ESA-MOST Dragon Cooperation

中国科技部-欧洲空间局“龙计划”合作

2017 DRAGON 4 SYMPOSIUM

2017年“龙计划”四期学术研讨会

Lakes' change and water balance in the Tibetan Plateau

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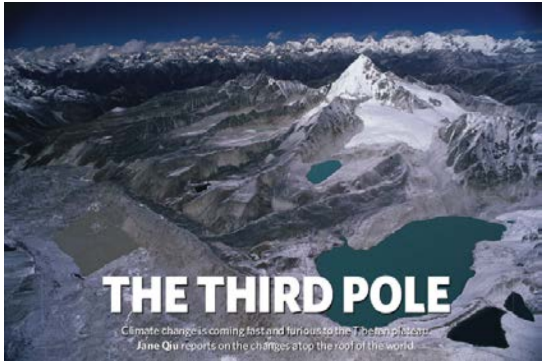
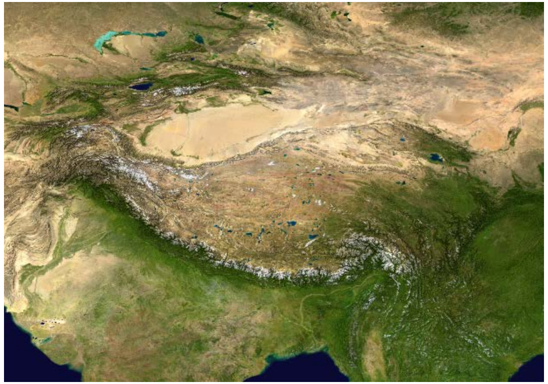
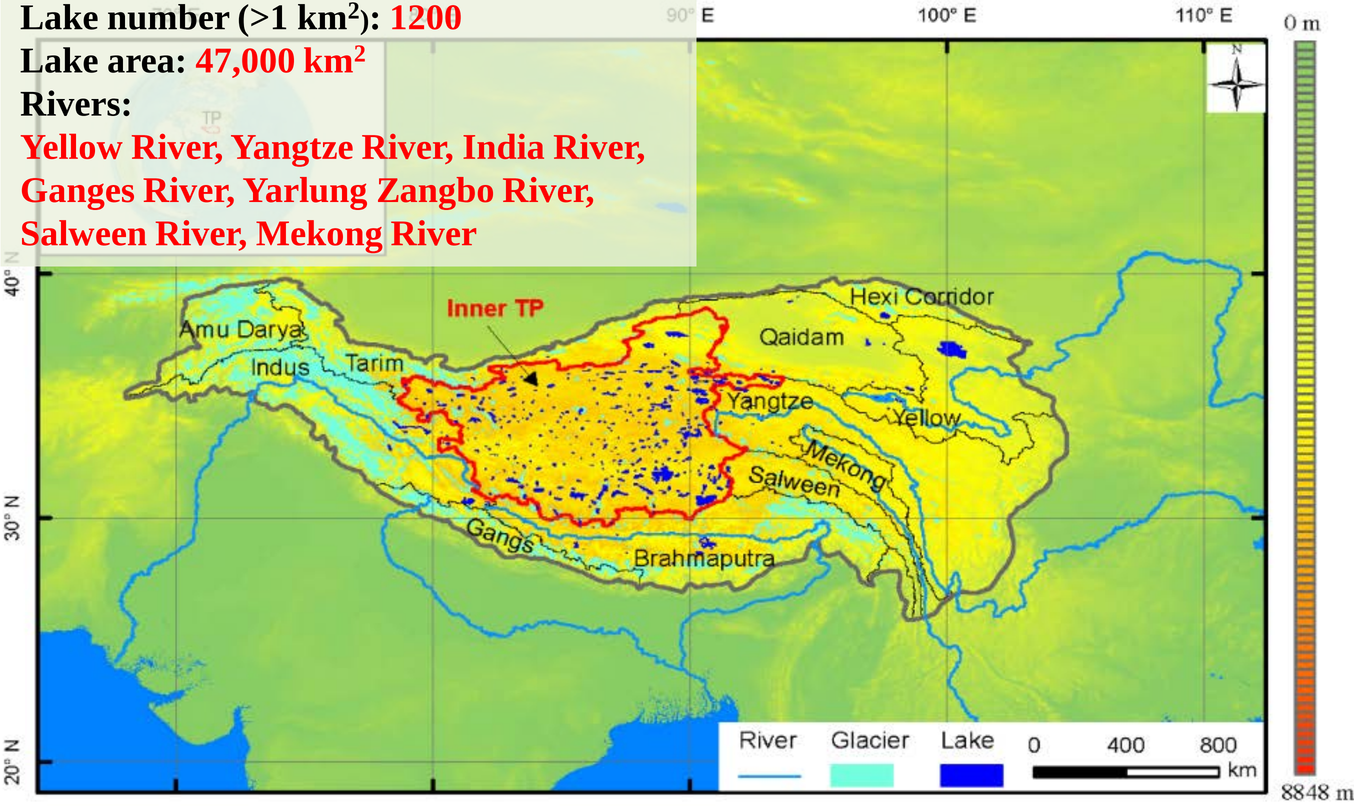
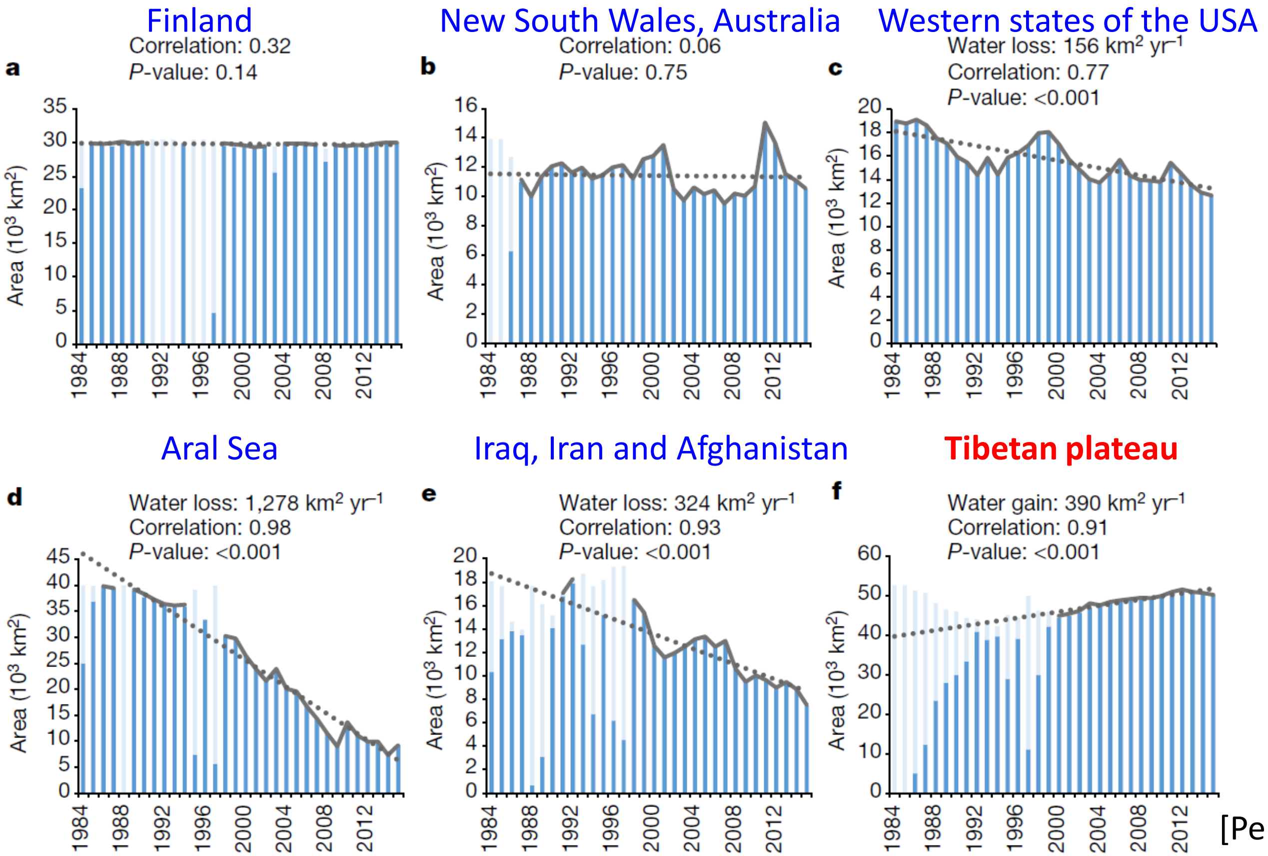




Glacier number: **> 46,000**
Glacier area: **100,000 km^2**
Lake number (>1 km^2): **1200**
Lake area: **47,000 km^2**
Rivers:
Yellow River, Yangtze River, India River, Ganges River, Yarlung Zangbo River, Salween River, Mekong River

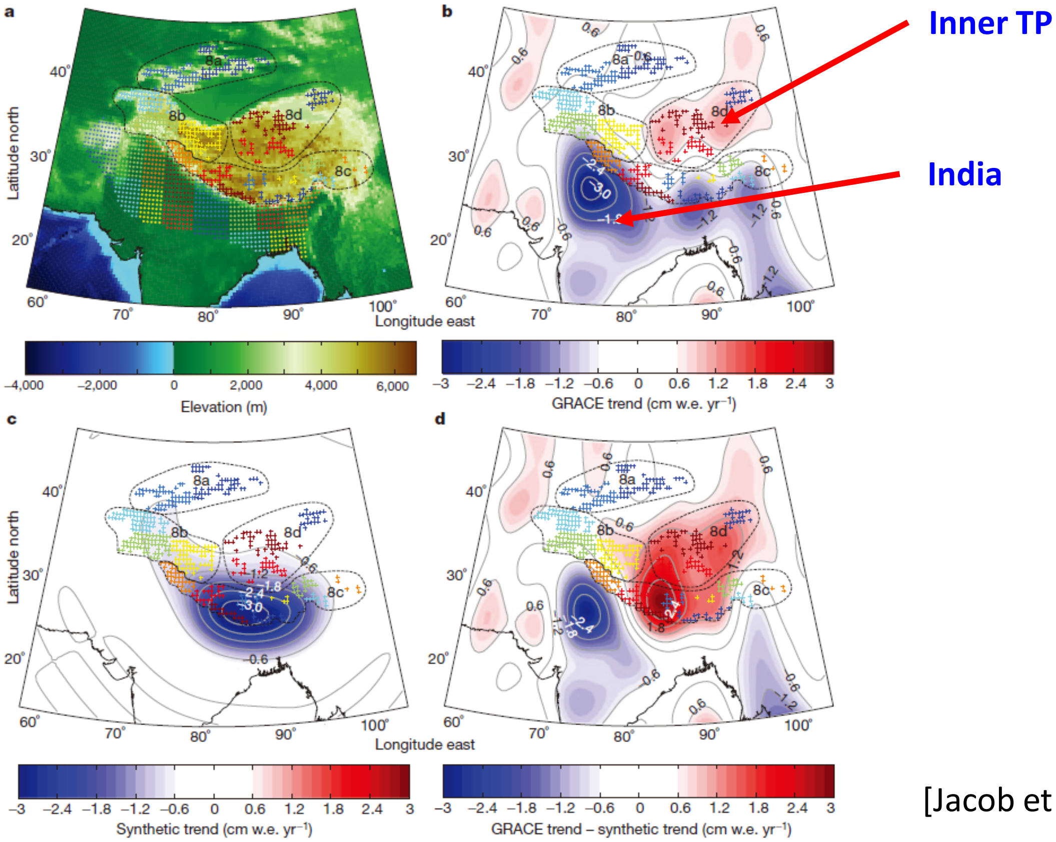


Water body change across the global



[Pekel et al., 2016, Nature]

HMA mass balance

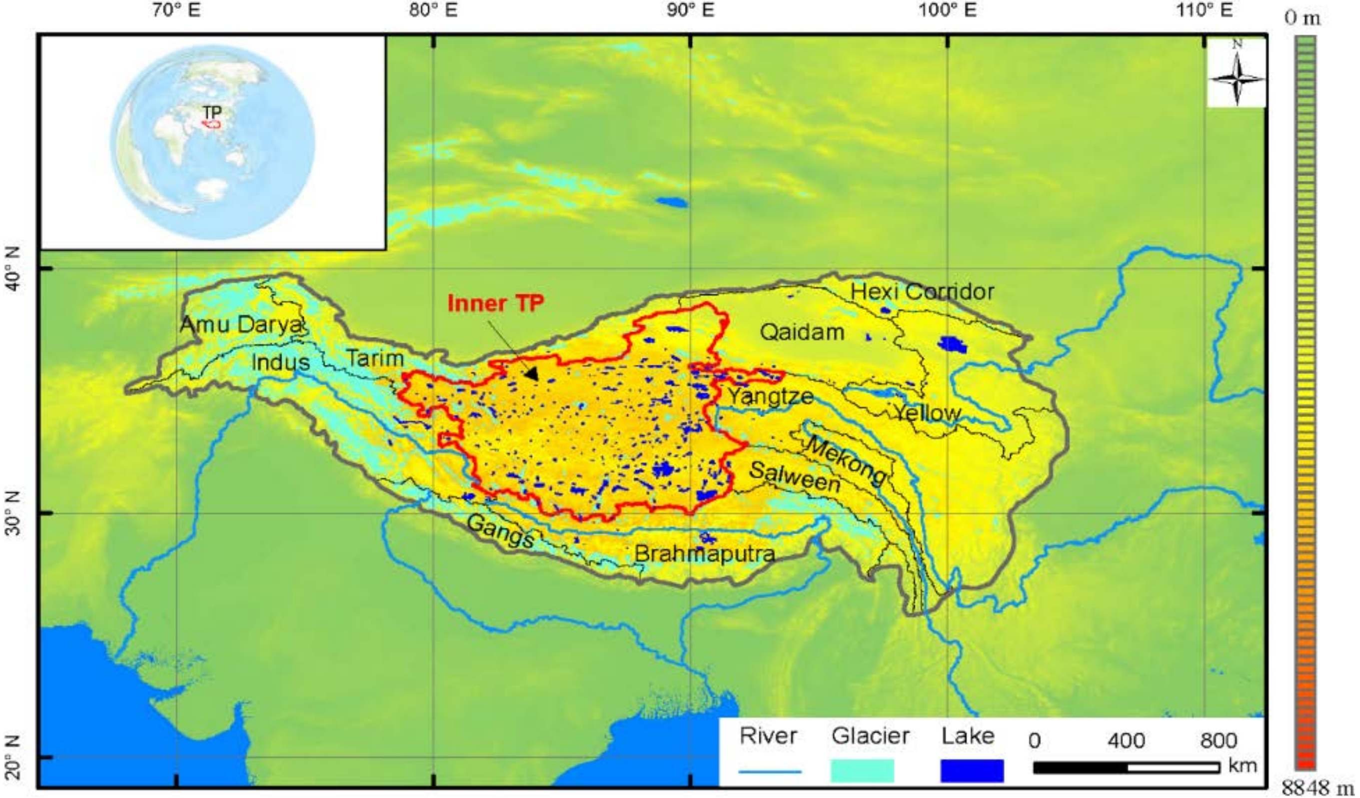


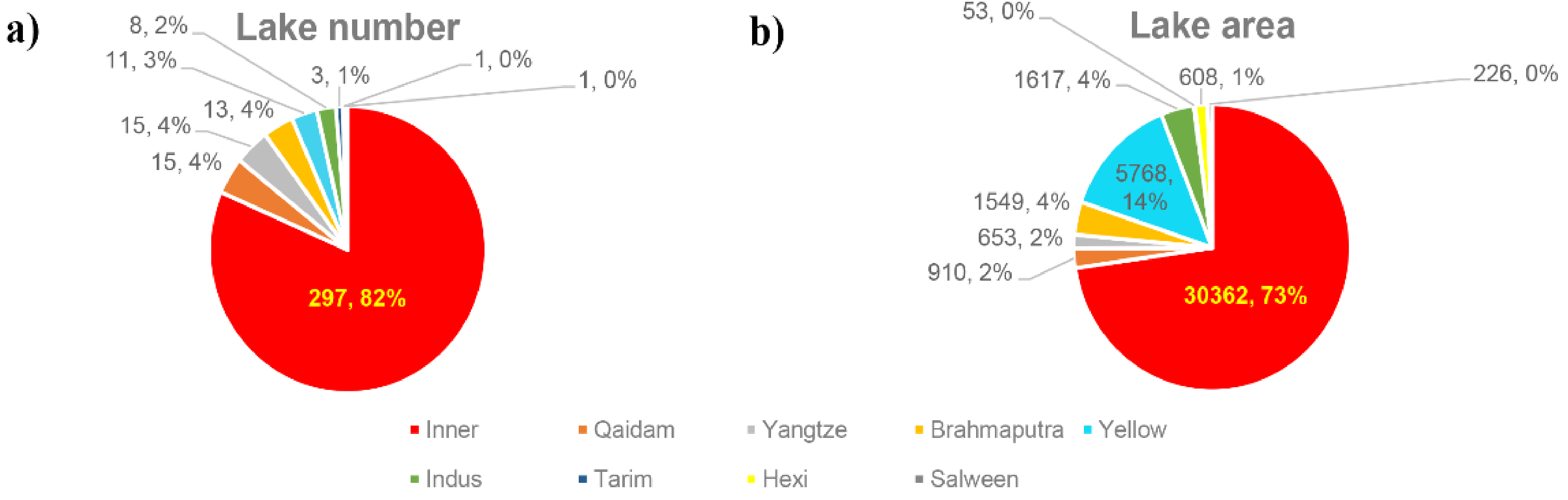
[Jacob et al., 2012]

Outline

1. Lake number and area change
2. Lake area change in response to climate change
3. Lake level, volume change and water balance

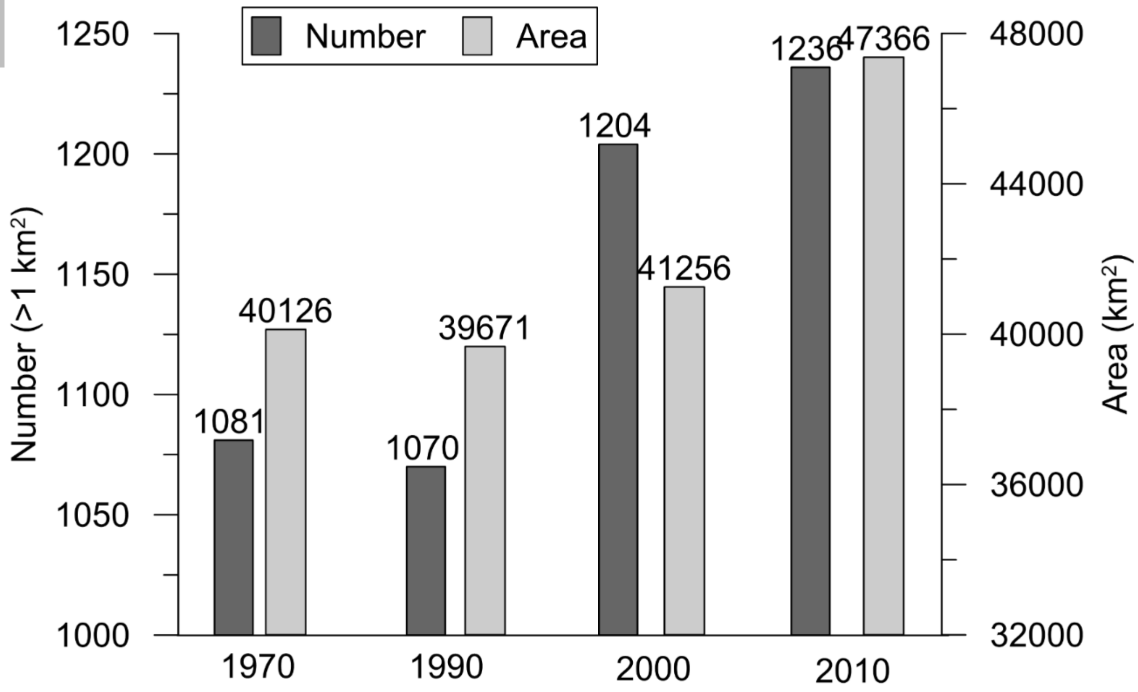
1. Lake number and area change


70° E
80° E
90° E
100° E
110° E
40° N
30° N
20° N
TP
N
Inner TP
Amu Darya
Indus
Tarim
Hexi Corridor
Qaidam
Yangtze
Yellow
Mekong
Salween
Gangs
Brahmaputra
River
Glacier
Lake
0
400
800
km
0 m
8848 m

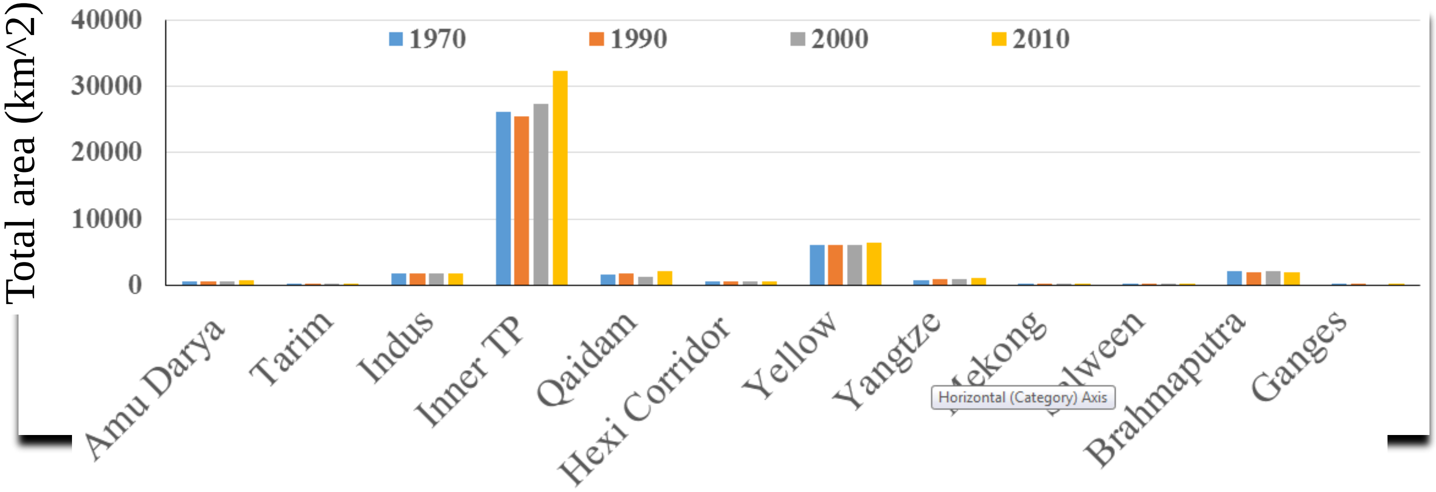

a)
Lake number
8, 2%
11, 3%
3, 1%
1, 0%
1, 0%
13, 4%
15, 4%
15, 4%
297, 82%
b)
Lake area
53, 0%
1617, 4%
608, 1%
226, 0%
5768, 14%
1549, 4%
653, 2%
910, 2%
30362, 73%
Inner
Qaidam
Yangtze
Brahmaputra
Yellow
Indus
Tarim
Hexi
Salween

Lake number and area change from 1970 to 2010

>1 km^2



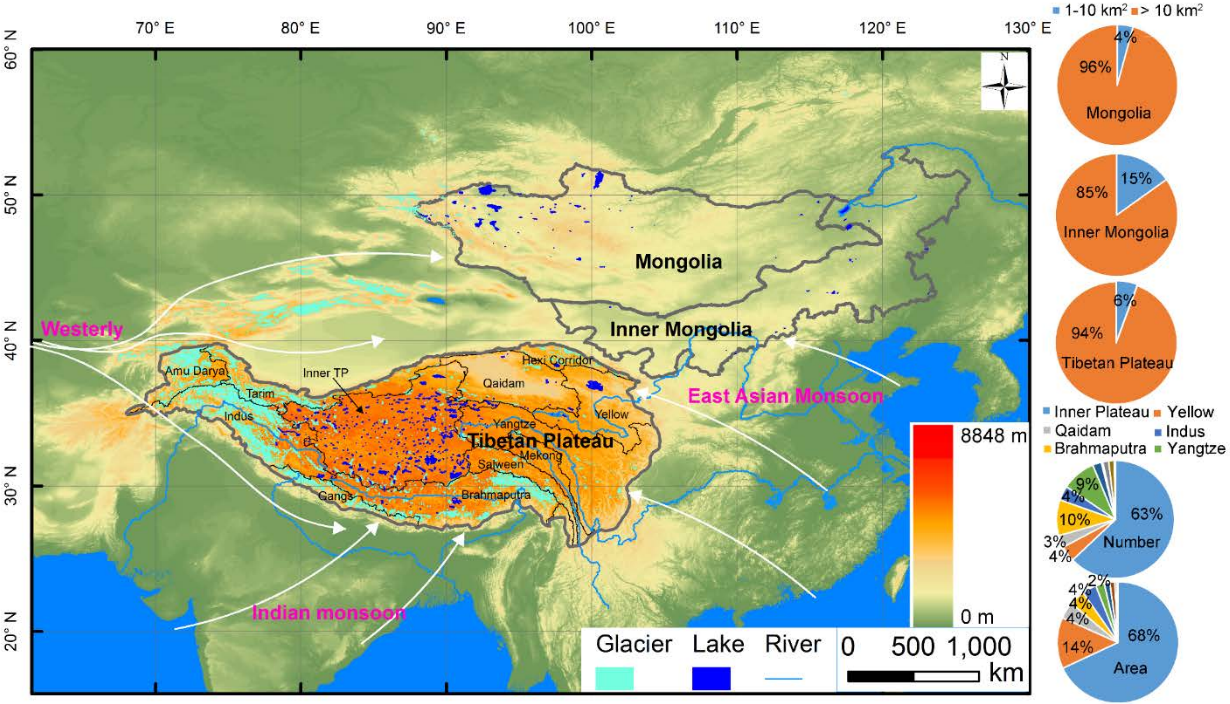
Lake area change in different basins



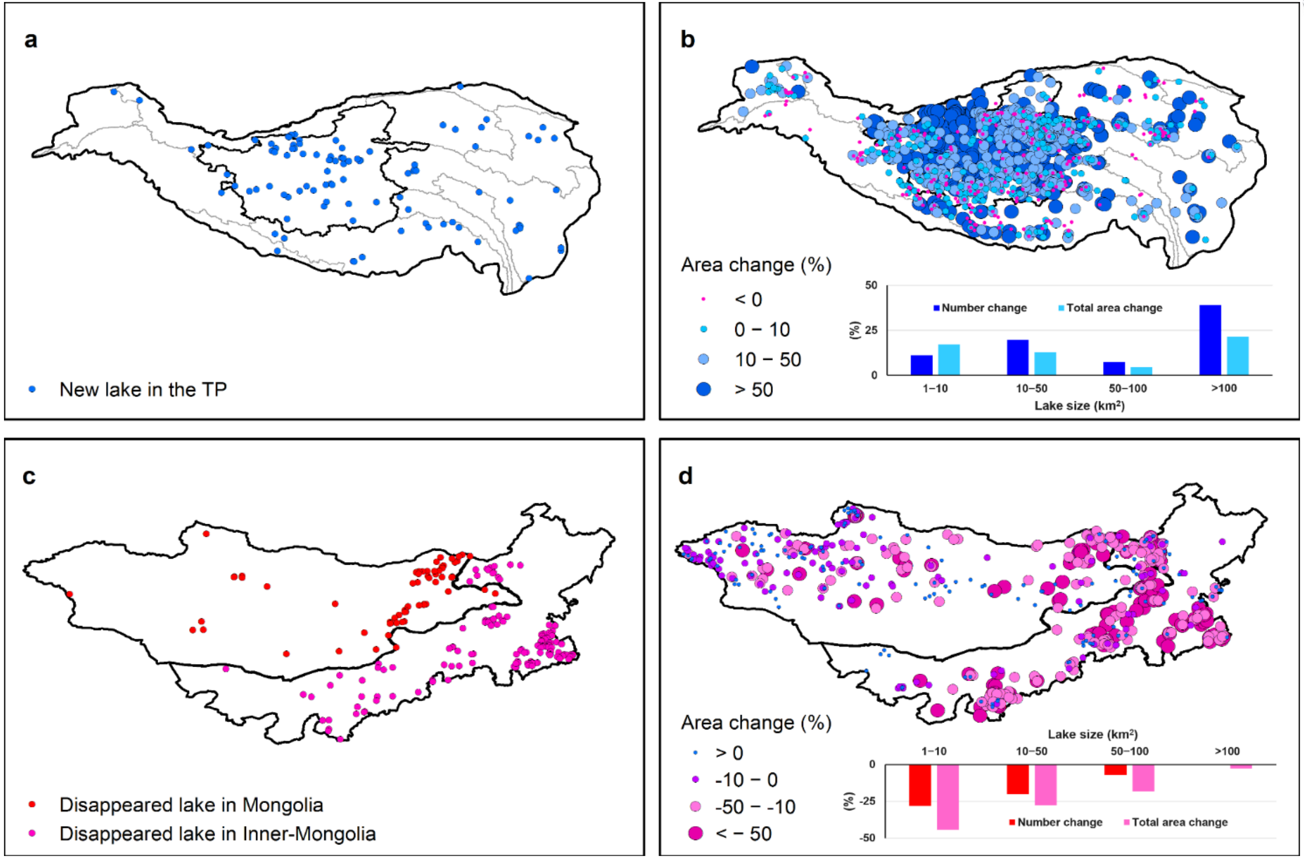
A increase of total area of 6099 km^2 (23%) occurred in the Inner TP in 1970-2010.

2. Lake area change in response to climate change

Contrasting pattern of lake change in the Tibetan and Mongolia Plateaus

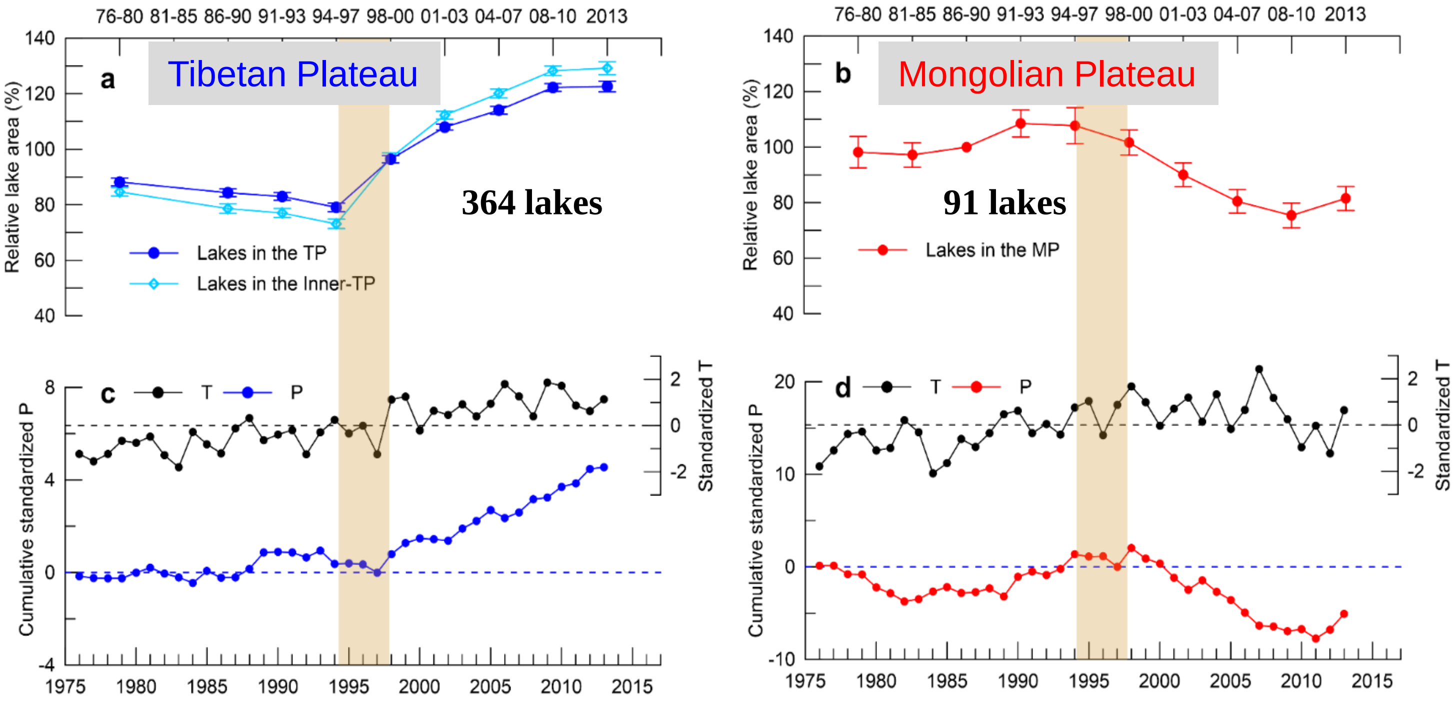


Emerged/expanded lakes, and disappeared/shrunk lakes

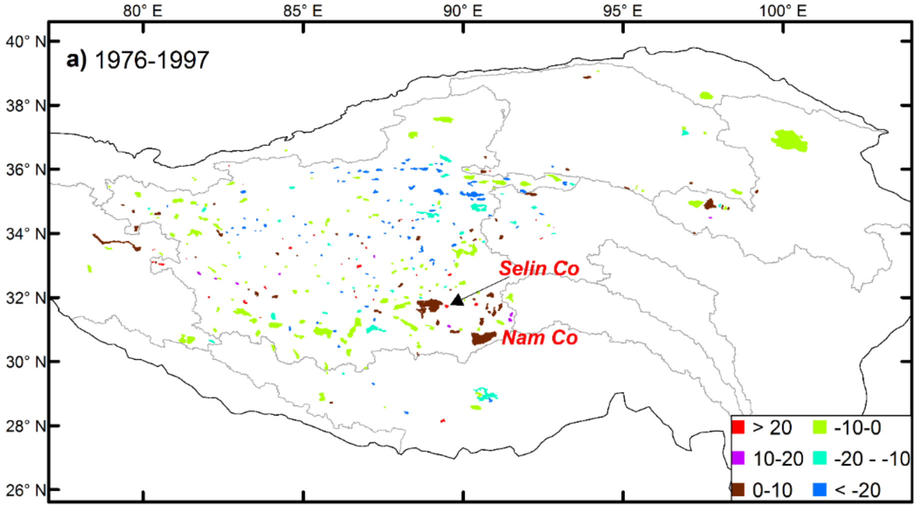


Lake area, surface air temp. and prec. changes

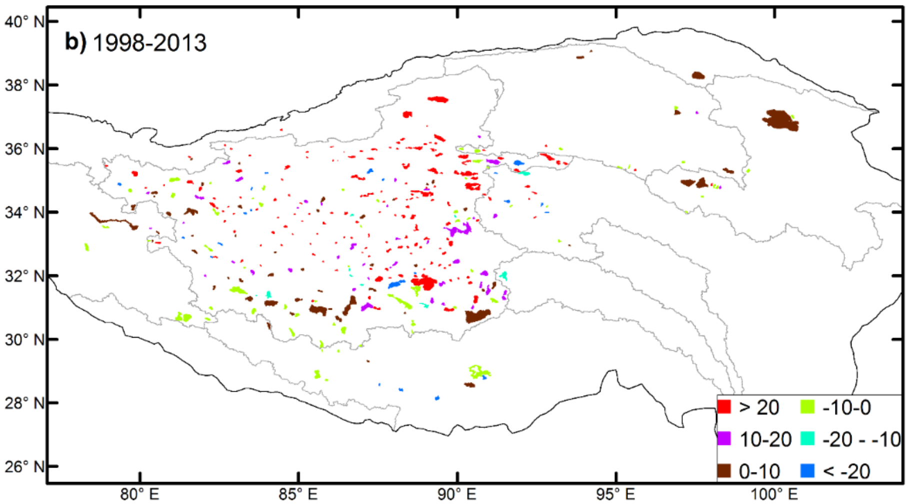
(> 10 km^2)



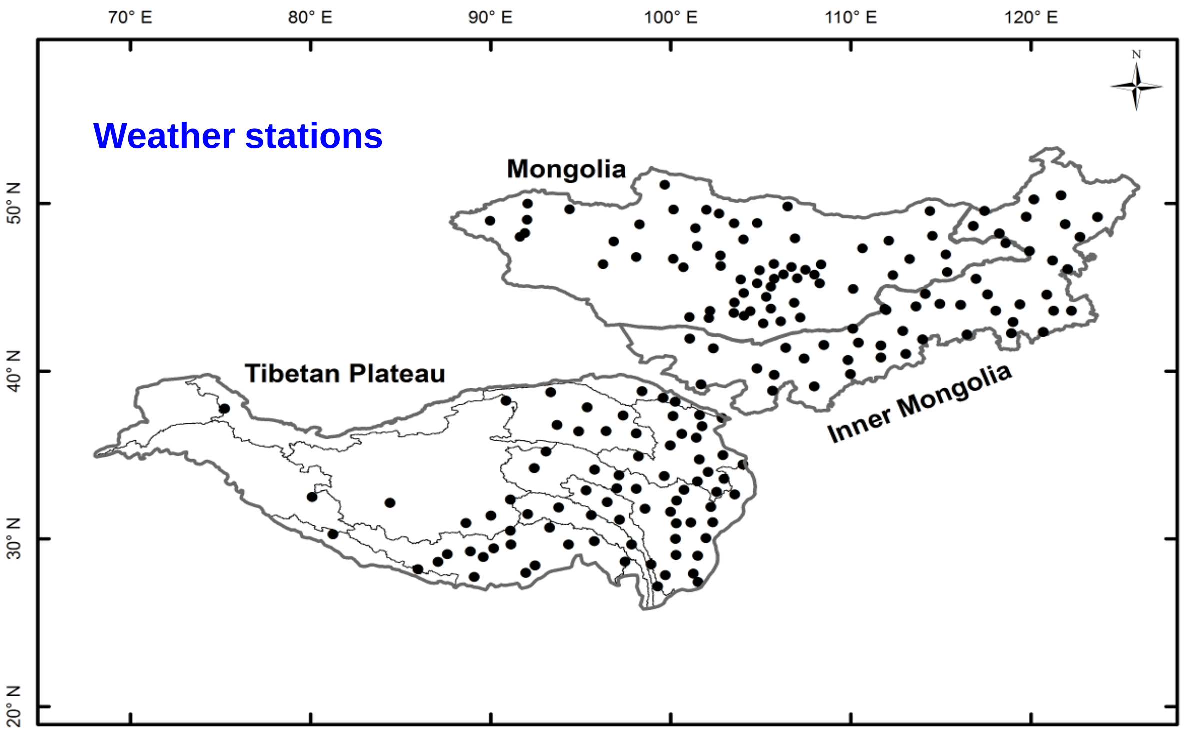
1976-1997



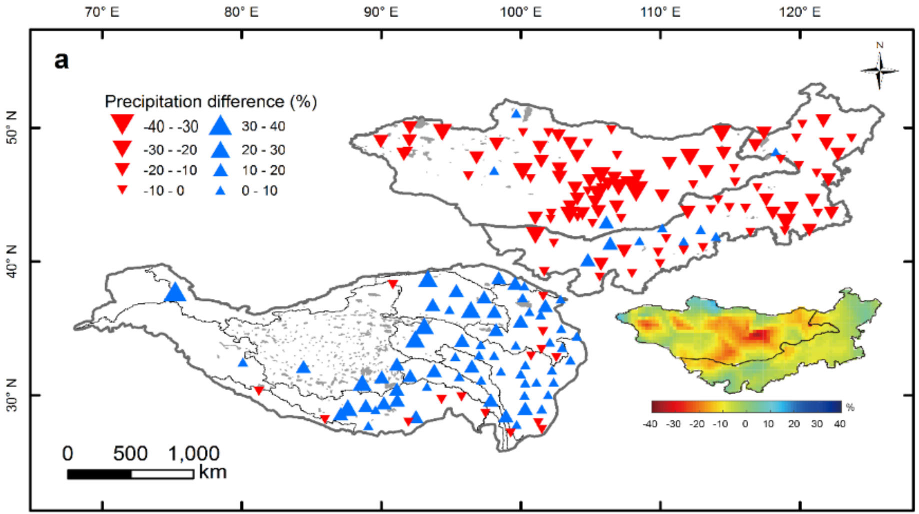
1998-2013

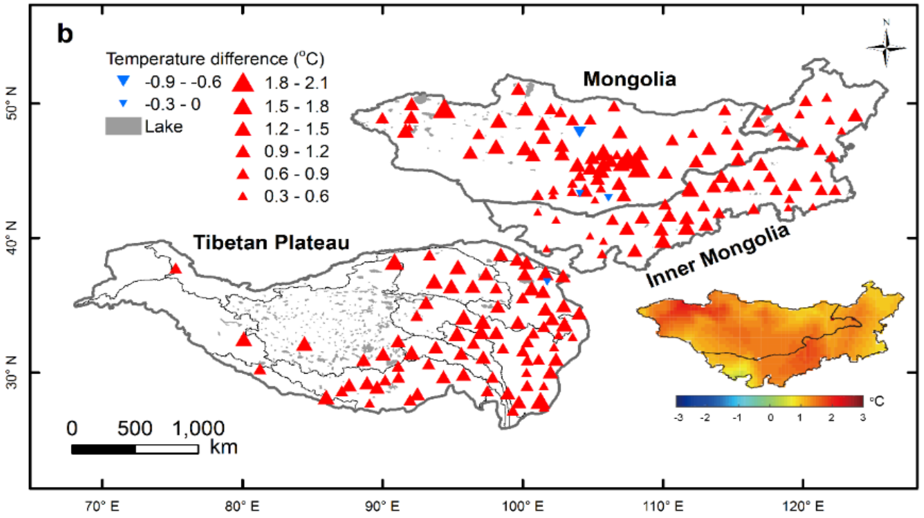


Drivers of lake change

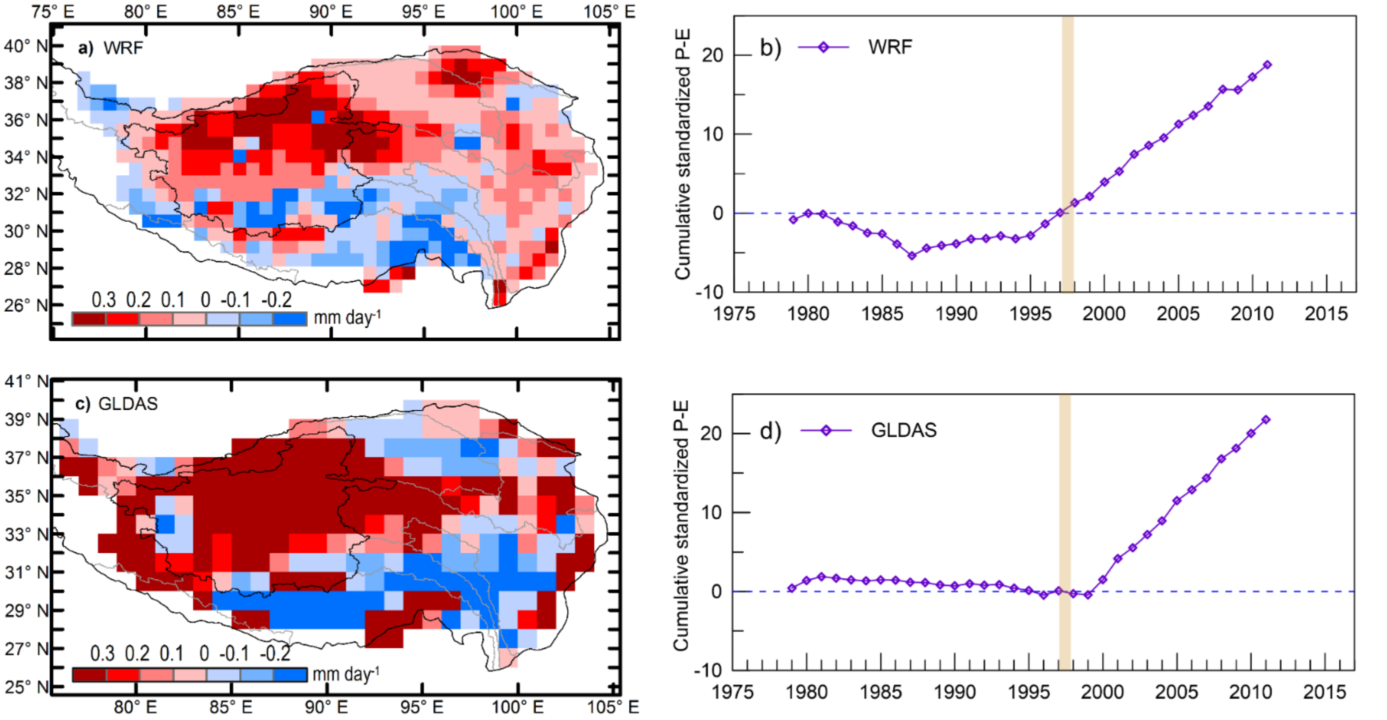


Differences in precipitation and temperature between 1998–2013 and 1976–1997

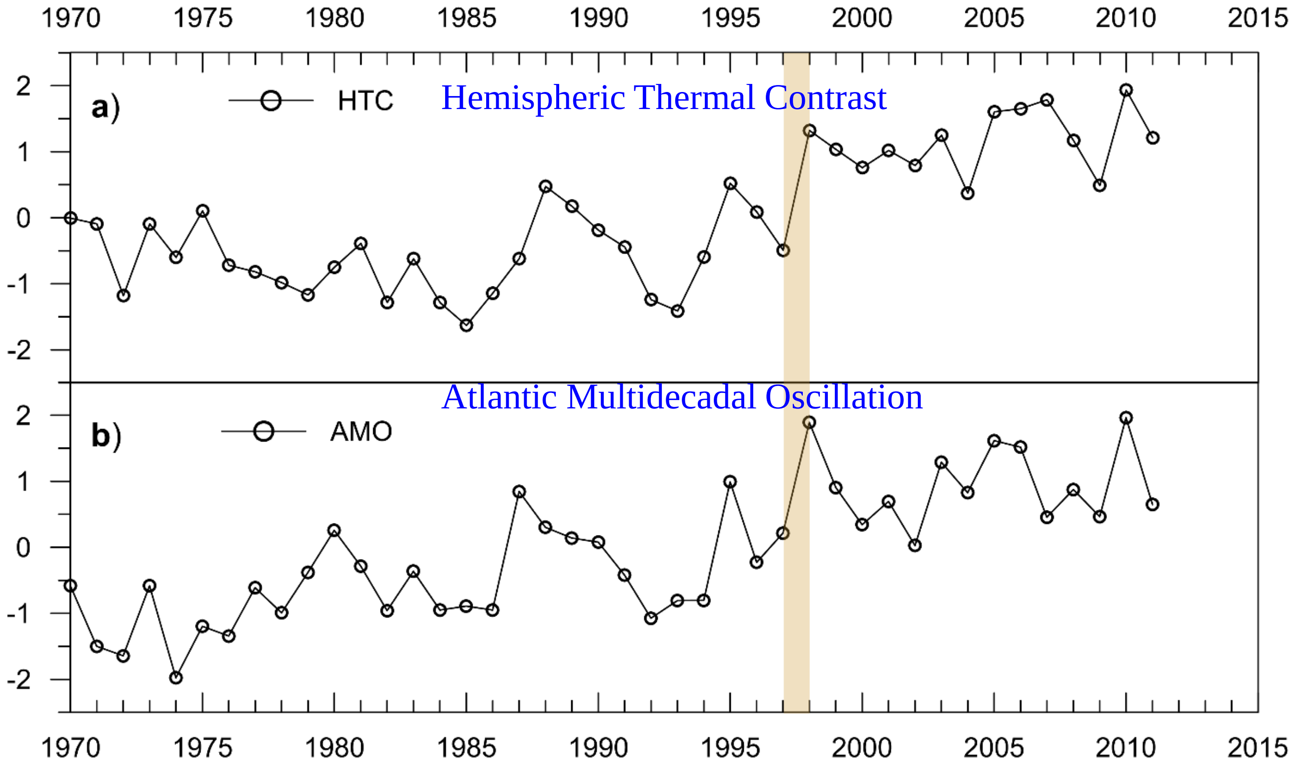




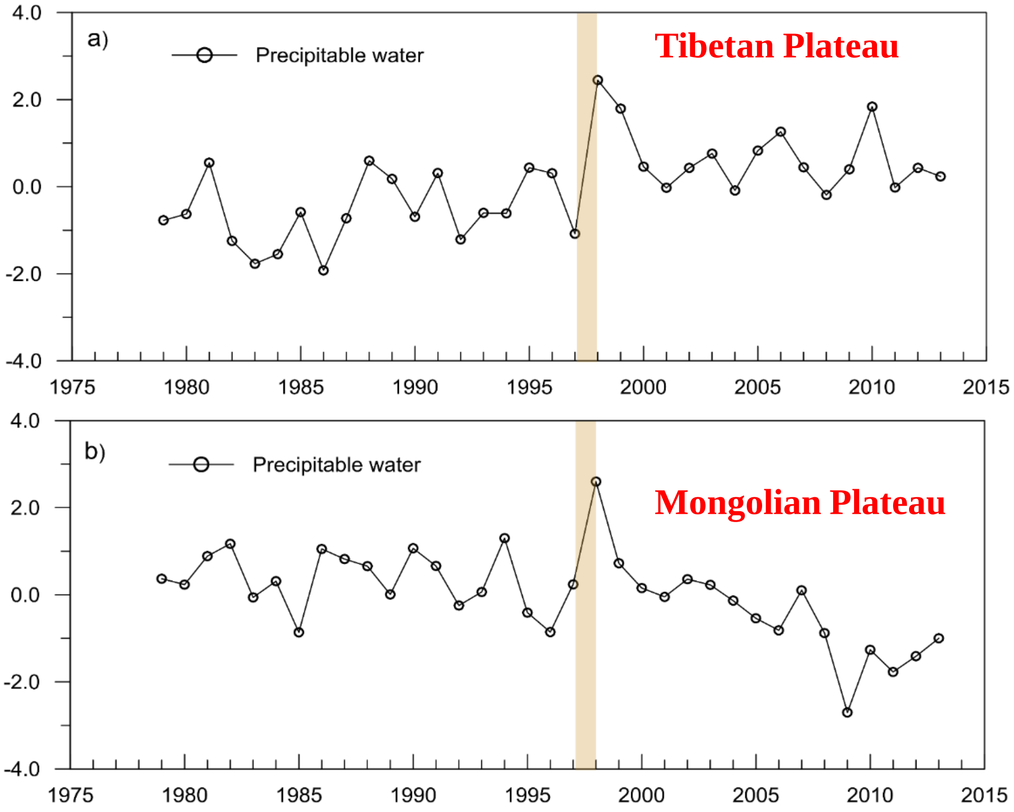
Difference in precipitation between 1998–2011 and 1979–1997 and net precipitation (precipitation minus evapotranspiration, P–E)



Large-scale atmosphere circulation indices



Standardized precipitable water from ERA-interim



Summary II:

(1) Contrasting patterns of lake change between the Mongolian Plateau and Tibetan Plateau;

(2) a clear statistical significant inflection point of lake change occurred during 1997/1998 on both plateaus;

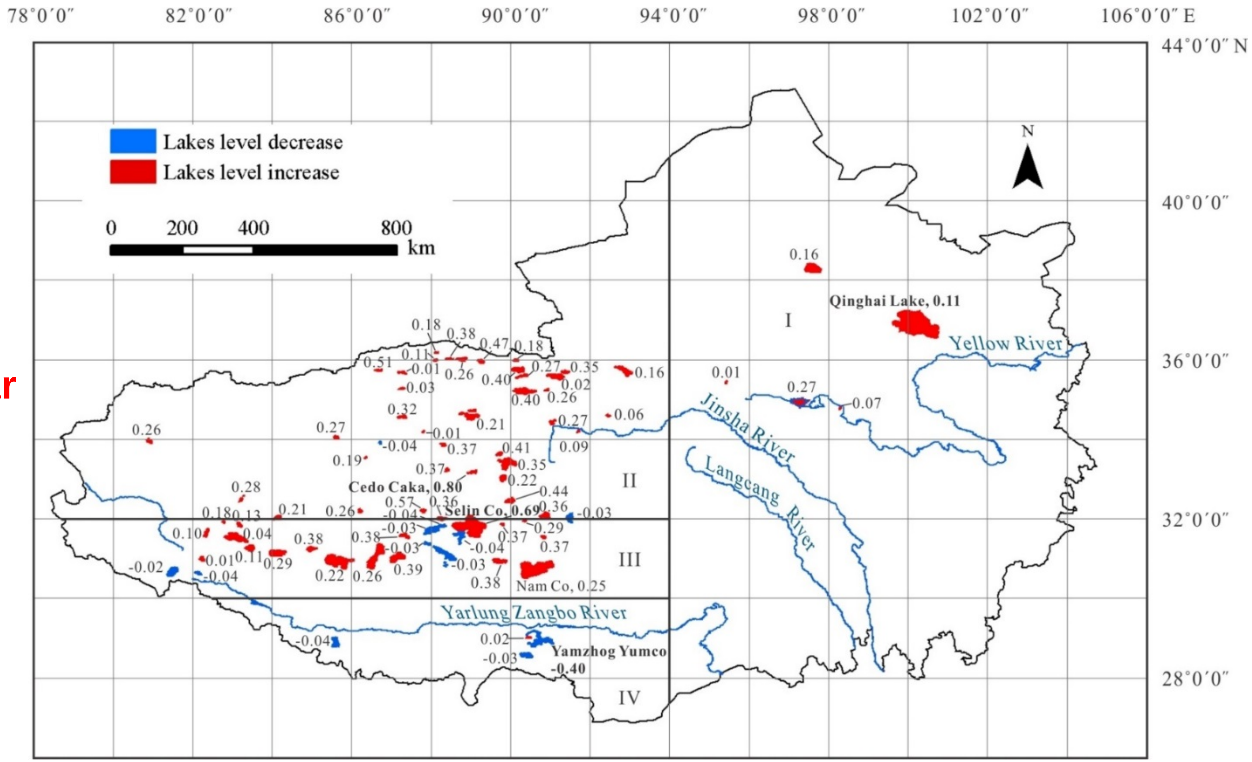
(3) comparing the climate patterns of the two plateaus showed that the MP was getting warmer and drier, whereas the TP was getting warmer and wetter, which could have driven the reverse patterns of lake change between two plateaus.

3. Lake level, volume change and water balance

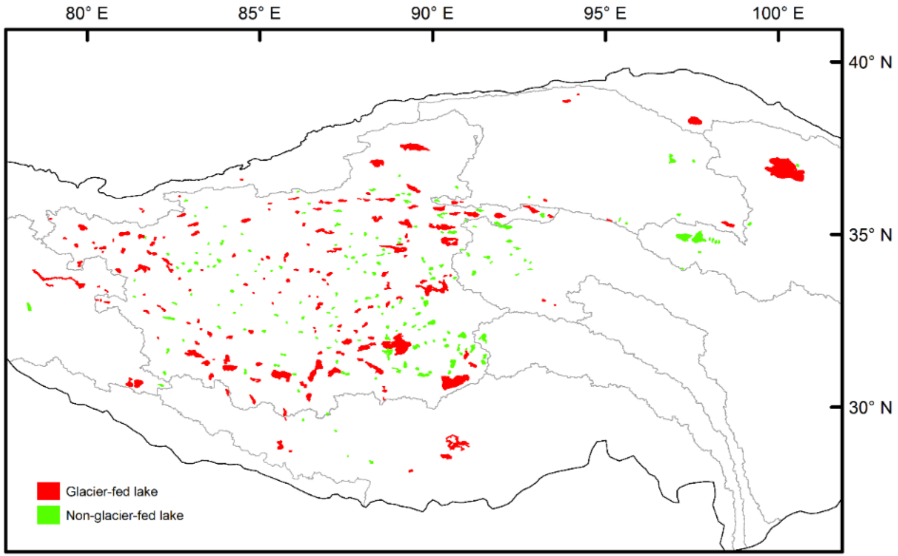
Lake level changes from ICESat data (m/year)（2003-2009）

62 lakes (84%) ↑
12 lakes (16%) ↓

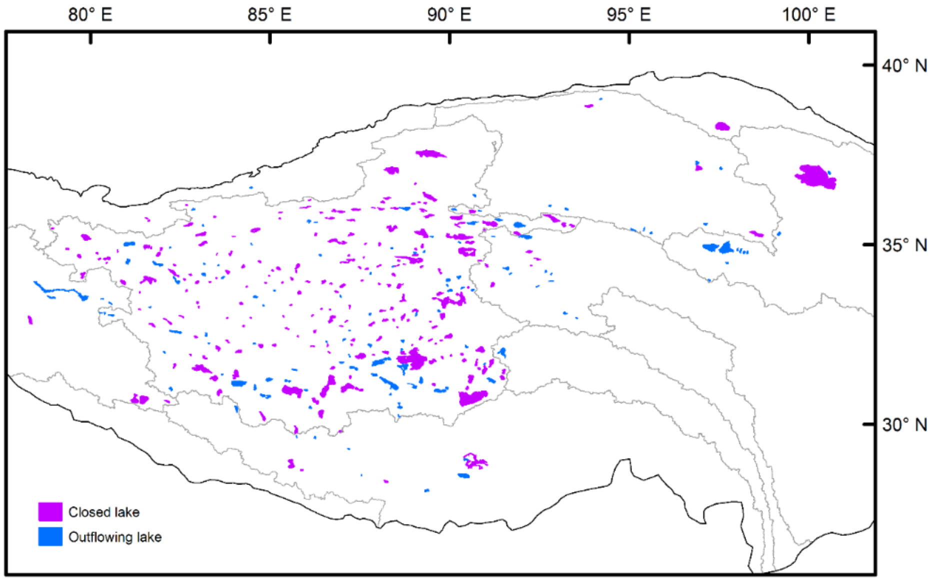
Mean rate：0.21 m/year

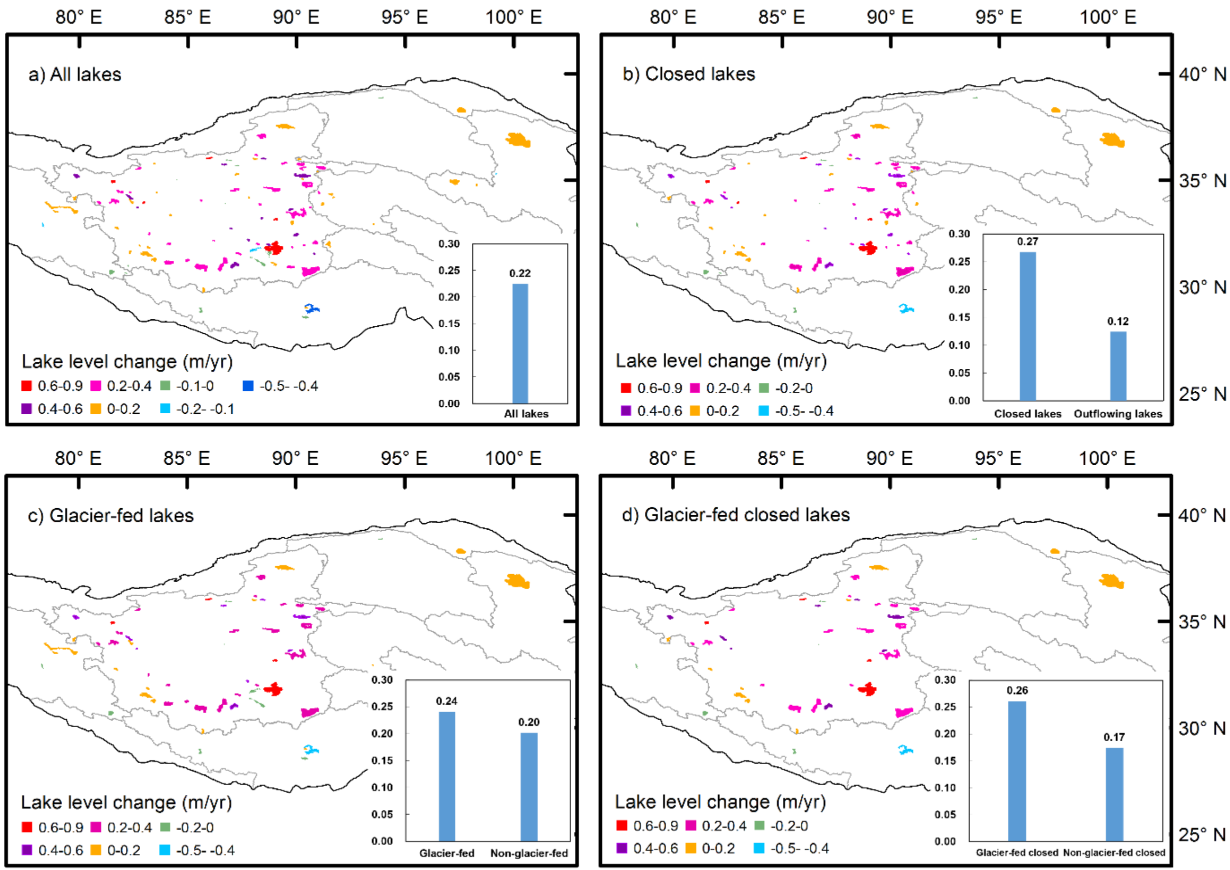


Glacier-fed and non-glacier-fed lakes



Closed lakes and outflowing lakes





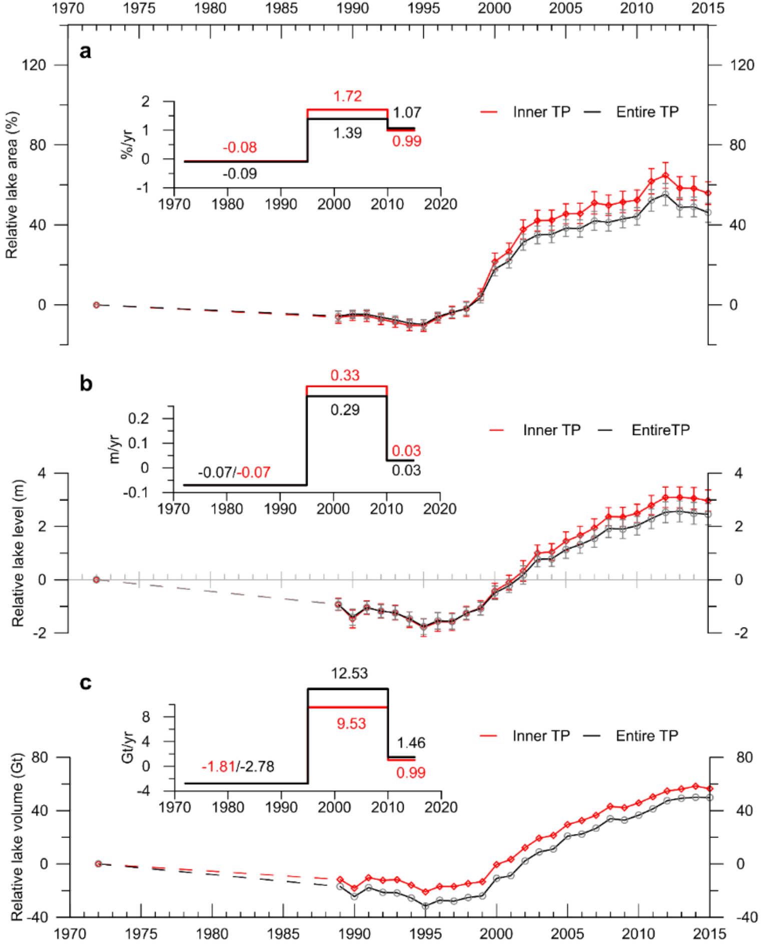
a) All lakes
b) Closed lakes
c) Glacier-fed lakes
d) Glacier-fed closed lakes
80° E
85° E
90° E
95° E
100° E
40° N
35° N
30° N
25° N
Lake level change (m/yr)
0.6-0.9
0.2-0.4
-0.1-0
-0.5- -0.4
0.4-0.6
0-0.2
-0.2- -0.1
-0.2-0
0.22
All lakes
0.27
0.12
Closed lakes
Outflowing lakes
0.24
0.20
Glacier-fed
Non-glacier-fed
0.26
0.17
Glacier-fed closed
Non-glacier-fed closed

Annual Changes in

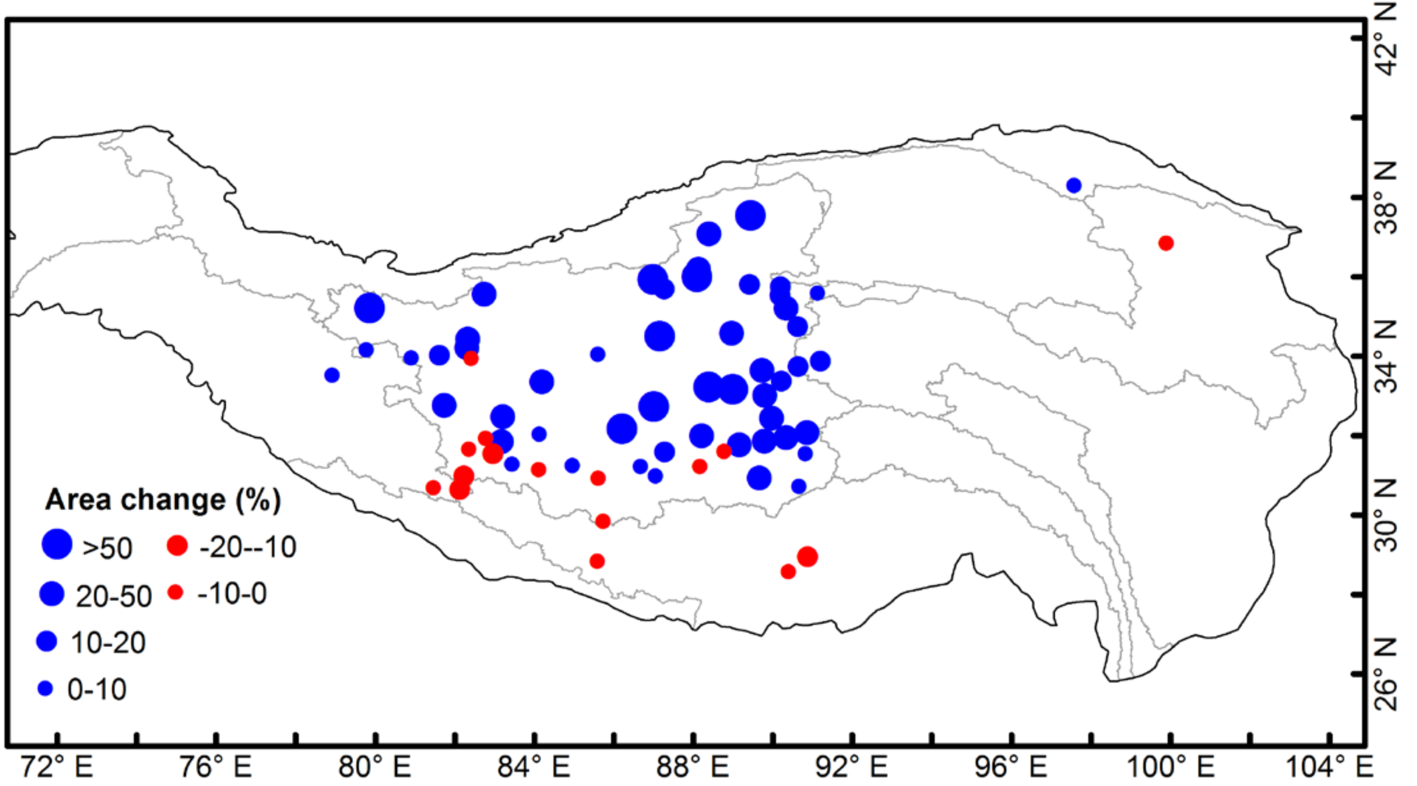
Lake area

Lake level

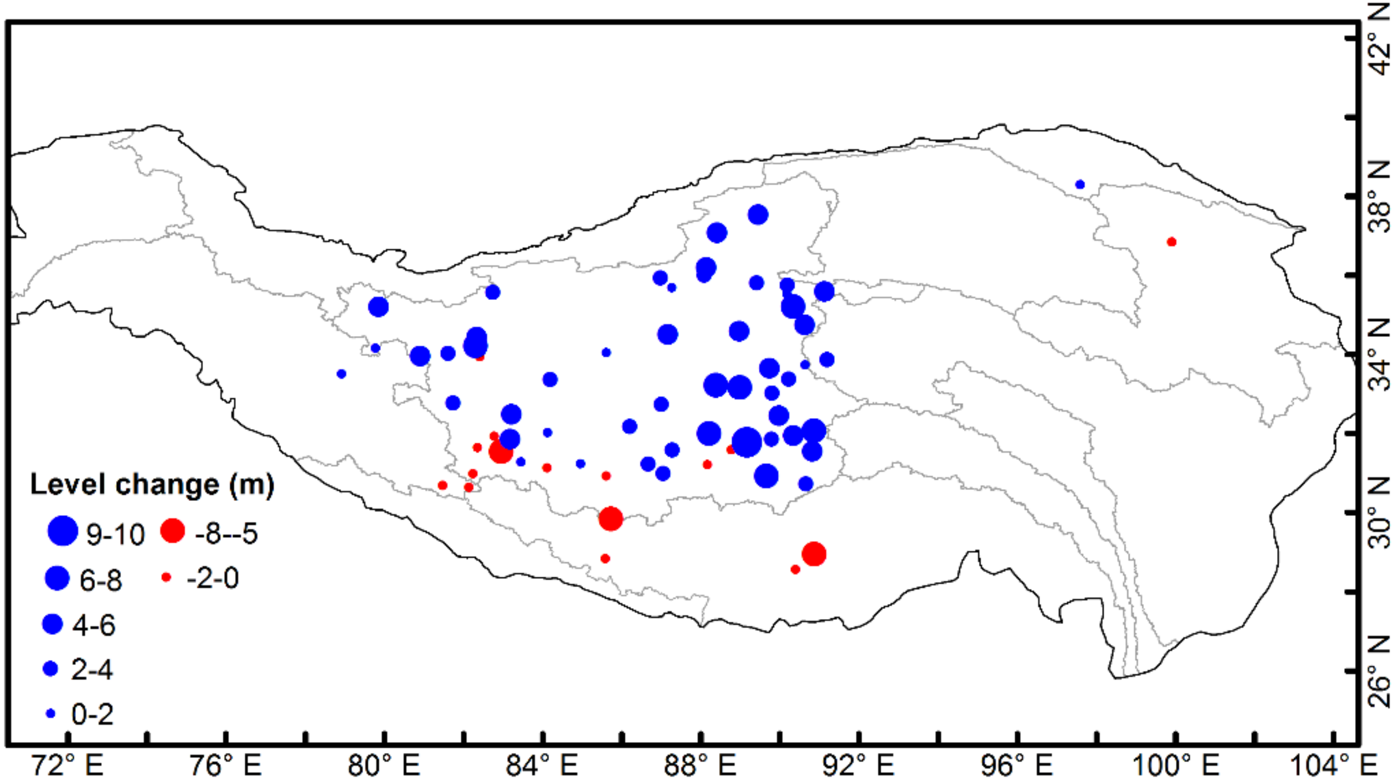
Lake volume



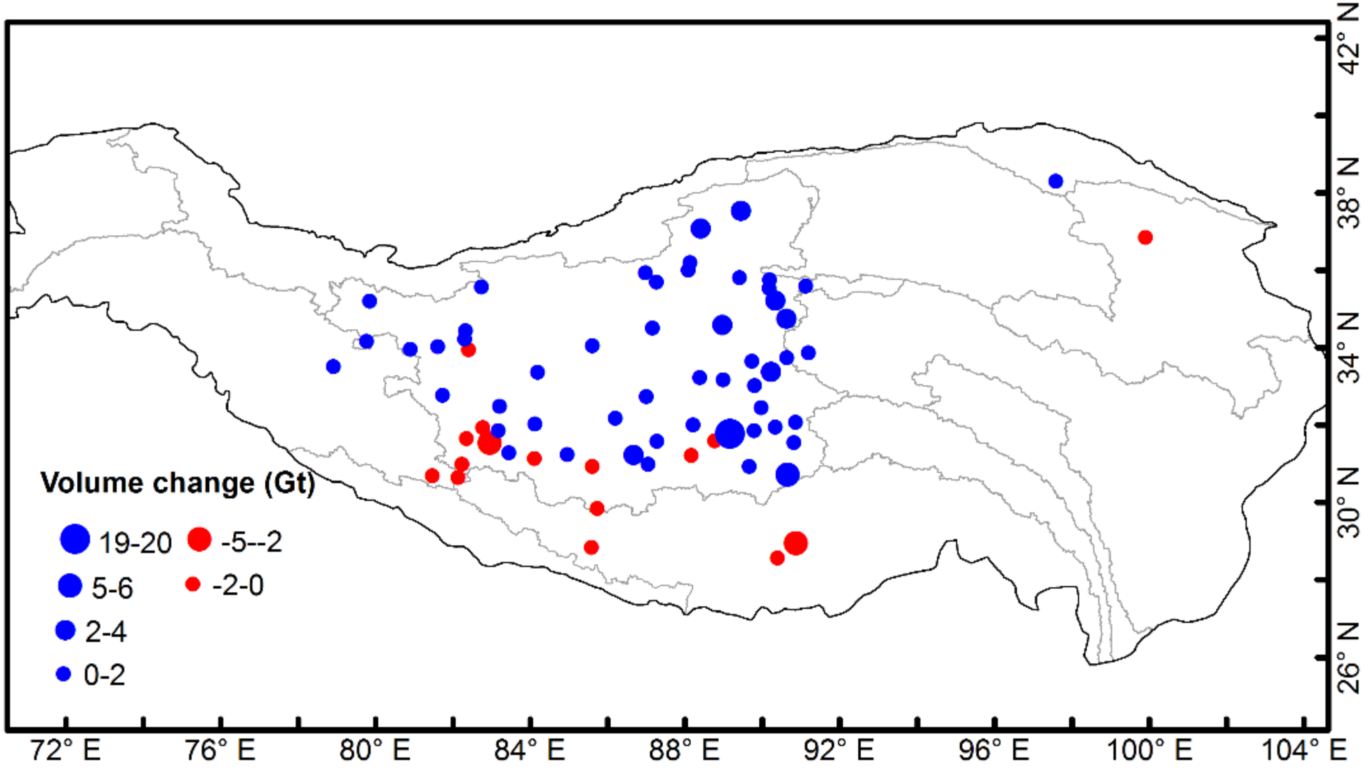
Lake area change between 1970s and 2015



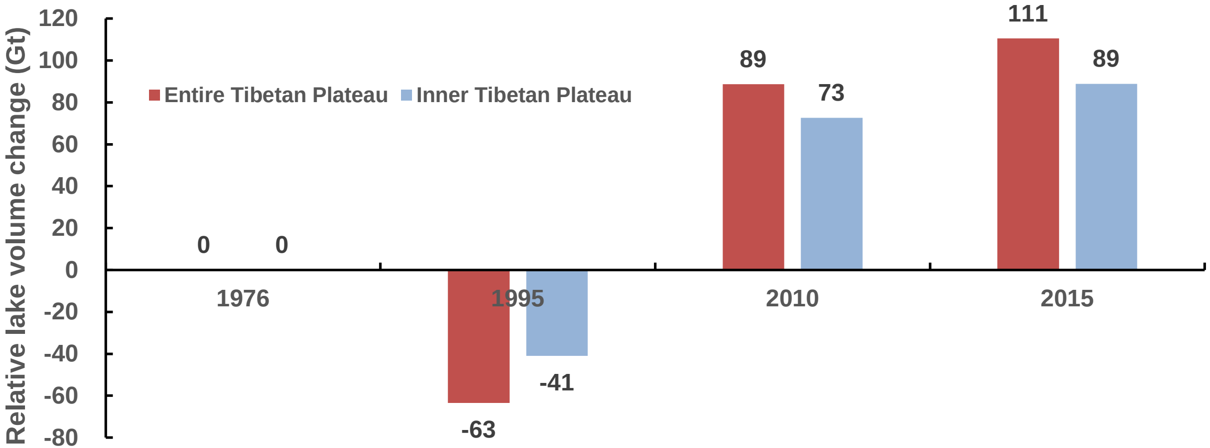
Lake level change between 1970s and 2015



Lake volume change between 1970s and 2015



Lake water volume changes in 1995, 2010 and 2015 relative to 1976 in the entire Tibetan Plateau and Inner Tibetan Plateau



Water mass balance is constrained in 2003-2009

Mass balance:

The change in terrestrial water storage (TWS) in the TP includes:

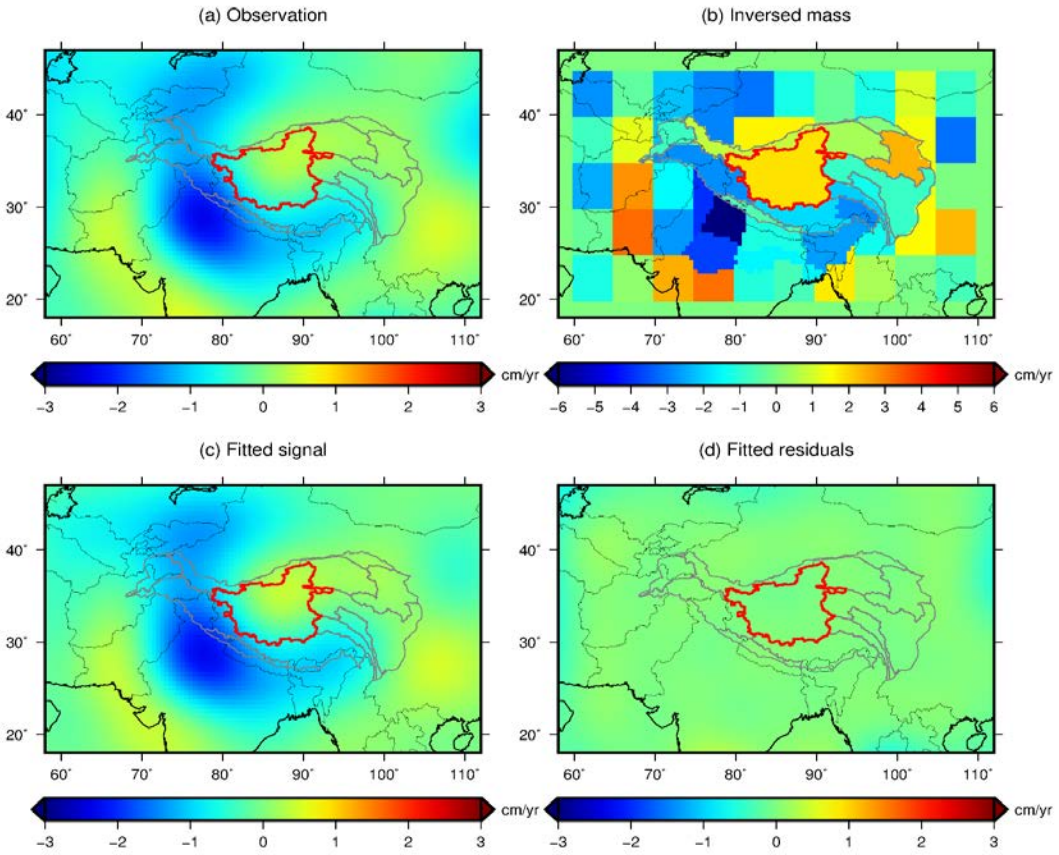
- lake water (L)
- glacier (G)
- snow water equivalent (SWE)
- soil moisture (SM)
- permafrost (PM)
- groundwater (GW)

$$\Delta TWS = \Delta L + \Delta G + \Delta SWE + \Delta SM + \Delta PM + \Delta GW$$

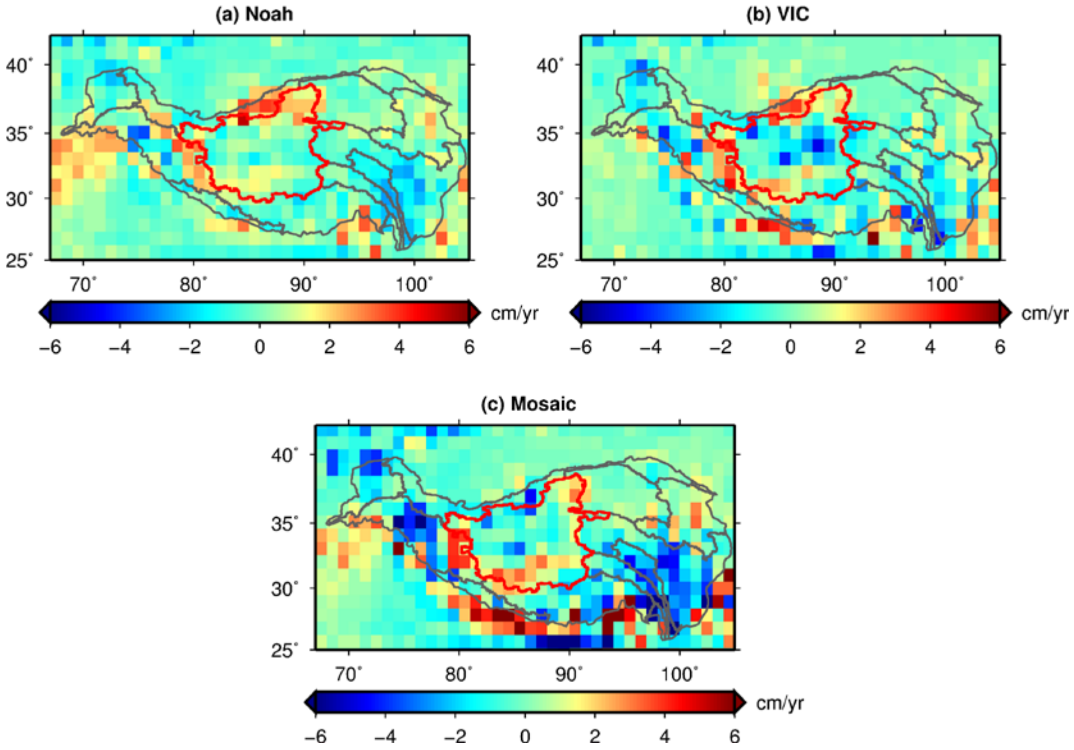
Lake water balance:

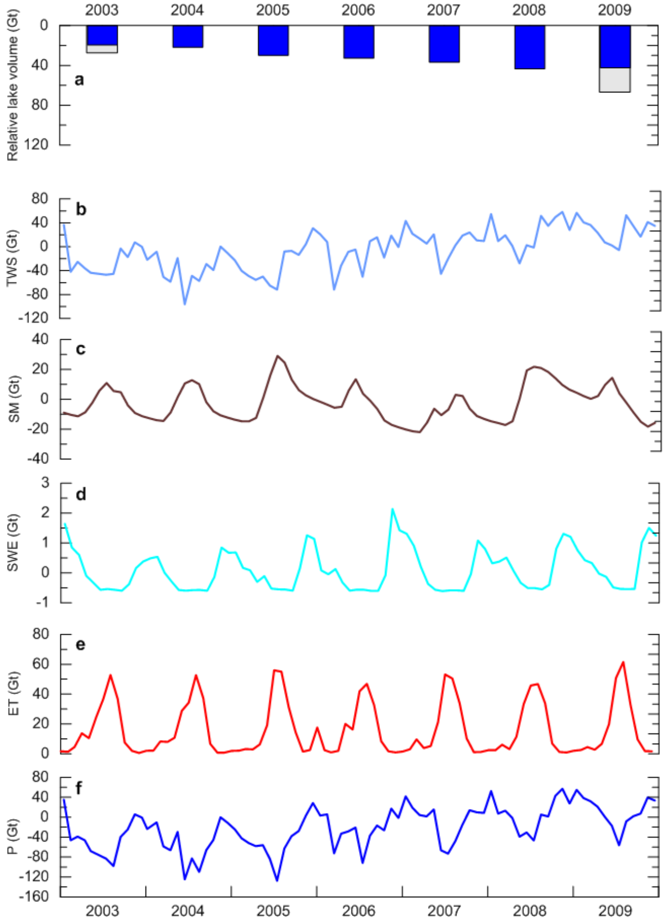
$$\Delta L = \Delta G + \Delta SWE + \Delta PM + \Delta P$$

TWS anomaly observed from GRACE data



Soil moisture variation from GLDAS: (a) Noah, (b) VIC, and (c) Mosaic

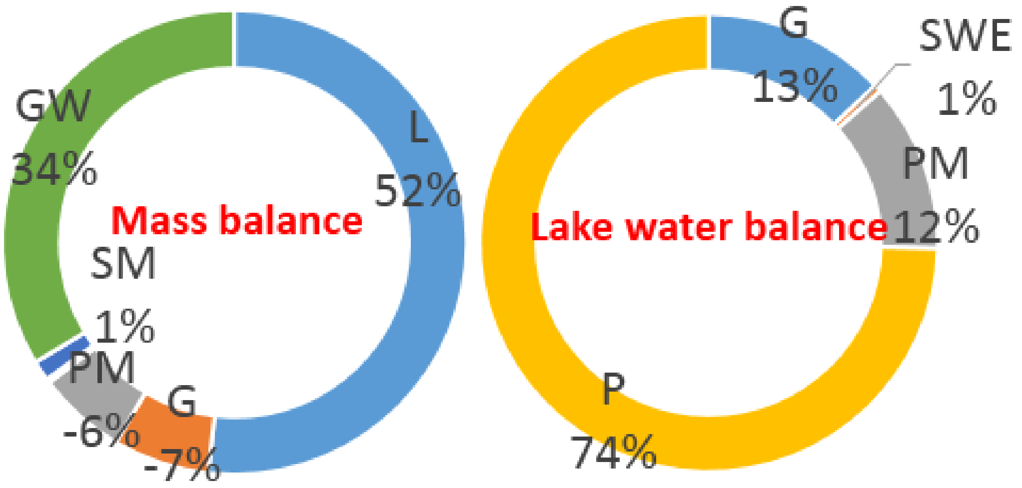




Water balance in the Inner Tibetan Plateau between 2003 and 2009

- lake water (L),
- glacier (G),
- snow water equivalent (SWE),
- soil moisture (SM),
- permafrost (PM),
- groundwater (GW)

Water balance between 2003 and 2009



lake water (L), glacier (G), snow water equivalent (SWE), soil moisture (SM), permafrost (PM), groundwater (GW)

Summary III:

- Lake area, level and volume vary in three stages: slight decrease (1970s–1995), rapid increase (1996–2010) and recent slowdown (2011–2015).
- Similar increase rate of lake volume (7.72±0.63 Gt/yr) and groundwater storage (5.01±1.59 Gt/yr) in the TP' endorheic basin over 2003–2009.
- Increased precipitation contributes a major water supply (74%) for the total lake volume increase, followed by glacier melting (13%).

Plans for the next 4 years (2017-2020)

NSFC-SNSF(中瑞) project：

Recent and future EVOlution of GLacial Lakes in China (EVOGLAC): Spatio-temporal diversity and hazard potential

近期和未来中国冰湖演变：时空多样性及潜在危害

THANK YOU!