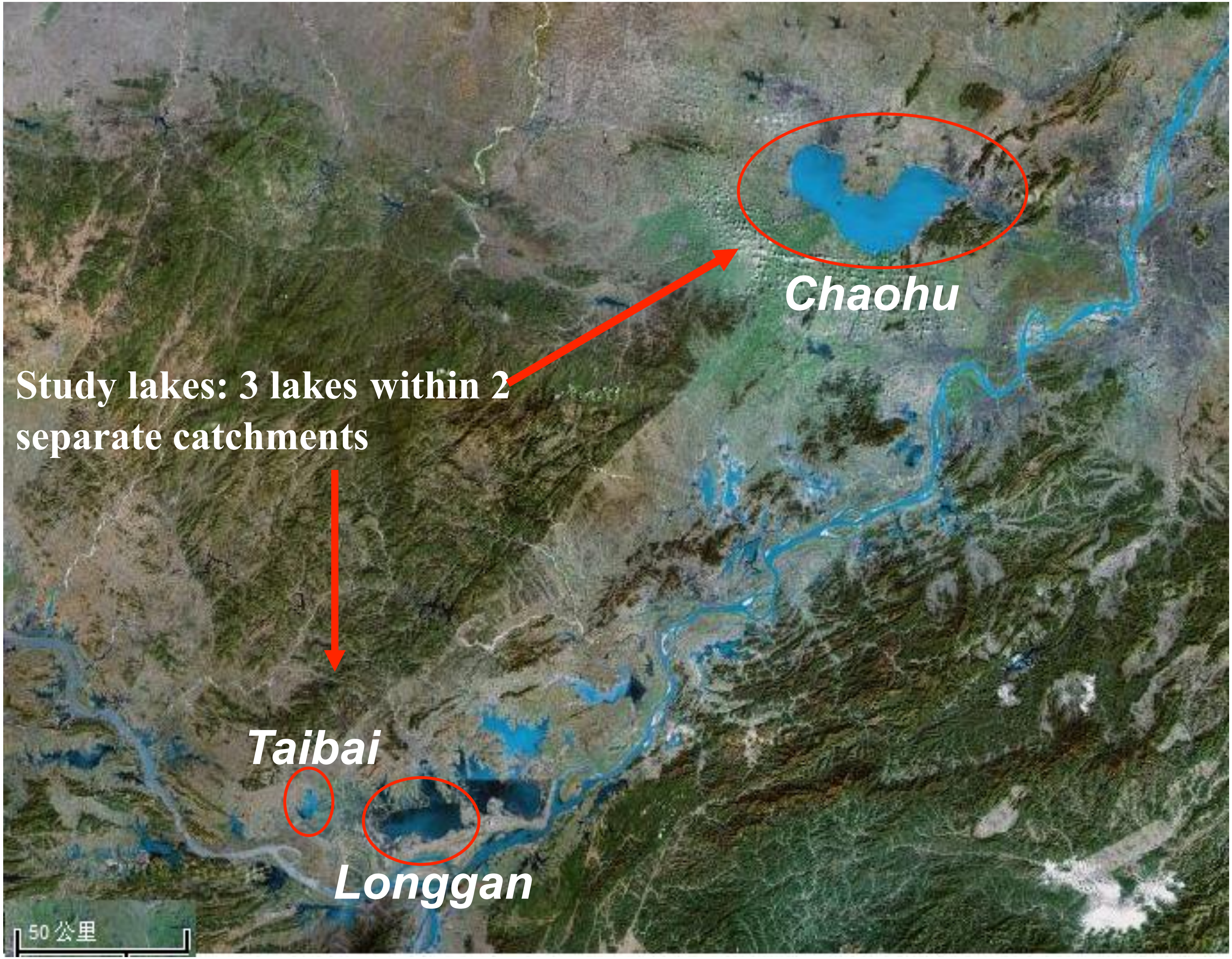
Catchment landuse is the key influencing factor, including deforestation, farming, and the modern agriculture practice in the last several decades (i.e. chemical fertilizer usage).

(Gui et al., 2007; Gui et al. 2008)

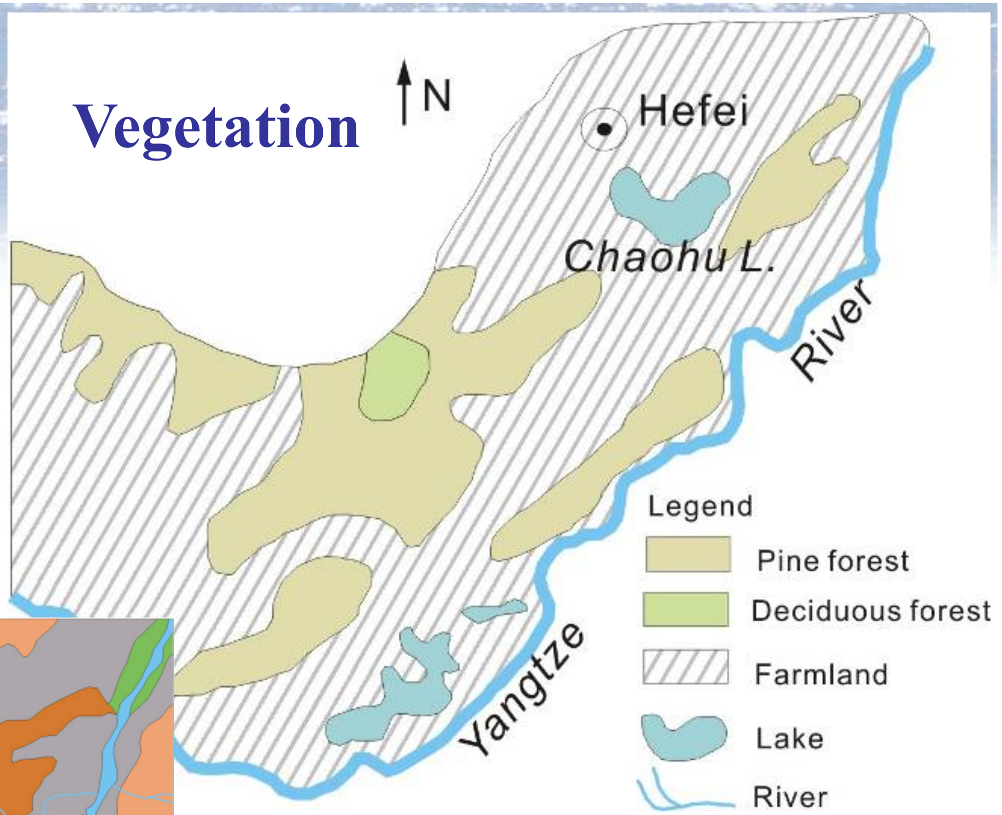
3. Case studies on plaleolimnology

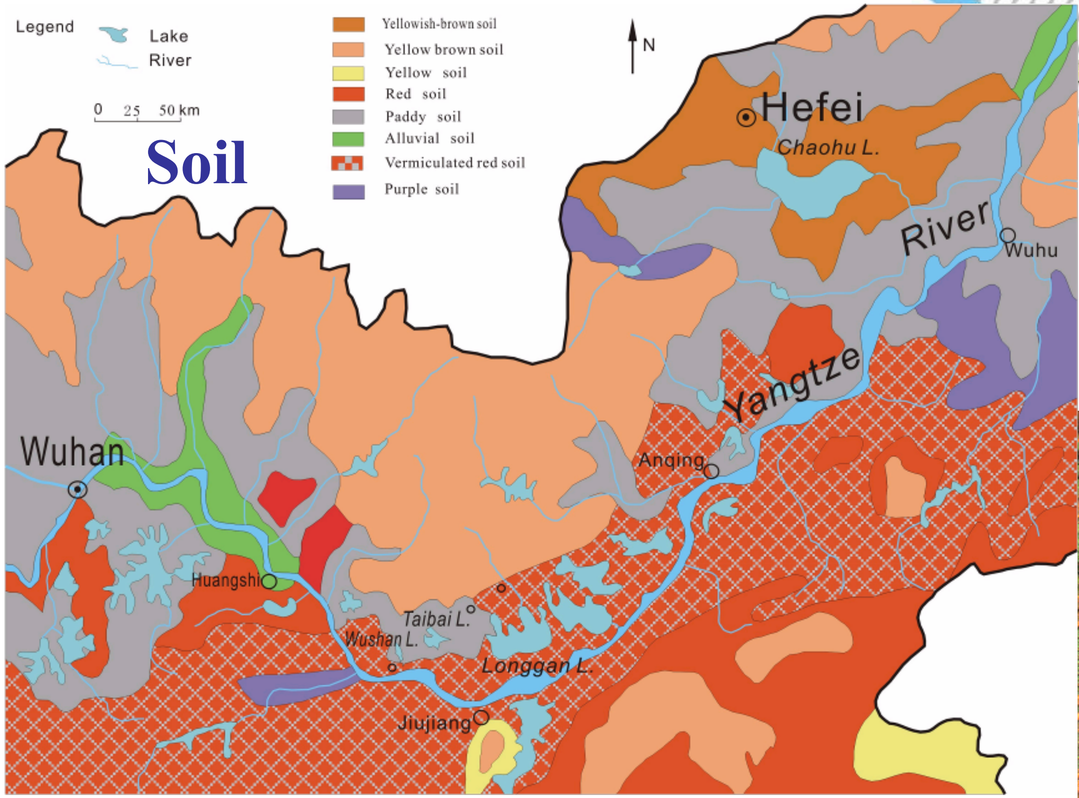
Questions:

- When did the current catchment landscape form? Do the paleo-data match with document events?
- Which processes have driven the lake ecosystem?
- How did the environment respond to human activity and climate change?


Study lakes: 3 lakes within 2 separate catchments
Chaohu
Taibai
Longgan
50 公里

Soil & vegetation in lake catchments

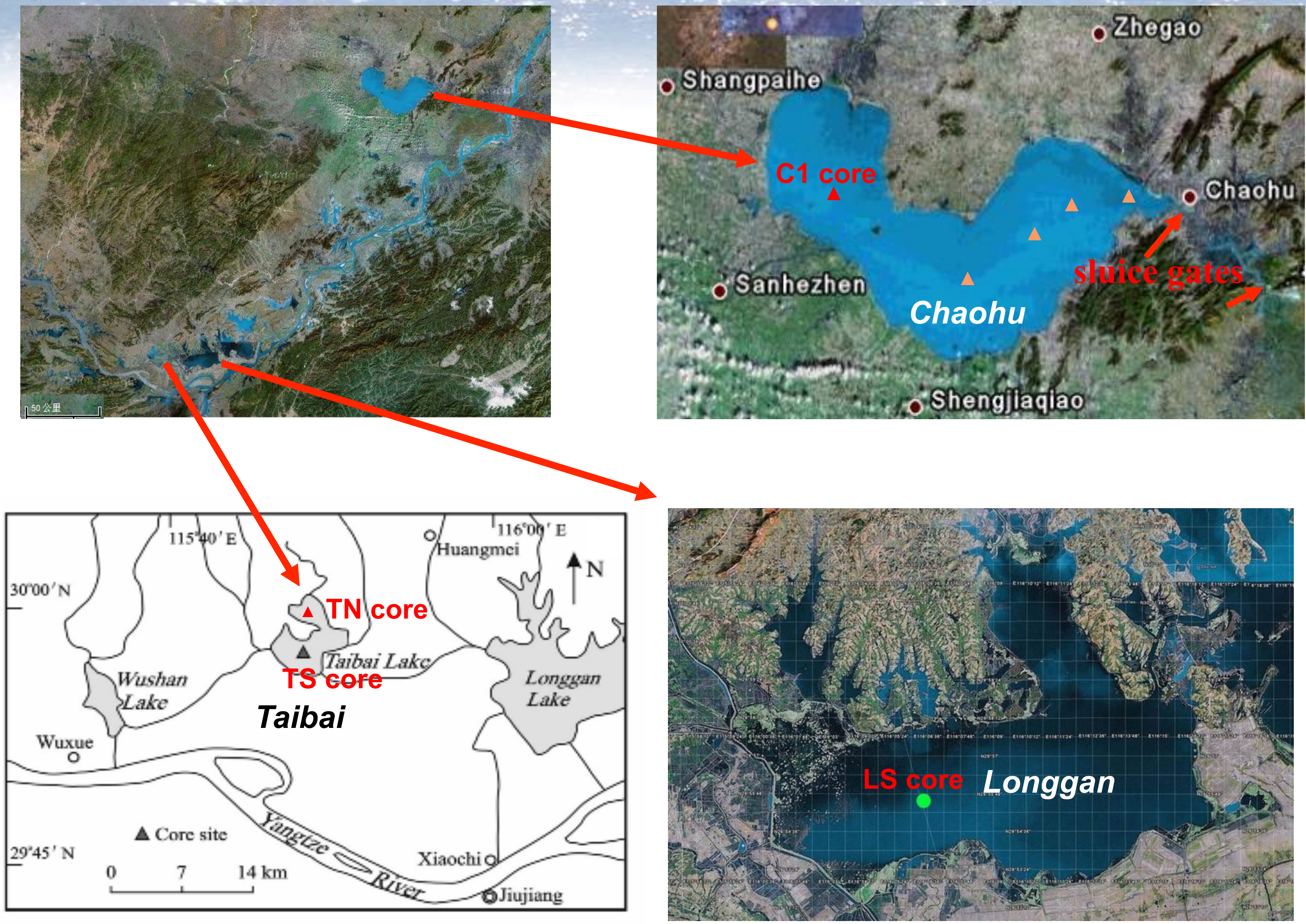




Yellow brown soil

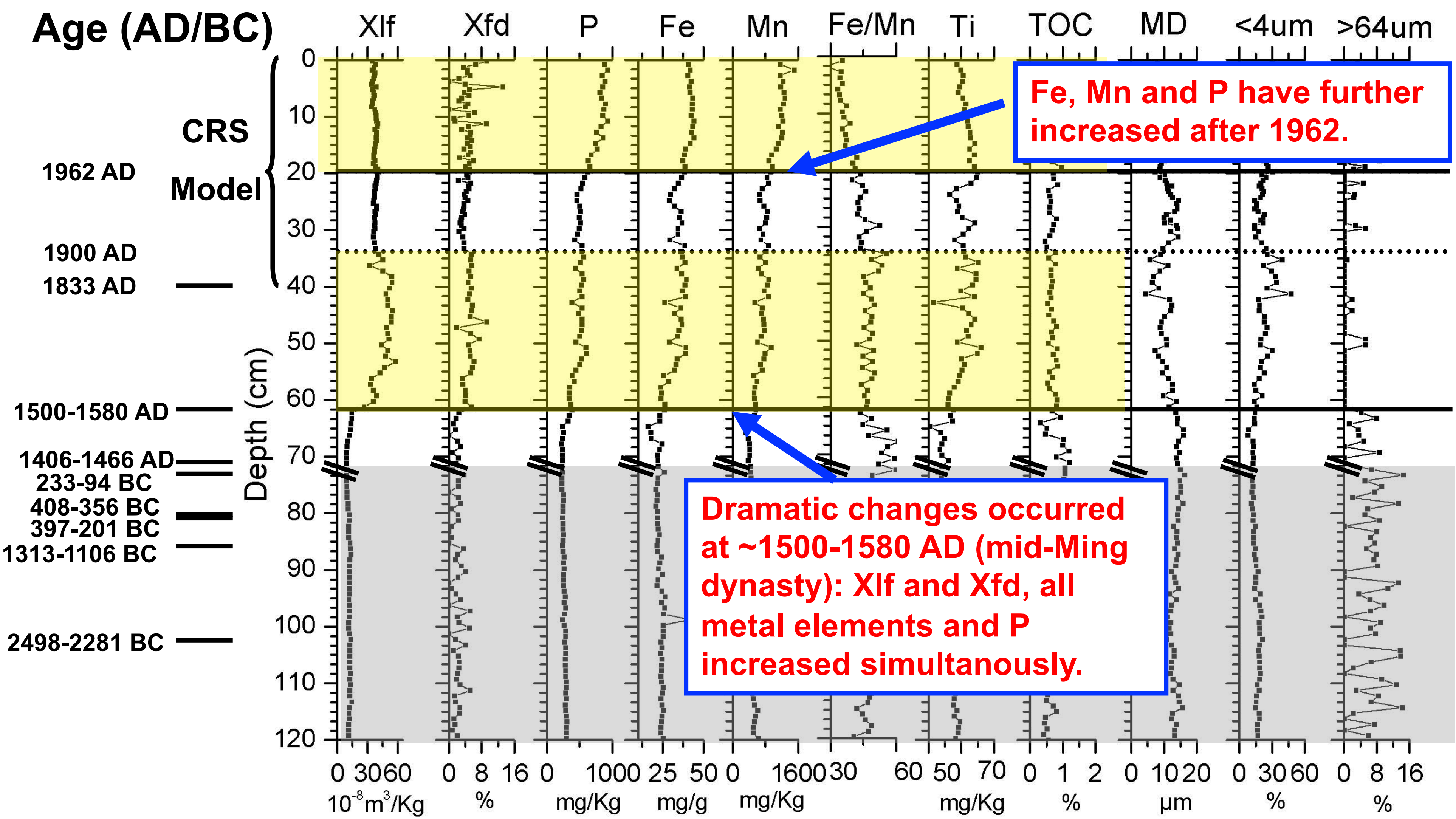
Information of selected lakes

	Longgan Lake	Taibai Lake	Chaohu Lake
Lake area (km^2)	316(579 km^2 before 1950)	26 (69 km^2 before 1950s)	770 (1170 km^2 before 1950s)
Catchment (km^2)	5511 (Susong & Huangmei counties)	607 (Huangmei county)	13486 (cover 1 city and 8 counties)
Depth (m)	max.: 4.58, ave: 3.78	max.: 3.9, ave: 3.2	max. depth: 3.77 m, Ave: 2.69 m
Water retention	N.D.	N.D.	120d before 1960; 7 yr recently
Reclamation & daming	in 1950s;	1950s, 1970s;	Sluice gates at the outlet in 1958-1962
Eco-type	Macrophyte dominated	Macrophyte to algal dominated	Algal dominated
TP (μg/L)	51	South: 125; North: < 100	1999: 264.0; 2000: 177.0; 2001: 193.7
Human activities	Agriculture, Fishing	Fishing, Agriculture, Sewage	Fishing, Agriculture, Sewage, Industrial effluent

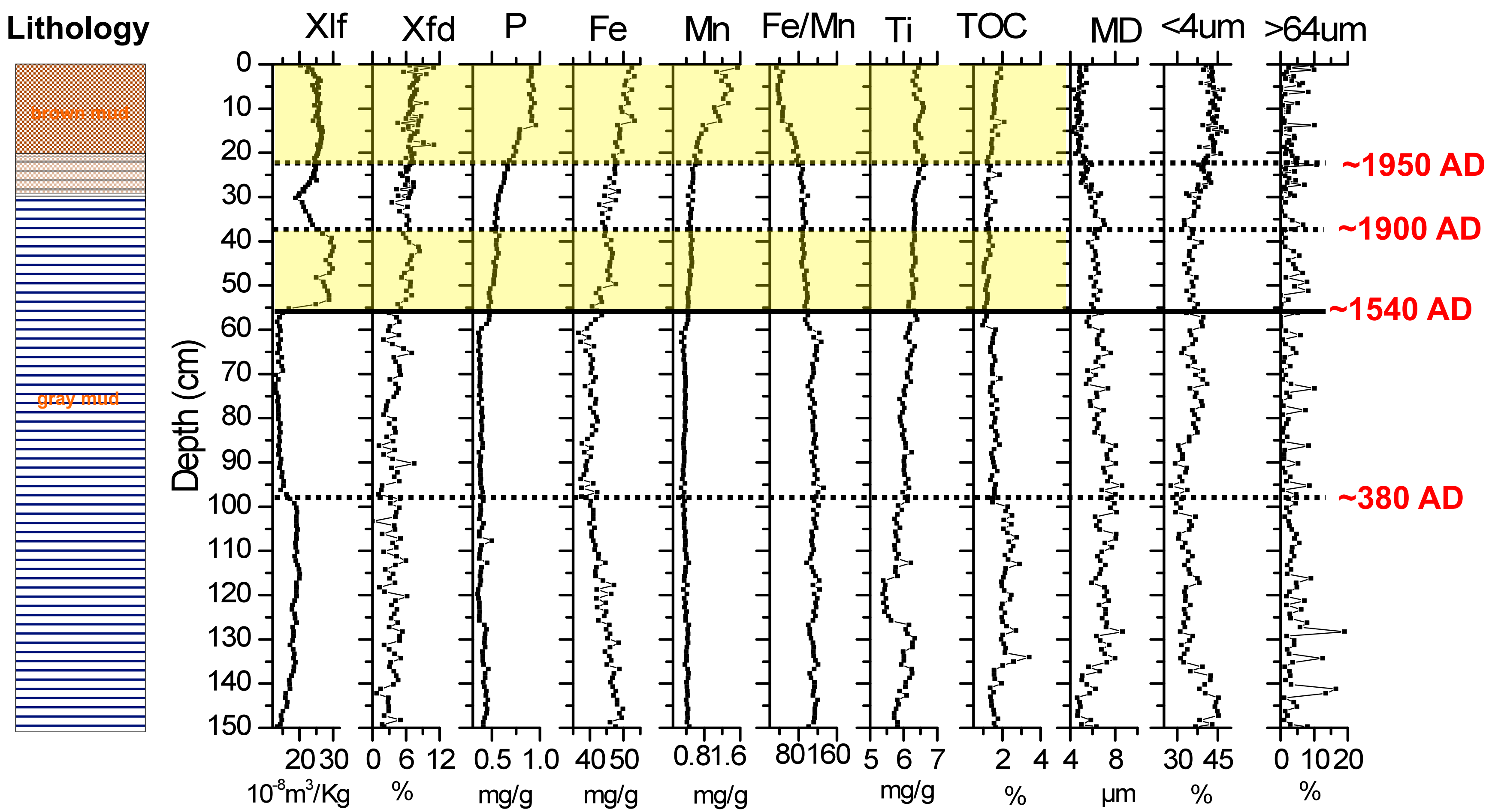

50 公里
Zhegao
Shangpaihe
C1 core
Chaohu
Sanhezhen
sluice gates
Chaohu
Shengjiaqiao
115°40′ E
116°00′ E
Huangmei
N
30°00′ N
TN core
Taibai Lake
TS core
Wushan
Lake
Longgan
Lake
Taibai
Wuxue
Core site
Yangtze
River
Xiaochi
Jiujiang
29°45′ N
0
7
14 km
LS core
Longgan

— catchment soil erosion & discharge

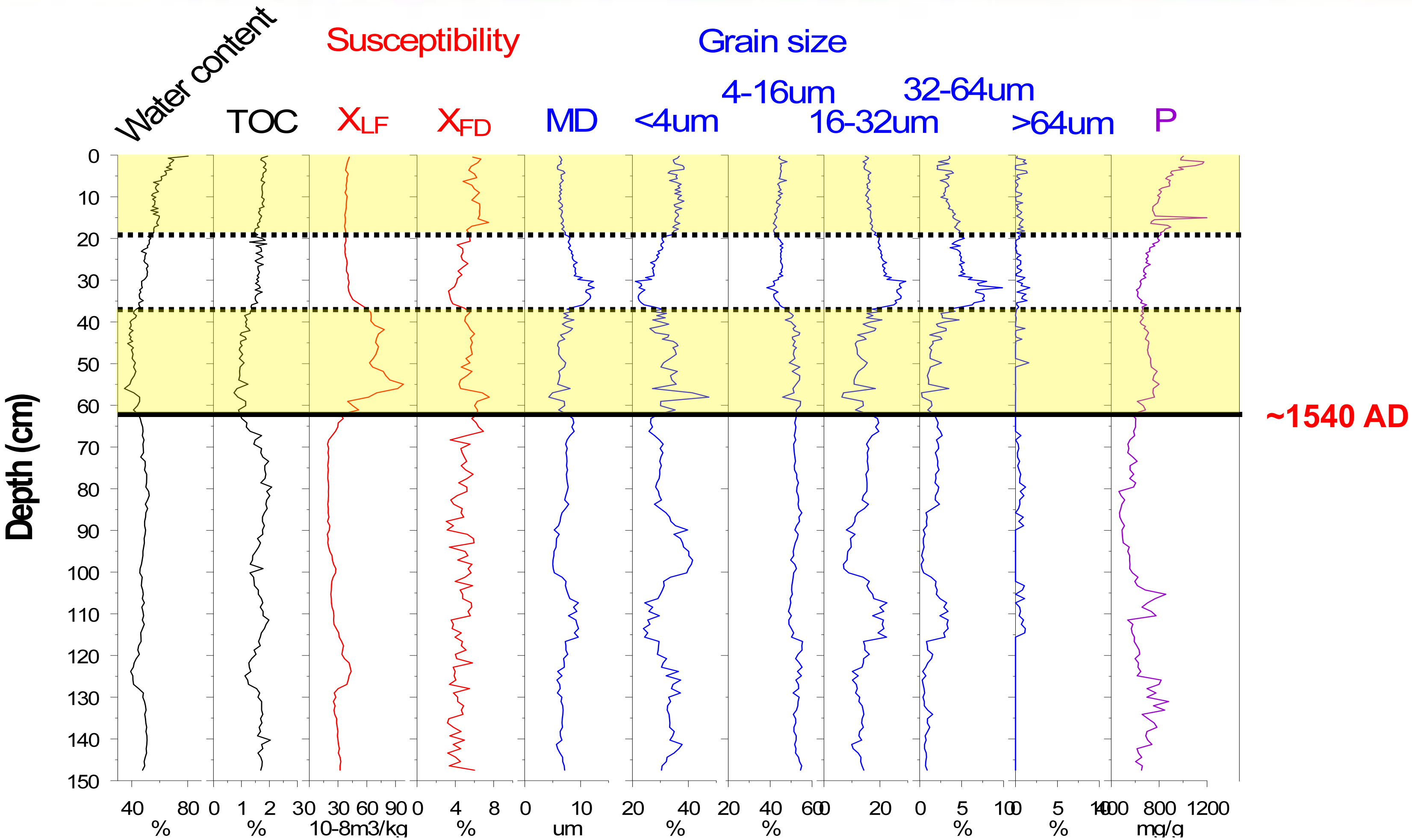
C1 core multi-proxies (Chaohu)



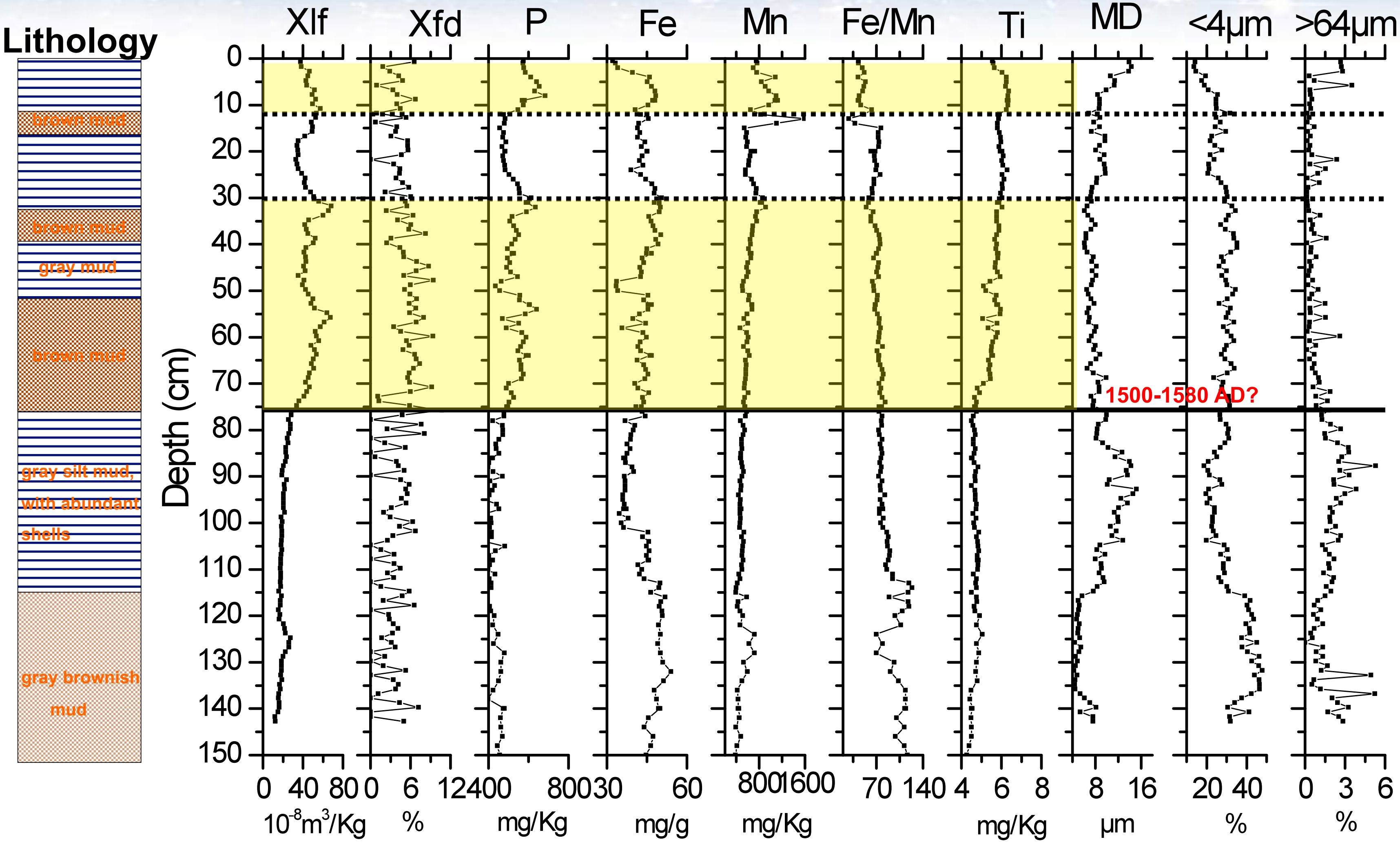
TN core multi-proxies (north Taibai)



TS core multi-proxies (south Taibai)

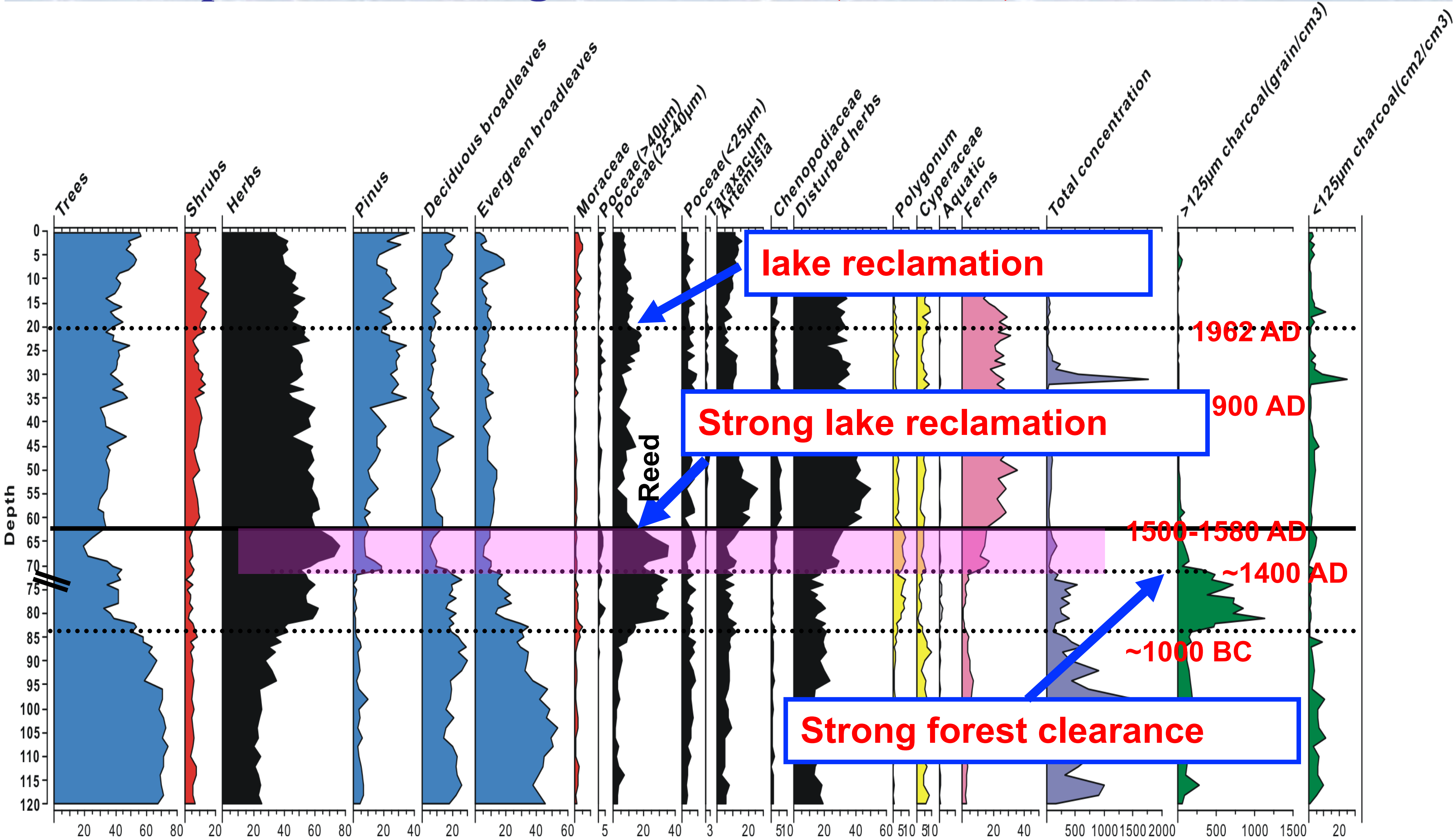


LS core multi-proxies (Longgan)

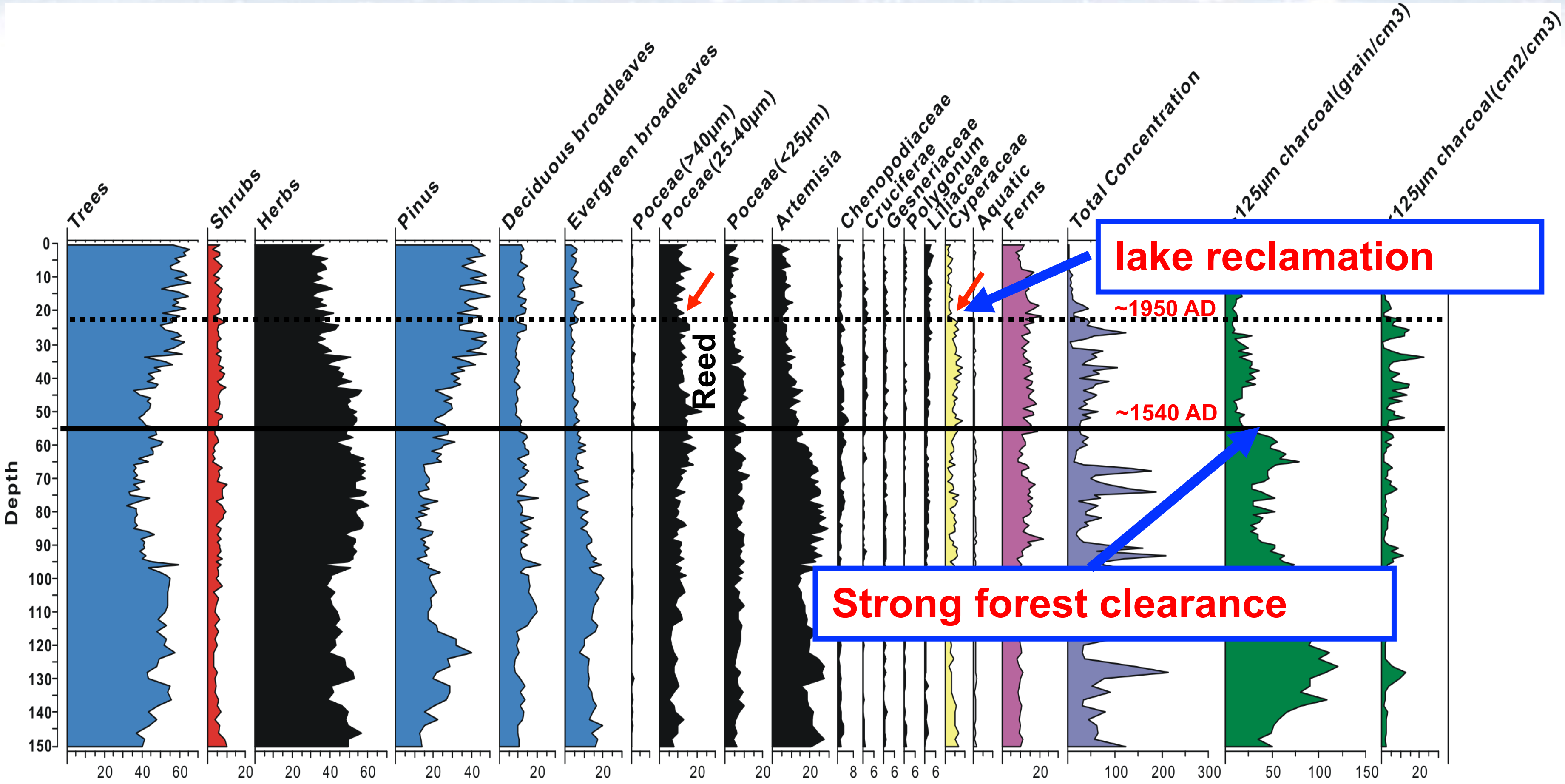


— catchment deforestation

C1 core pollen assemblage & charcoal (Chaohu)



TN core pollen assemblage



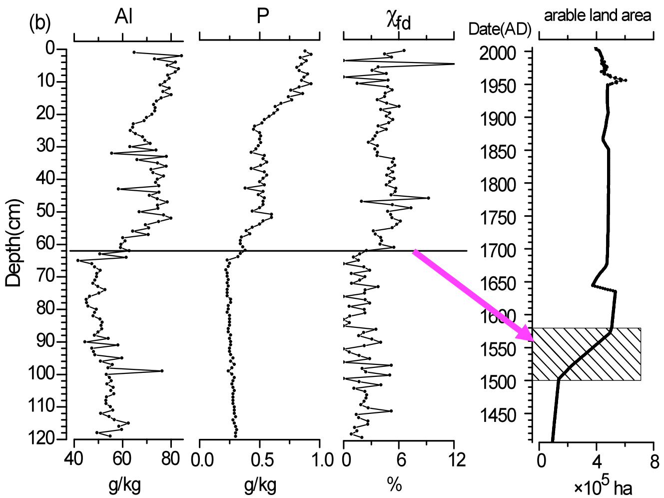
General conclusions （1）

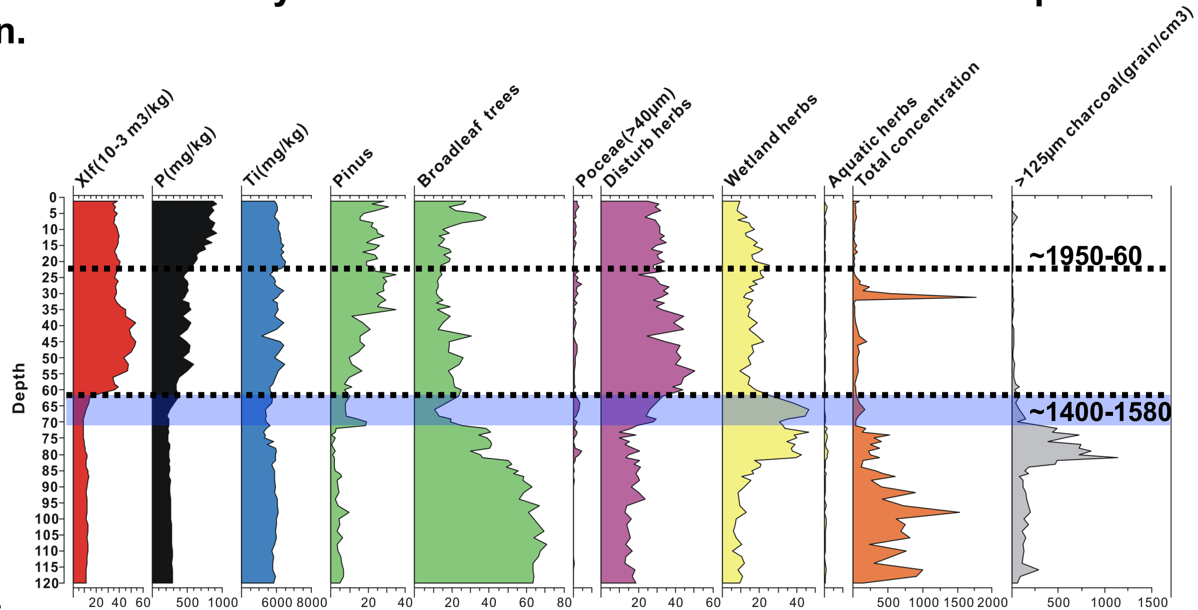
■ “Catchment indicators” in studied lakes reflect similar changes in catchment soil erosion and vegetation over the past 600 years.

■ Strong deforestation and erosion started from early- to mid-Ming dynasty (1400-1580 AD), resulting in the quick increase of discharge in nutrient and detritus from whole lake catchment, corresponding to the expansion of landuse areas at the same period.

■ The strong forest clearance and reclamation in Ming dynasty suggest that the human activity influenced on both the highland vegetation of the catchment and the low wetland system. The pollen records can match to the documents (the timing of dryland crops introduction, immigration of people from Northern China, and the increase of rice production during mid-Ming to Qing Ages).

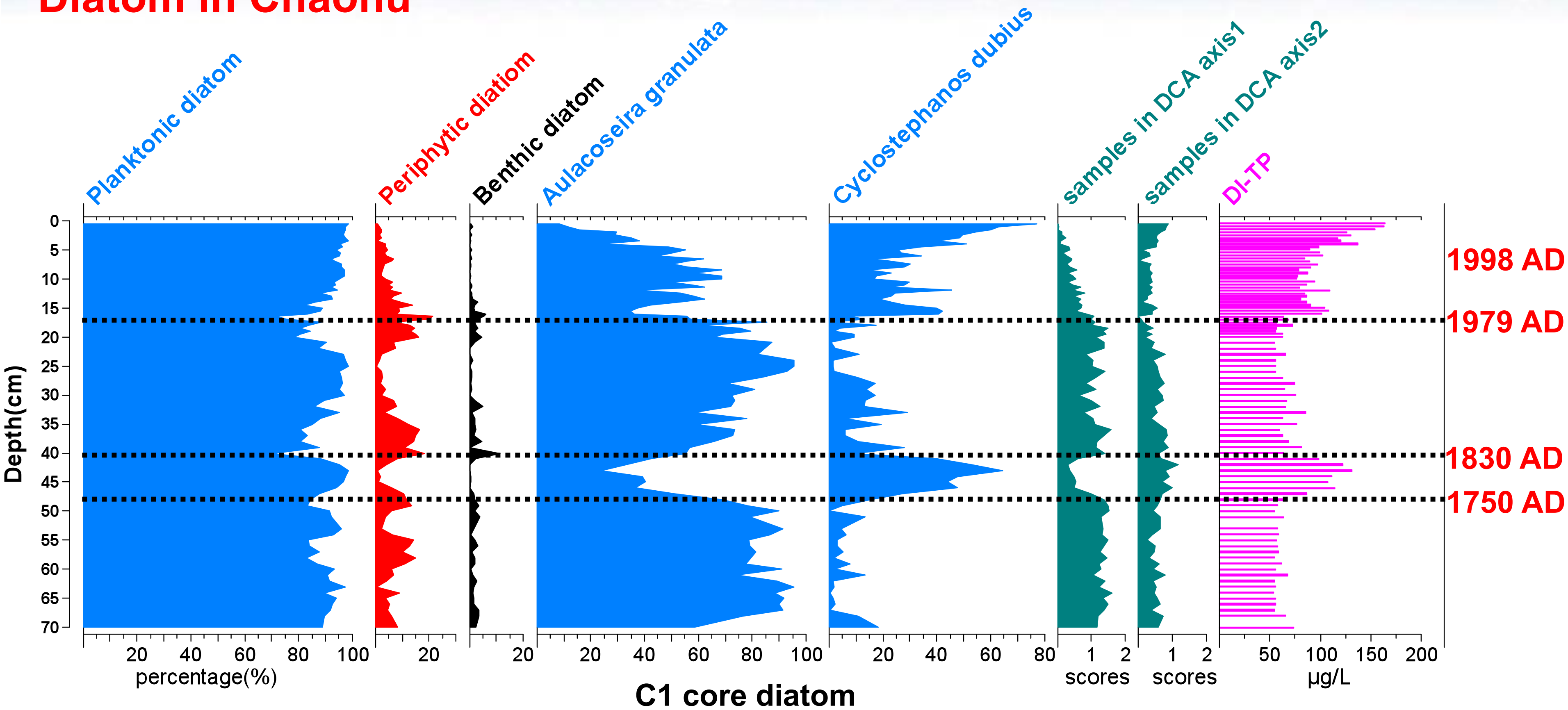
■ The increases of nutrient inputs in the last 50 years were contributed to the enhanced top-soil erosion and lake reclamation.





Interaction between environment – lake's biota

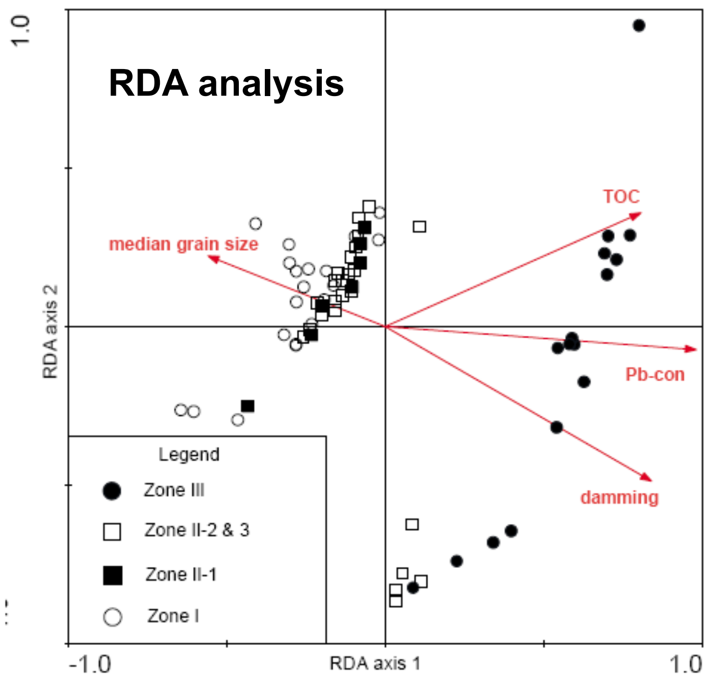
Diatom in Chaohu

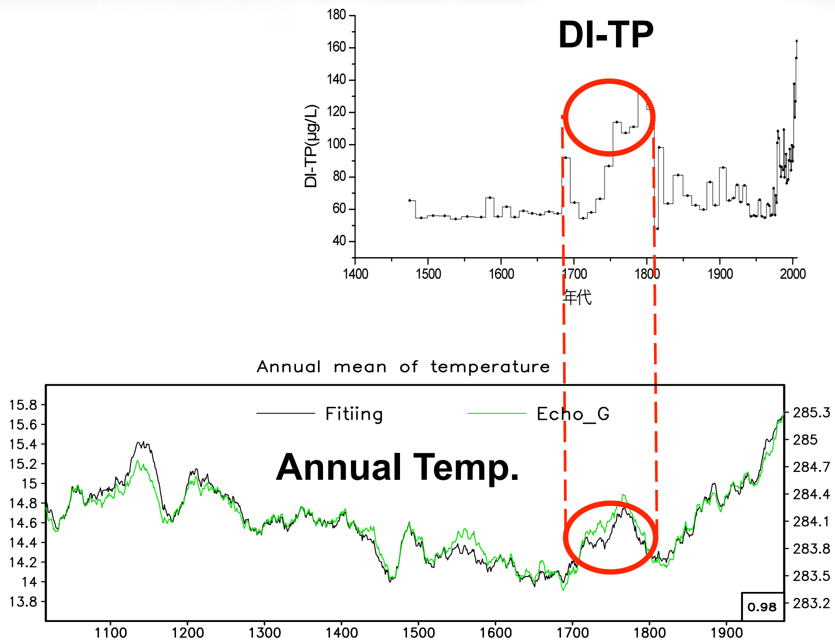


Increase of Aulacoseira granulata indicate an enhenced water turbidity, Cyclostephanos dubius is a typical eutrophic species.

Diatom inferred TP concentrations show two nutrient enrichment periods (1750-1830 AD and post-1979 AD).

RDA with multi-proxies

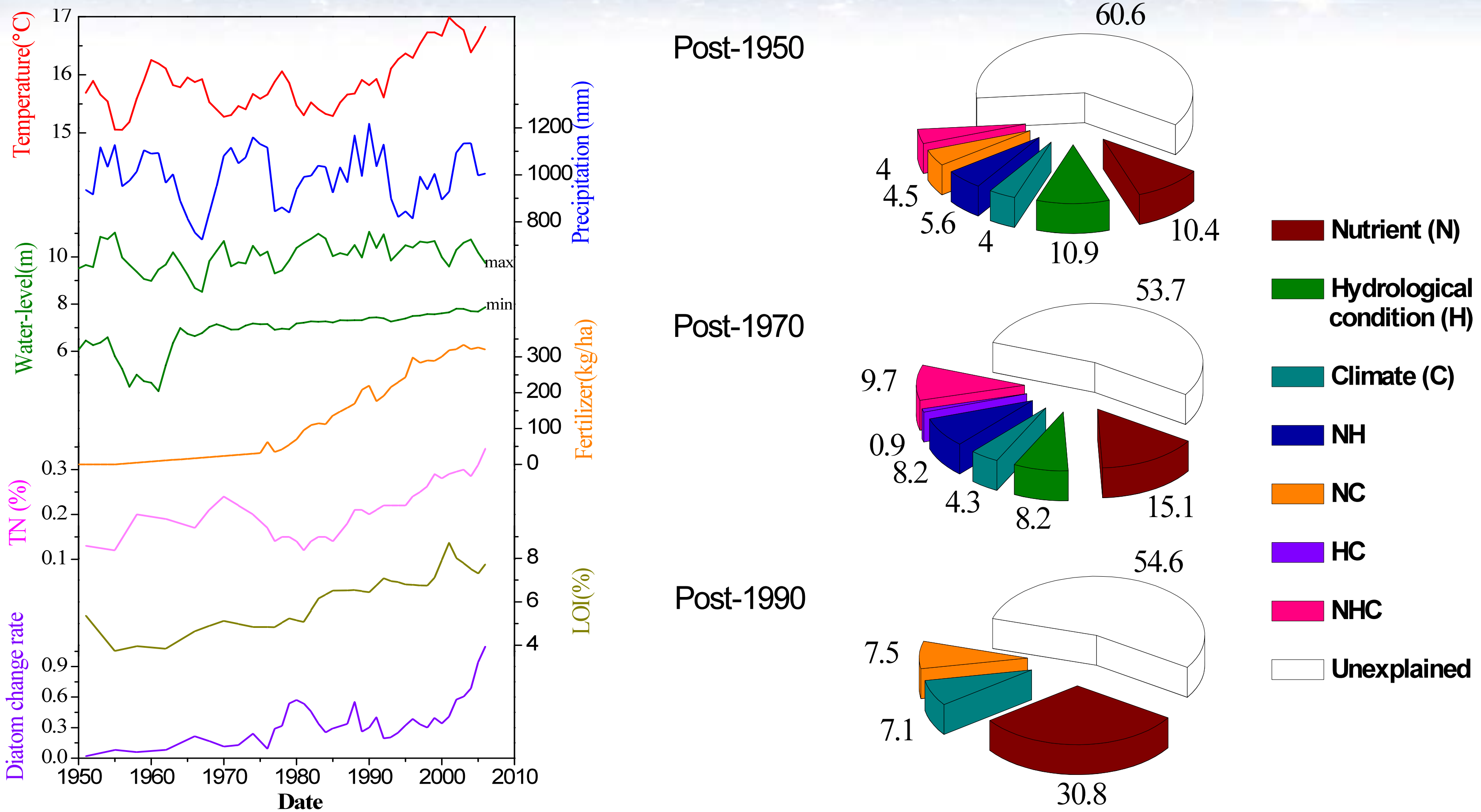




Daming, TOC, Pb and MD can explain the most diatom change.

Climate warming is probably an important influencing factor.

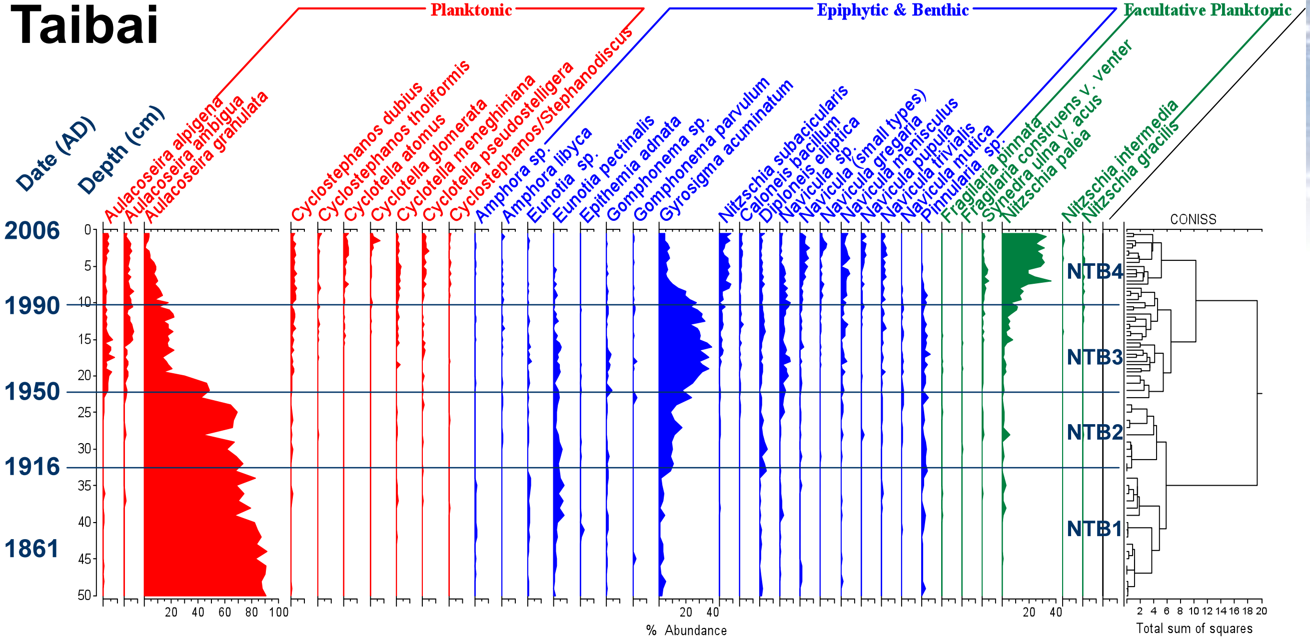
Relationships between diatom and climate, nutrient, hydrology, and their interactions



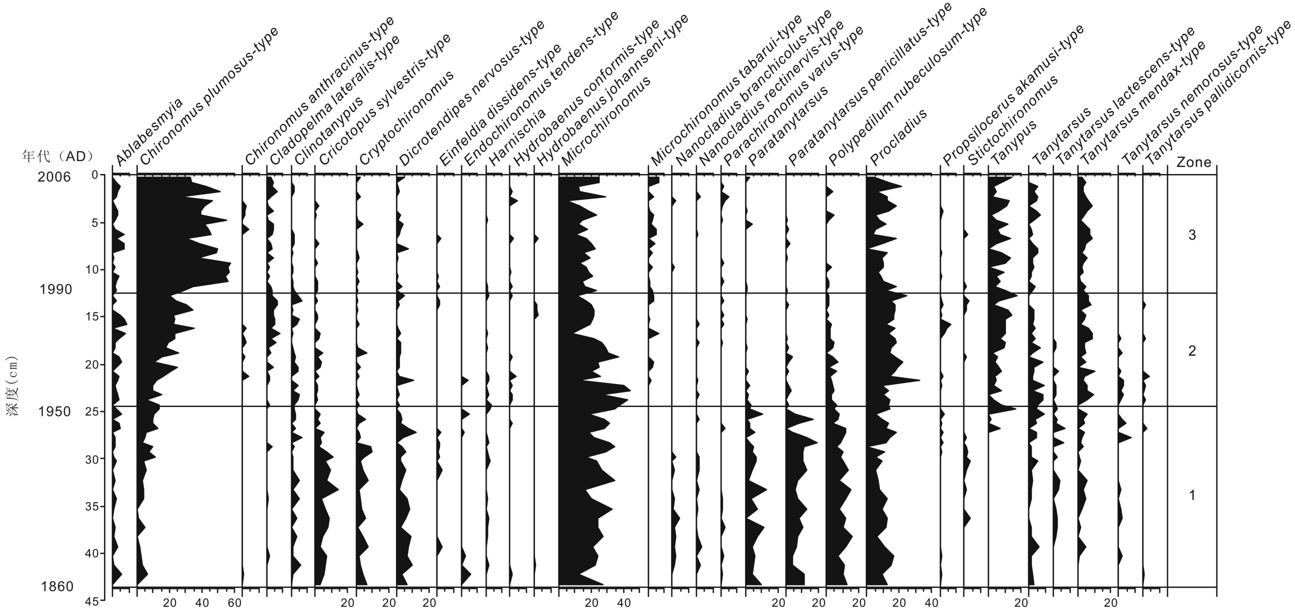
Before 1970, Hydrological condition (H) and the interaction of NH are the main influencing factors in diatom change;

After 1990, nutrient (N), warming (C) and the interaction of NC are the main influencing factors.

Taibai



Diatom records in Taibai sediment (TN core)



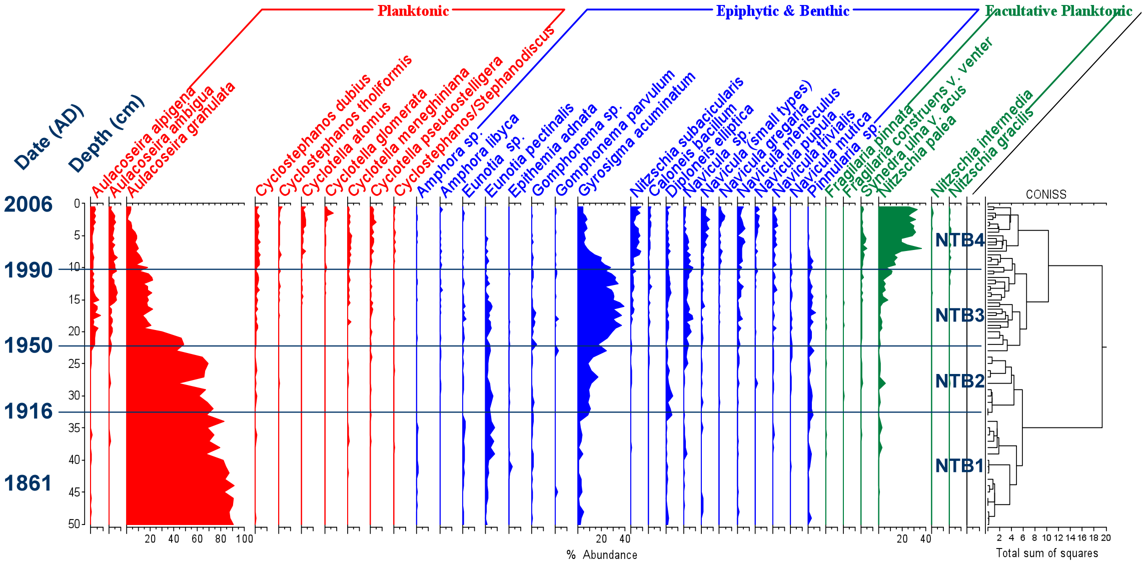
Chironomid records in Taibai sediment (TN core)

Forcing:

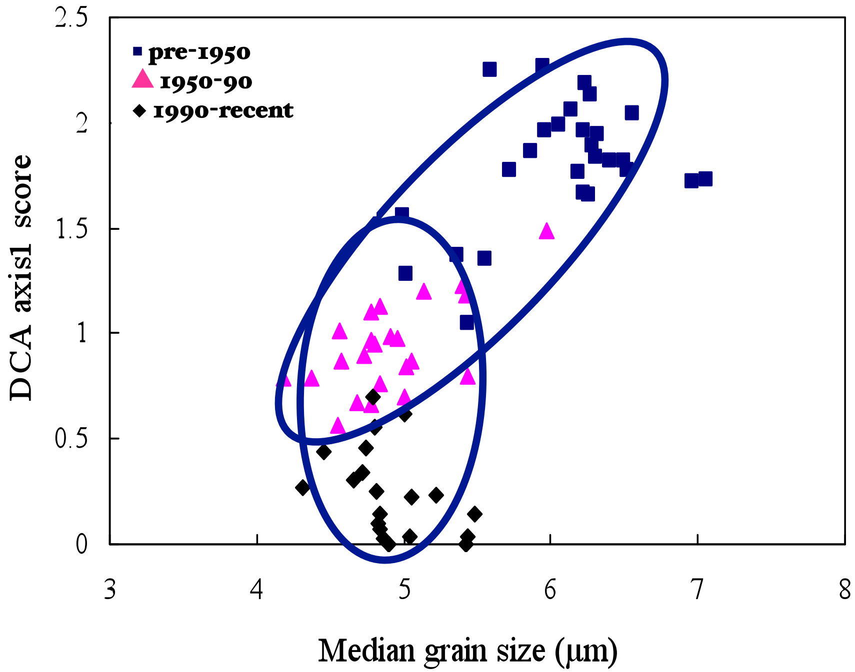
Hydro-dynamics

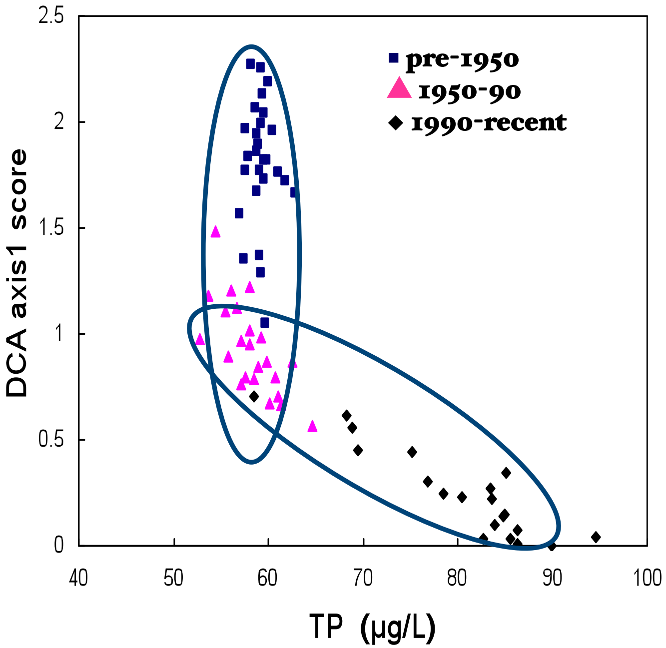
or

Nutrient?



Diatom shift in ~1950 was the result of altered hydro-dynamics, while diatom shift in ~1990 were driven by further nutrient enrichment.



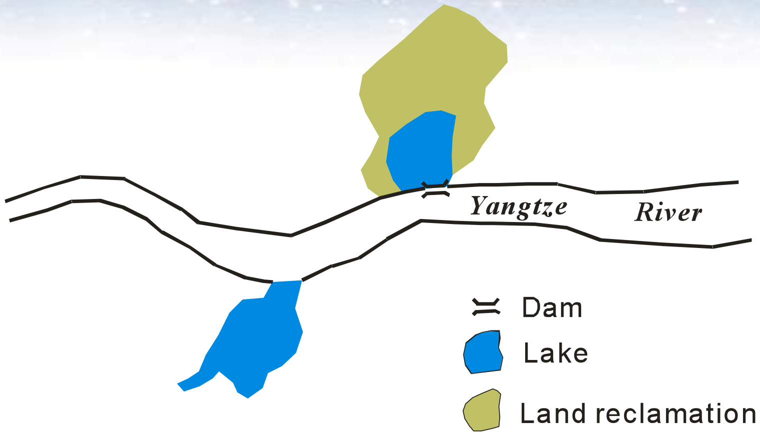


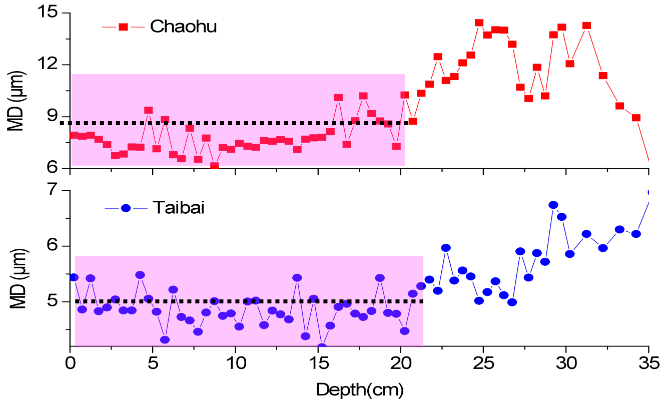
General conclusion（2）

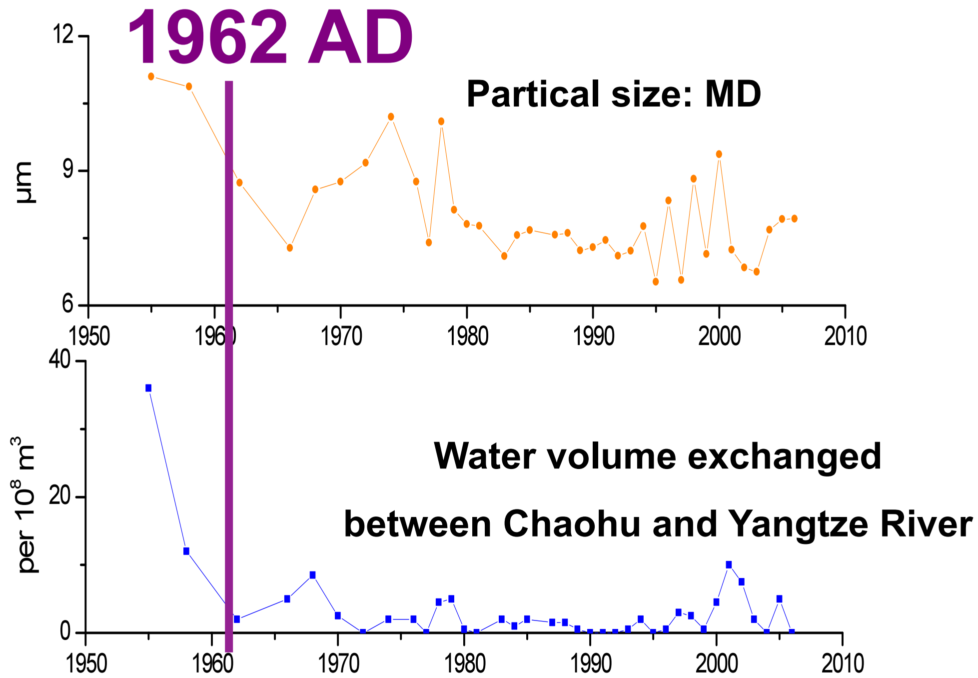
■ Lake's biota responds to climate, human-induced nutrient input and hydrology (agriculture practice, chemical fertilizer usage, aquculture, reclamation and daming), and their interactions.

Thanks for your attention!

Grain size vs Hydro-dynamics



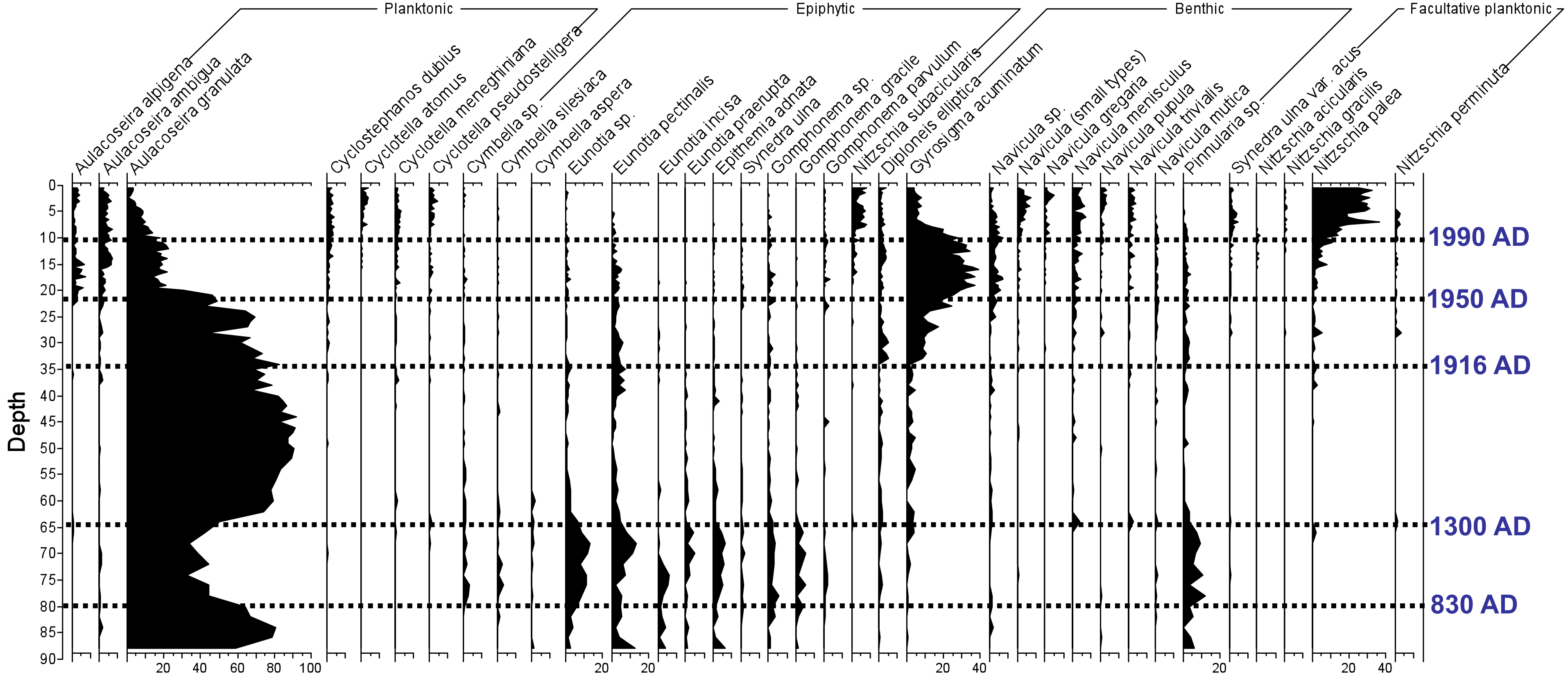




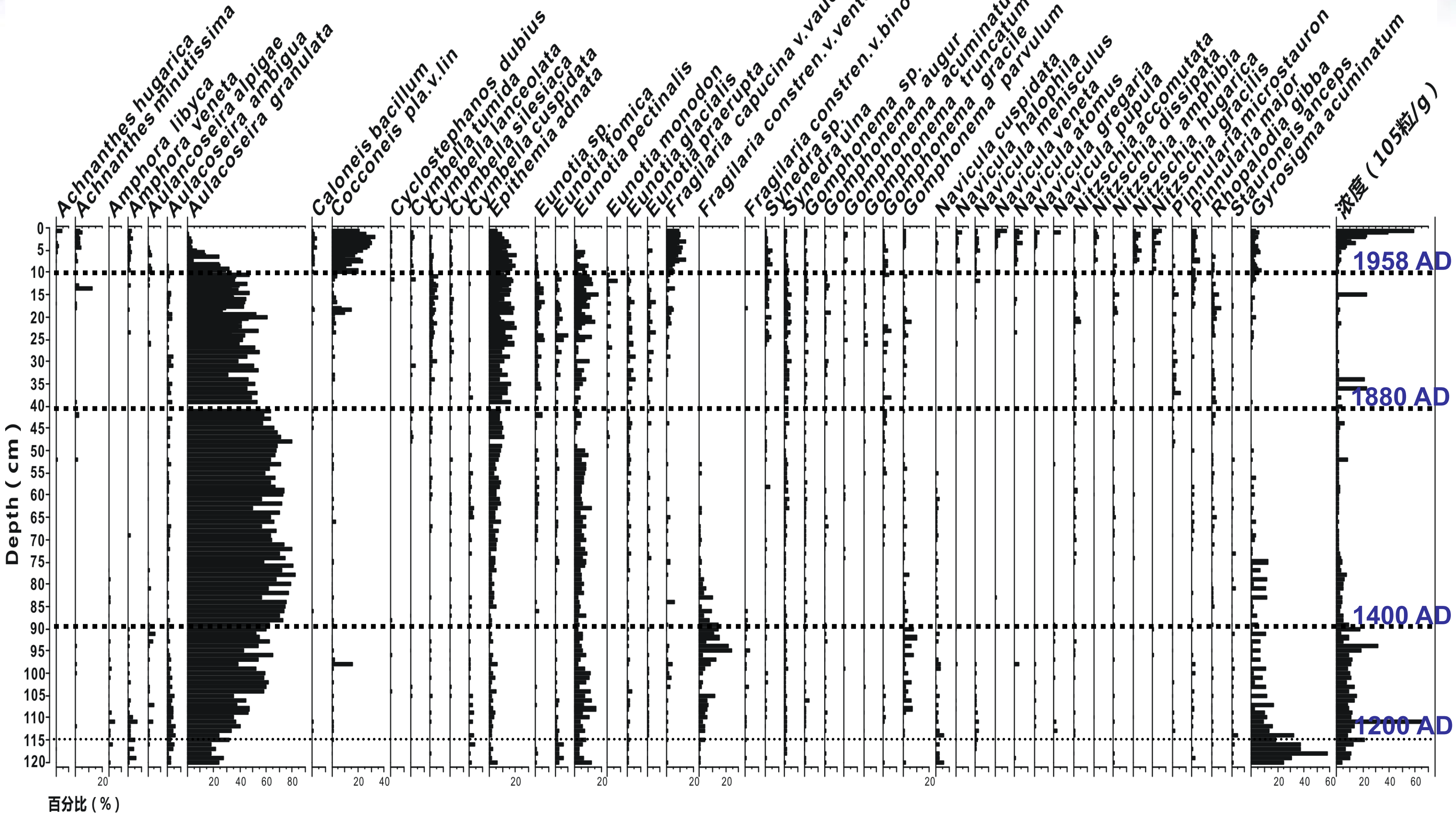
Grain size vs water volum exchange in the past 50 years

Grain size is indicative of lake water retention time, daming and reclamation influenced hydrological process overtime

Taibai Lake

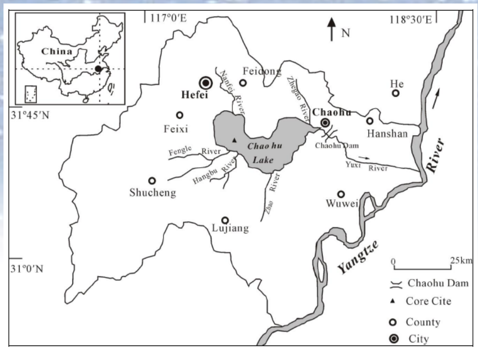

Planktonic
Epiphytic
Benthic
Facultative planktonic
Aulacoseira alpigena
Aulacoseira ambigua
Aulacoseira granulata
Cyclostephanos dubius
Cyclotella atomus
Cyclotella meneghiniana
Cyclotella pseudostelligera
Cymbella sp.
Cymbella silesiaca
Cymbella aspera
Eunotia sp.
Eunotia pectinalis
Eunotia incisa
Eunotia praerupta
Epithemia adnata
Synedra ulna
Gomphonema sp.
Gomphonema gracile
Gomphonema parvulum
Nitzschia subacicularis
Diploneis elliptica
Gyrosigma acuminatum
Navicula sp.
Navicula (small types)
Navicula gregaria
Navicula meniscullus
Navicula pupula
Navicula trivialis
Navicula mutica
Pinnularia sp.
Synedra ulna var. acus
Nitzschia acicularis
Nitzschia gracilis
Nitzschia palea
Nitzschia perminuta
Depth
1990 AD
1950 AD
1916 AD
1300 AD
830 AD

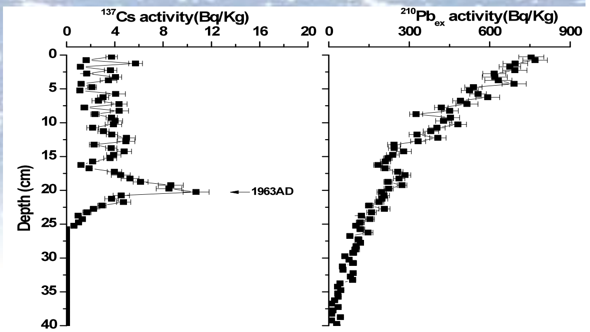
Longgan Lake

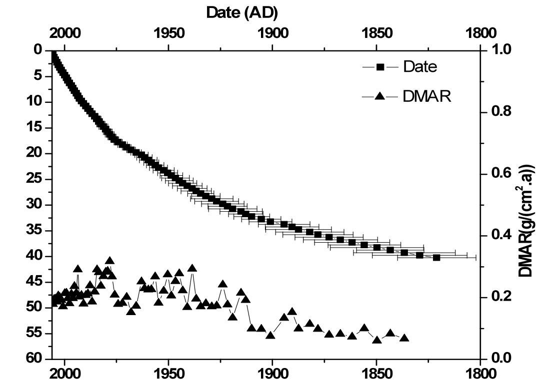


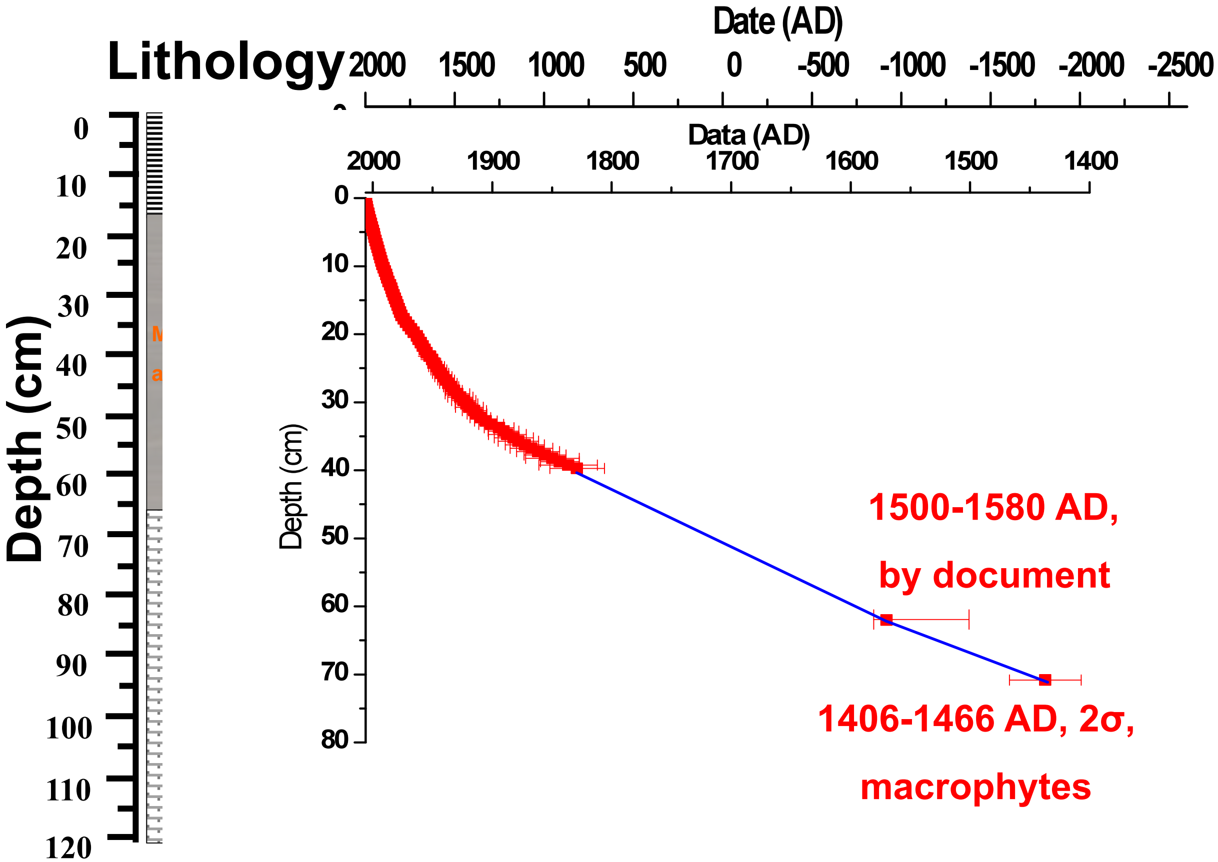
Chaohu Lake

C1 core chronology









, 2σ, macrophytes

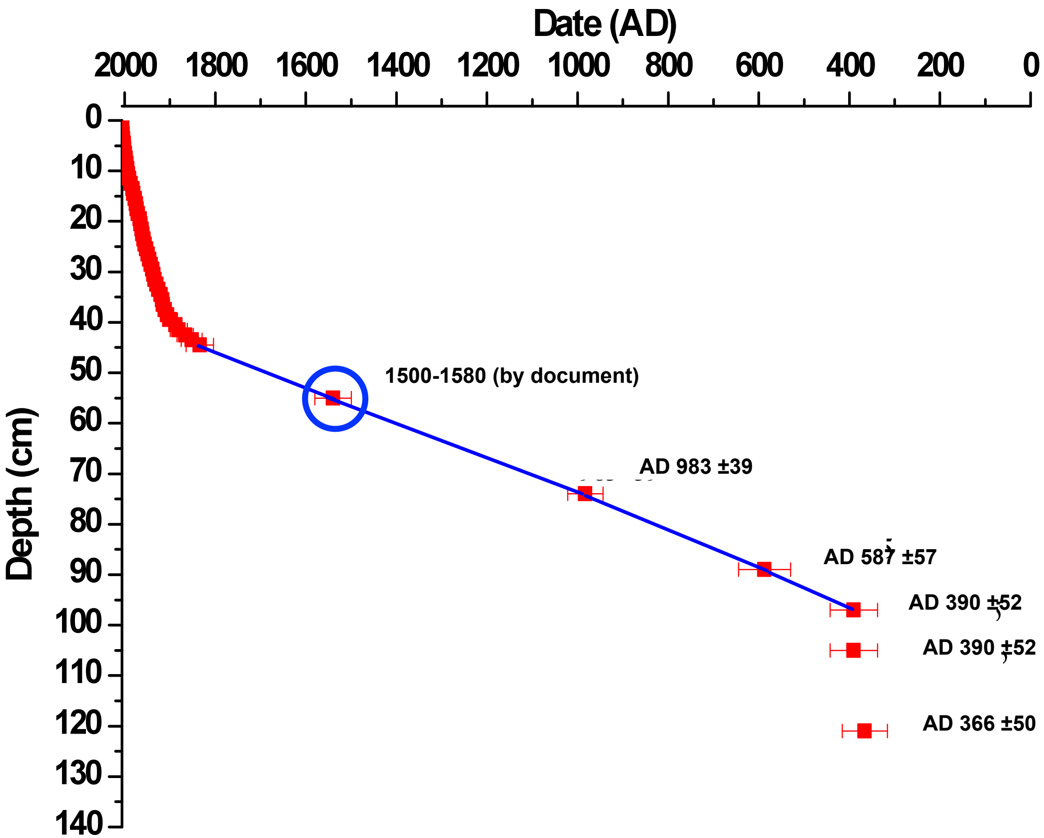
2498-2281 BC, 2σ,
macrophytes

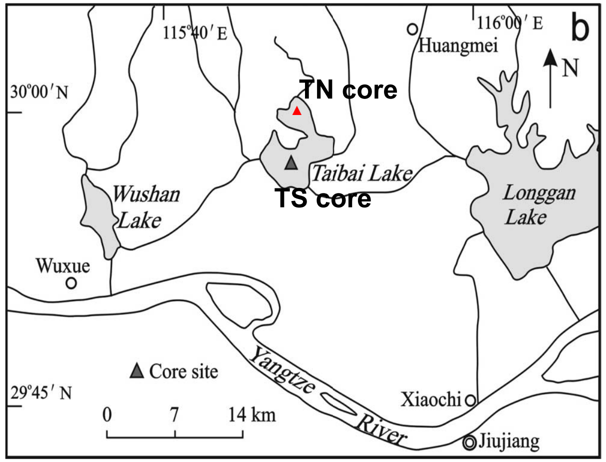
C1 core

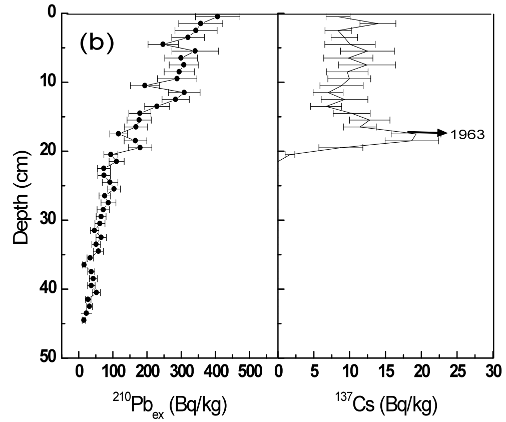
408-356 BC, 2σ, charcoal

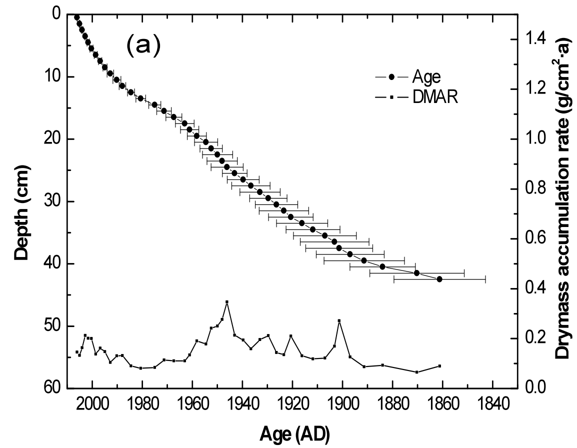
Taibai Lake

TN core chronology

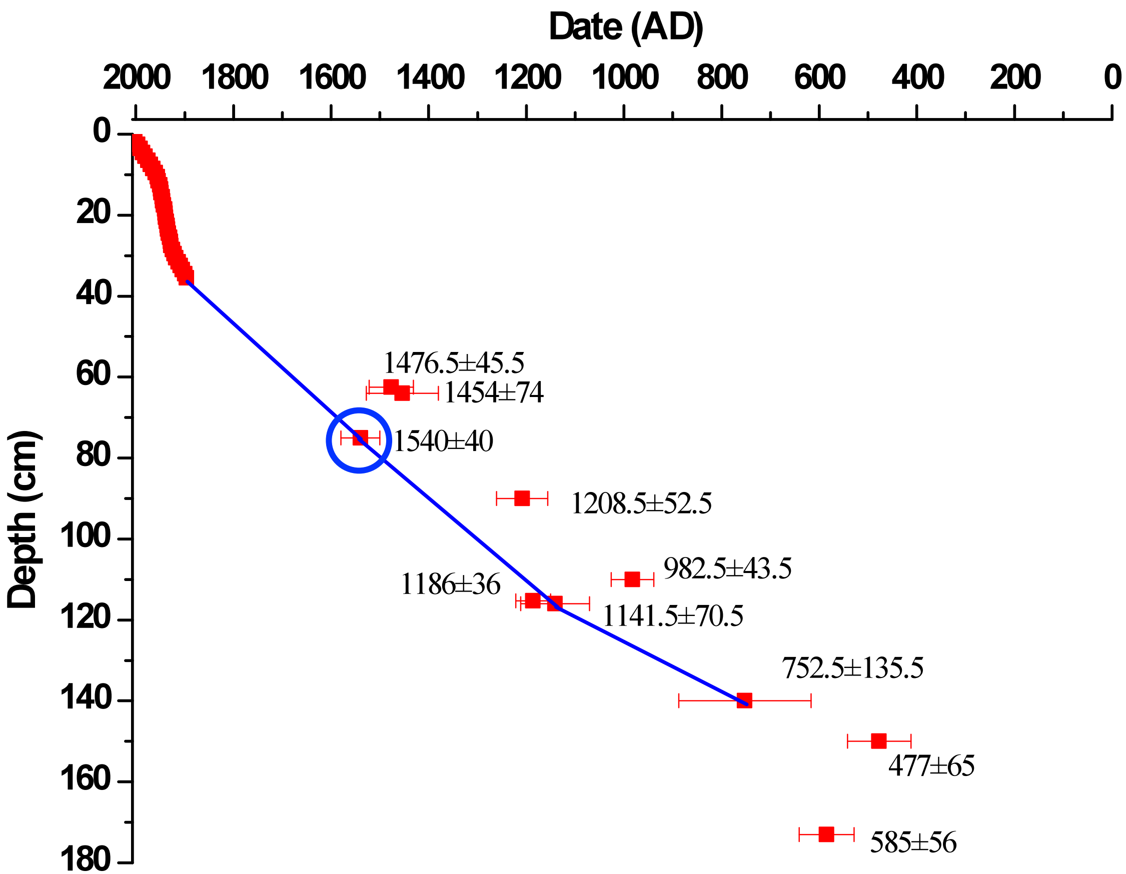


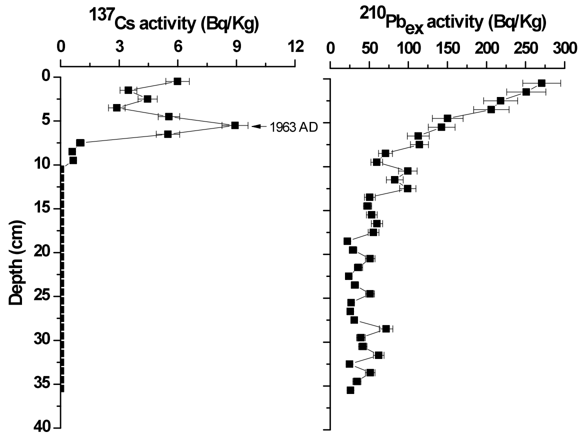


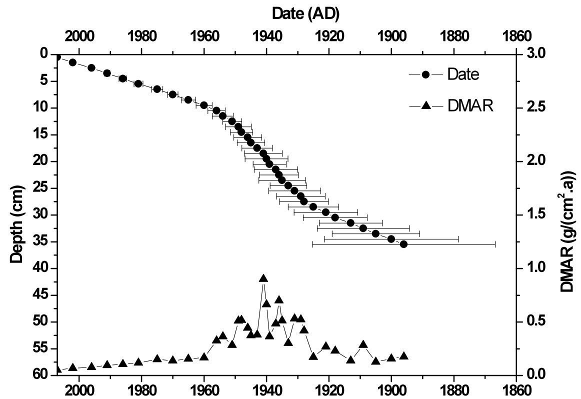




LS core chronology







思考：

（1）方法学

■ 关于侵蚀与旱作农业发展

小冰期是长江中下游大量移民迁入时期，文献记载了主要来自北方，显然相对于北方小冰期更寒冷气候，长江中下游气候更适合人类居住，人口的压力迫使对流域坡地强烈农业开垦。但目前仅从花粉数据很难提取旱作植物（包括玉米、小麦、黍、红薯等）的信息。可以通过测试植硅石、淀粉粒，补充并提取更多的人类活动的信息。

■ 关于湖泊古生态

生物是生态系统的重要组成部分。多生物指标的研究，有助于理解食物网结构和生态系统的结构和功能。沉积物中生物信息量丰富，但在长江中下游，目前多藻类色素、其他多生物门类化石尚需发展。怎么培养这方面的人才？通过什么渠道培养？

■ 关于浅水湖泊年代学和研究分辨率问题

浅水湖泊沉积物受人类干扰、生物扰动、风浪作用、再沉积作用、矿化和氧化作用等影响，对于大型浅水湖泊而言，沉积物中生物保存不好，有机质偏低，在长江洪泛区尤为如此。历史时期的沉积物定年精确度是一个难点，如何突破？怎么做？在这个情况下，研究分辨率控制在什么尺度？

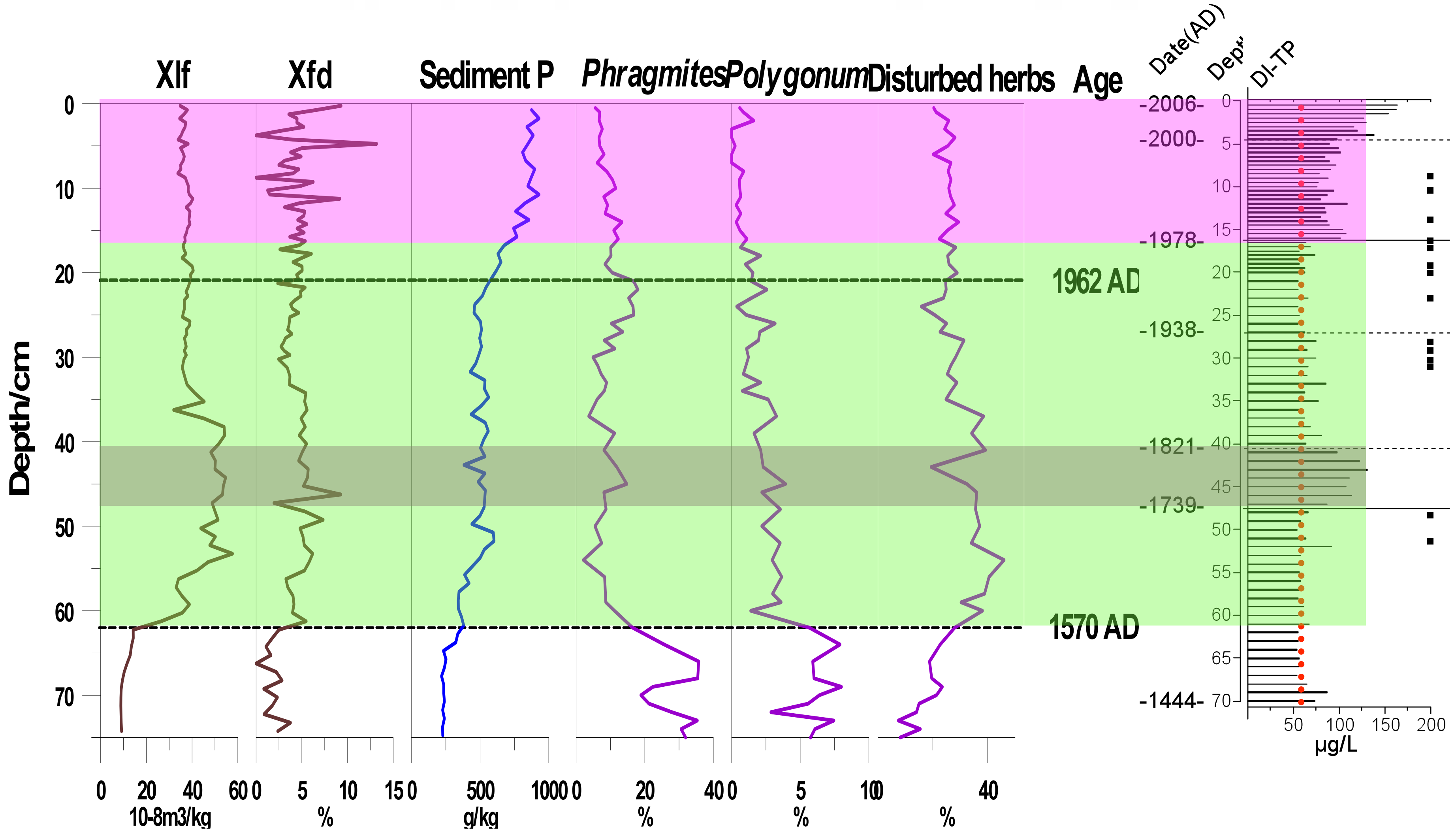
■ 关于沉积物中多指标归类问题

沉积指标本身是一个混合的记录。多指标作为影响指标时，如何分辨出是气候、还是人类活动的指标？

思考：

（2）**概念和理**论

■


Xlf
Xfd
Sediment P
Phragmites
Polygonum
Disturbed herbs
Age
Date(AD)
Dep
DI-TP
Depth/cm
1962 AD
1570 AD
-2006-
-2000-
-1978-
-1938-
-1821-
-1739-
-1444-
10-8m3/kg
%
g/kg
%
%
%
μg/L

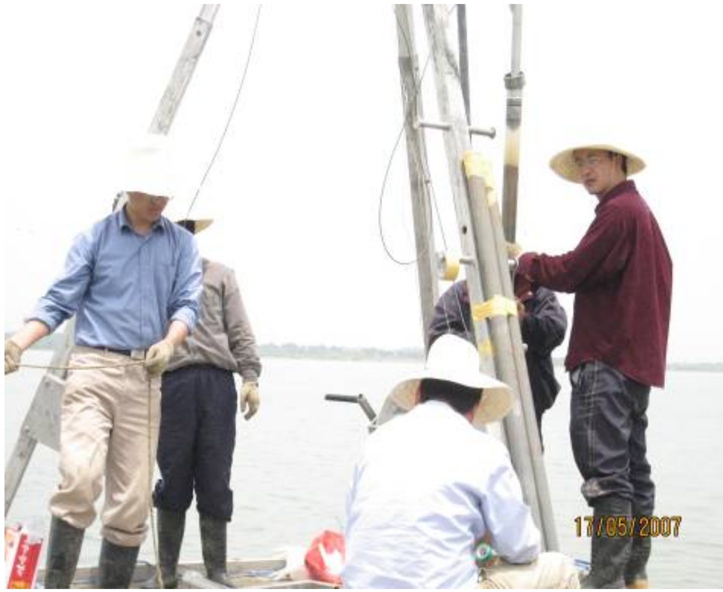
Multi-proxies for sediment records

Catchment indicators: magnitism, pollen, charcoal, geochemical proxies

Lake indicators: diatom, chironomid, particle size, TOC%

Chronology: 210Pb/137Cs, AMS14C, Document events

Numerical methods: CCA, RDA, DCA……



Magnitism susceptibility from other lakes