XVIII
World Water Congress
International Water Resources Association(IWRA)
Beijing, China | September 11-15, 2023

Impacts of Cryospheric Shrinking on Water Resources in China

Shichang Kang(康世昌)，Rensheng Chen(陈仁升)，Yong Yang(阳勇)

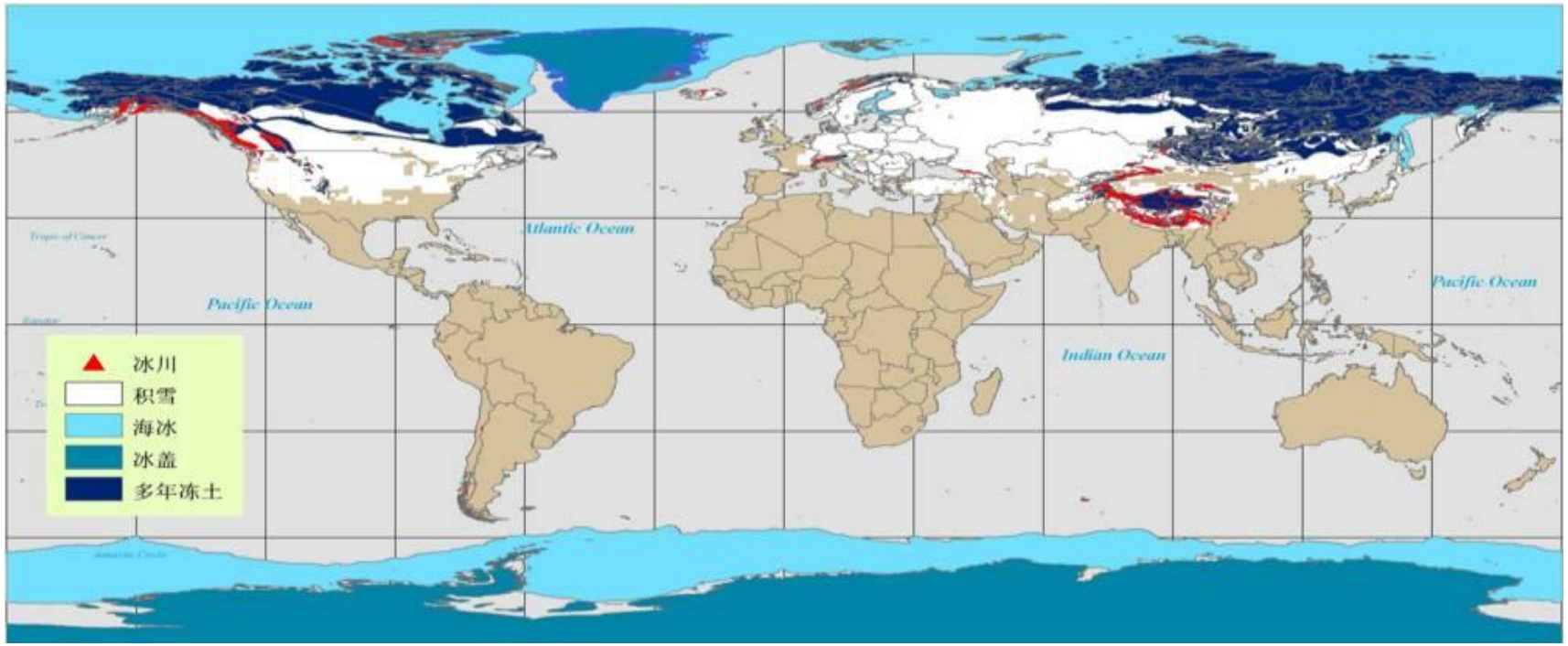
Northwest Institute of Eco-Environment and Resources
Chinese Academy of Sciences

Outline

1. Background
2. Glacial meltwater
3. Snowmelt
4. Hydrologic effects of permafrost degradation
5. Comprehensive impacts on water resources

1. Background

Cryosphere: a sphere on the earth's surface with a certain thickness, where temperature is continuously at or below 0 °C.



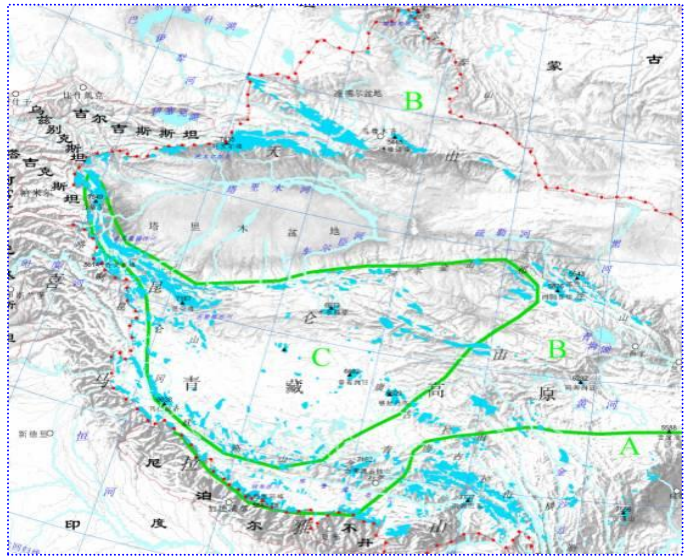
- Glacier (including ice sheet)
- Frozen ground (including permafrost and seasonally frozen ground)
- Snow cover
- River ice
- Lake ice
- Sea ice
- Ice shelf
- Iceberg
- Subsea permafrost
- Frozen water in the atmosphere

The cryosphere is the world's largest reservoir of fresh water resources (>70%)

1. Background

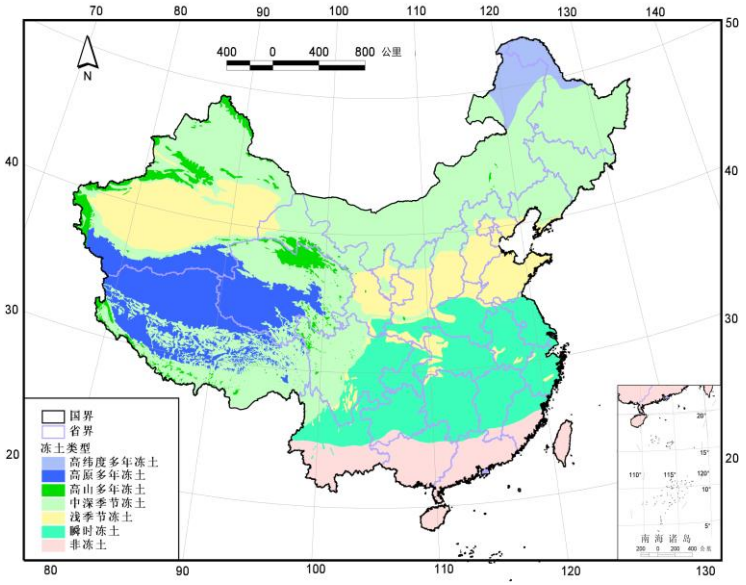
Cryosphere in China

Glacier



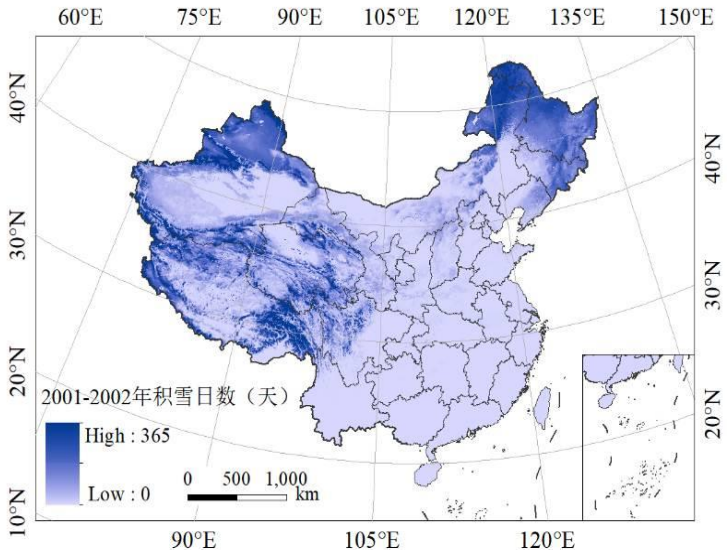
46,377
59425 km^2
5.6×10^{12} m^3

Frozen ground



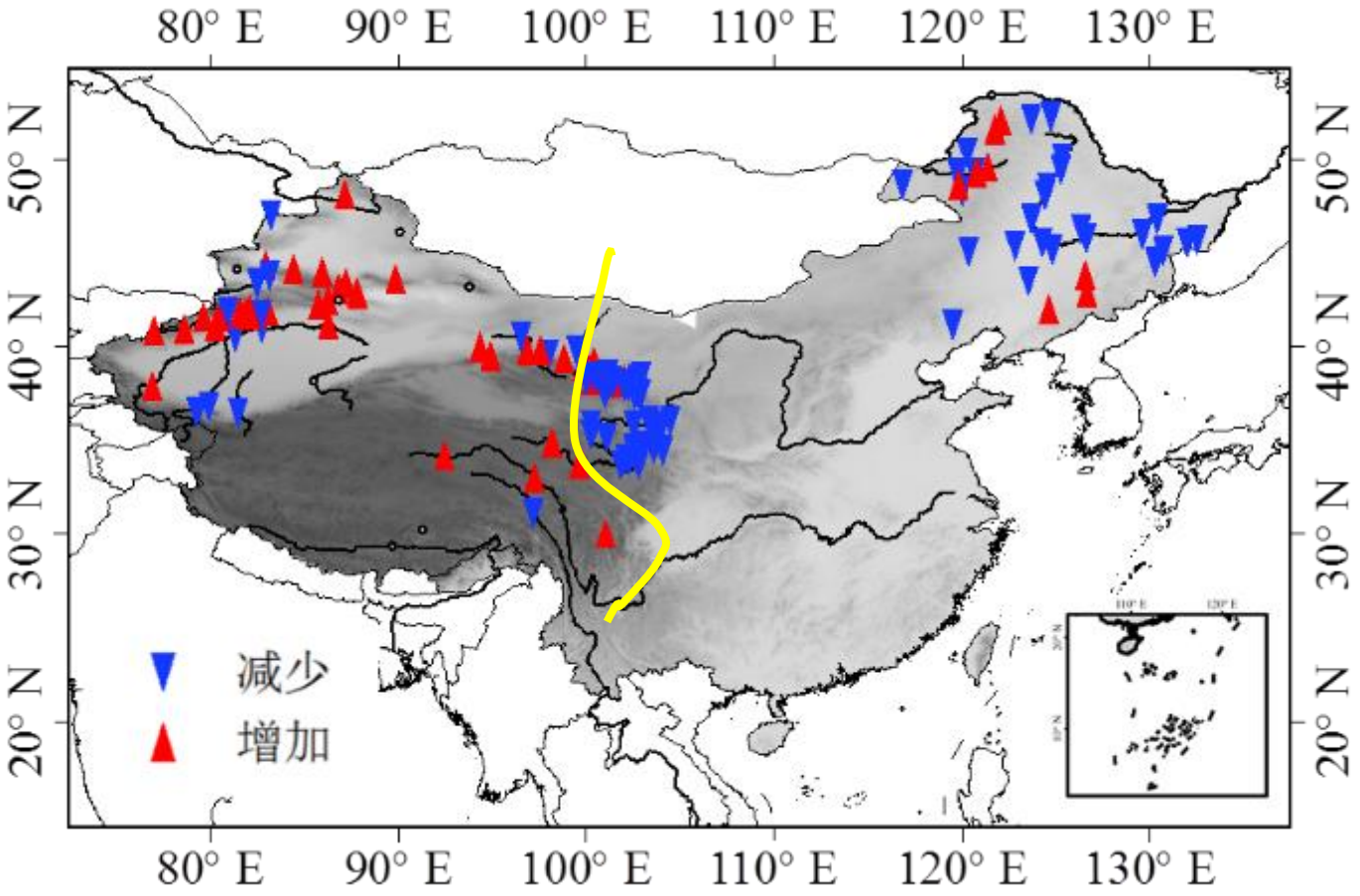
Permafrost
220×10^4 km^2

Snow cover



Stable snowcover region
420×10^4 km^2

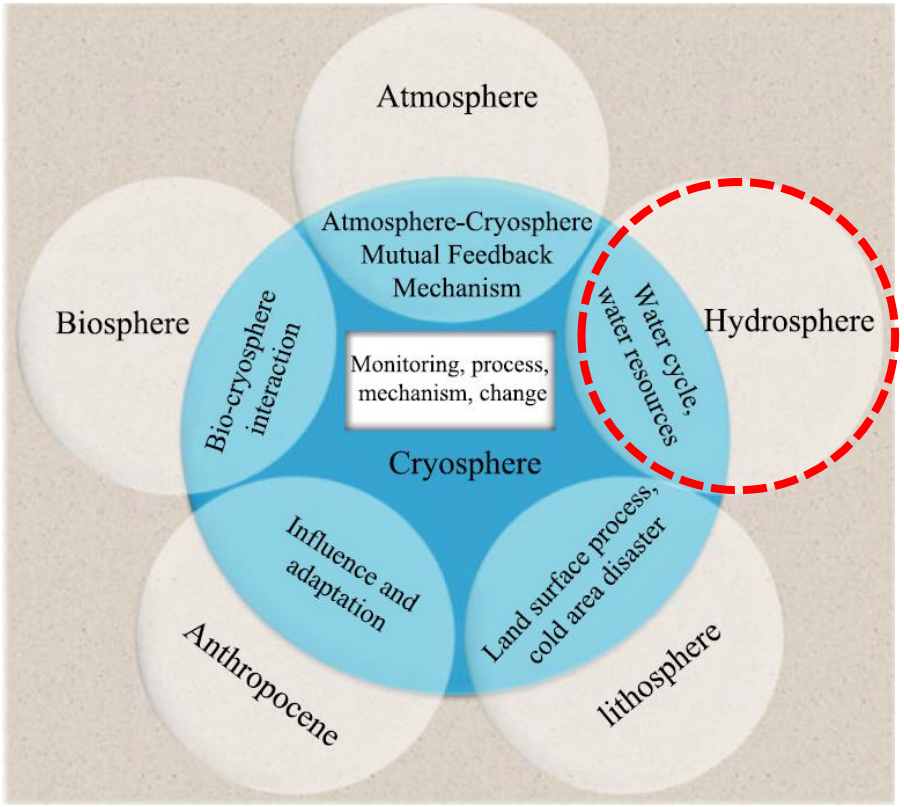
1. Background



Runoff ↑

West: west of the Heihe river

Northeast: Higher mountain elevations



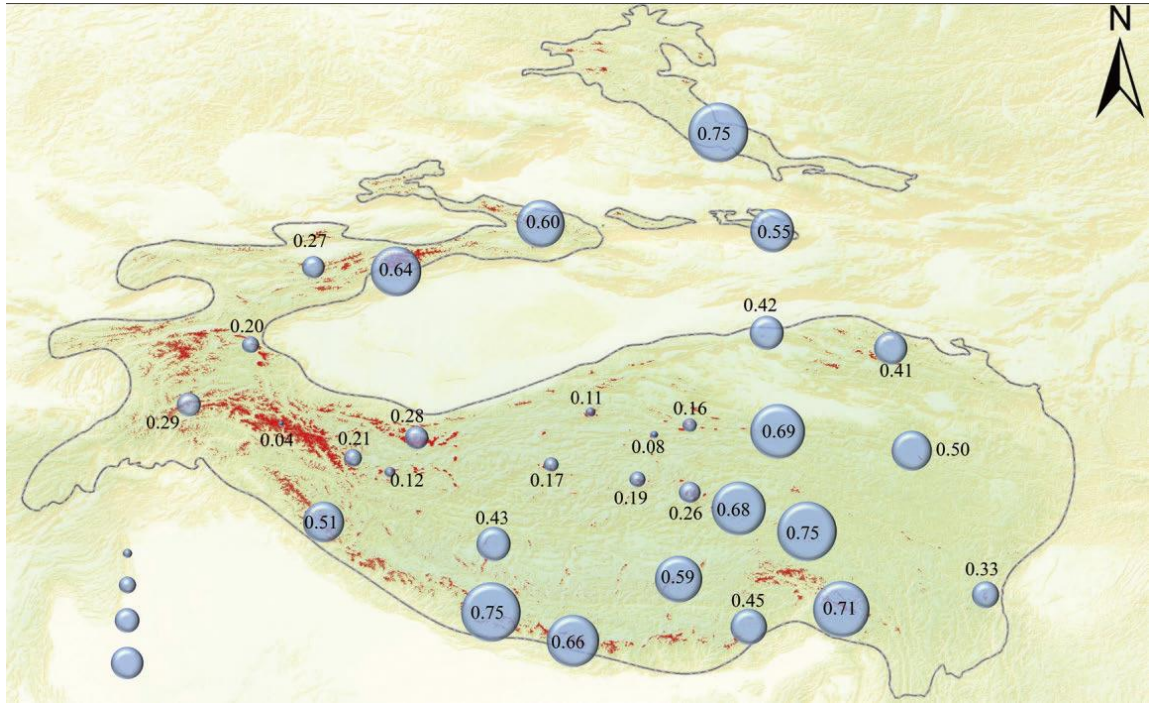
Cryospheric changing

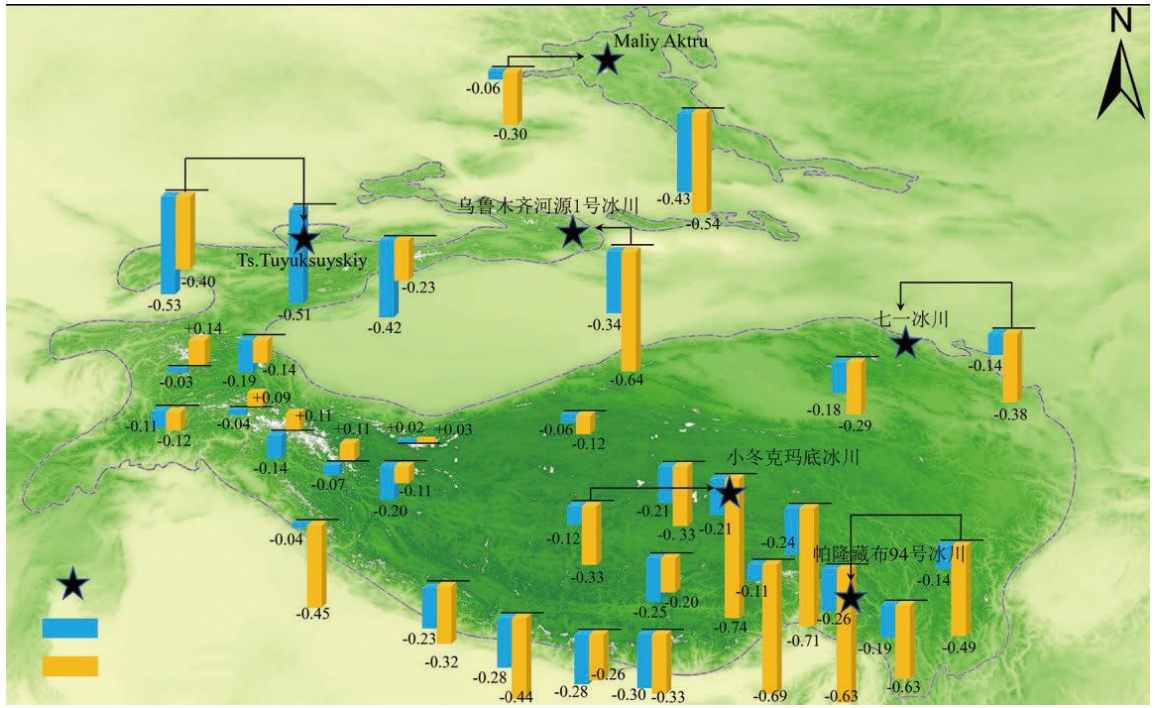
↓ ?

Water Resources

2. Glacial meltwater

Glacier change in China



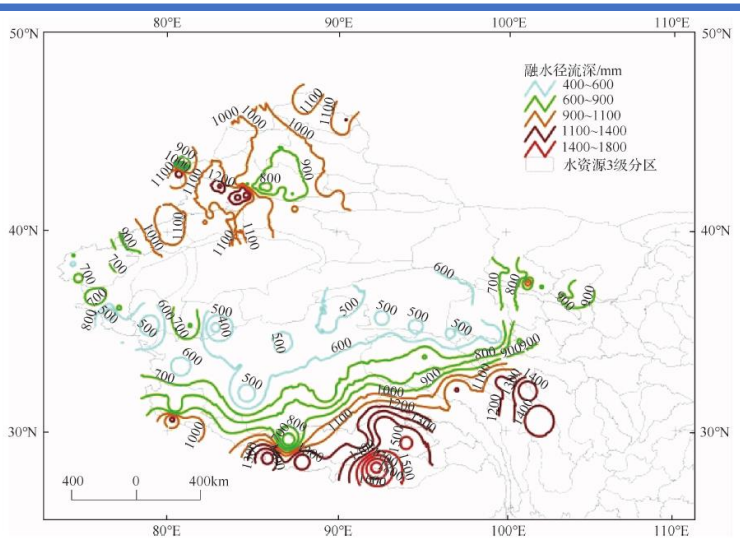


Glacier area: decreased

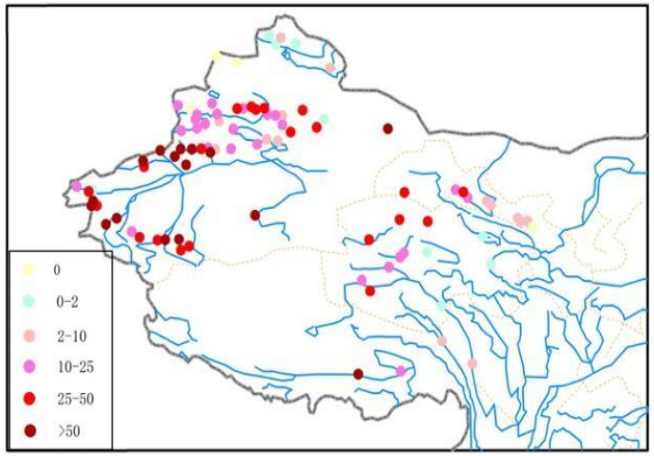
Glacier mass balance: negative

王宁练等，2019

2. Glacial meltwater

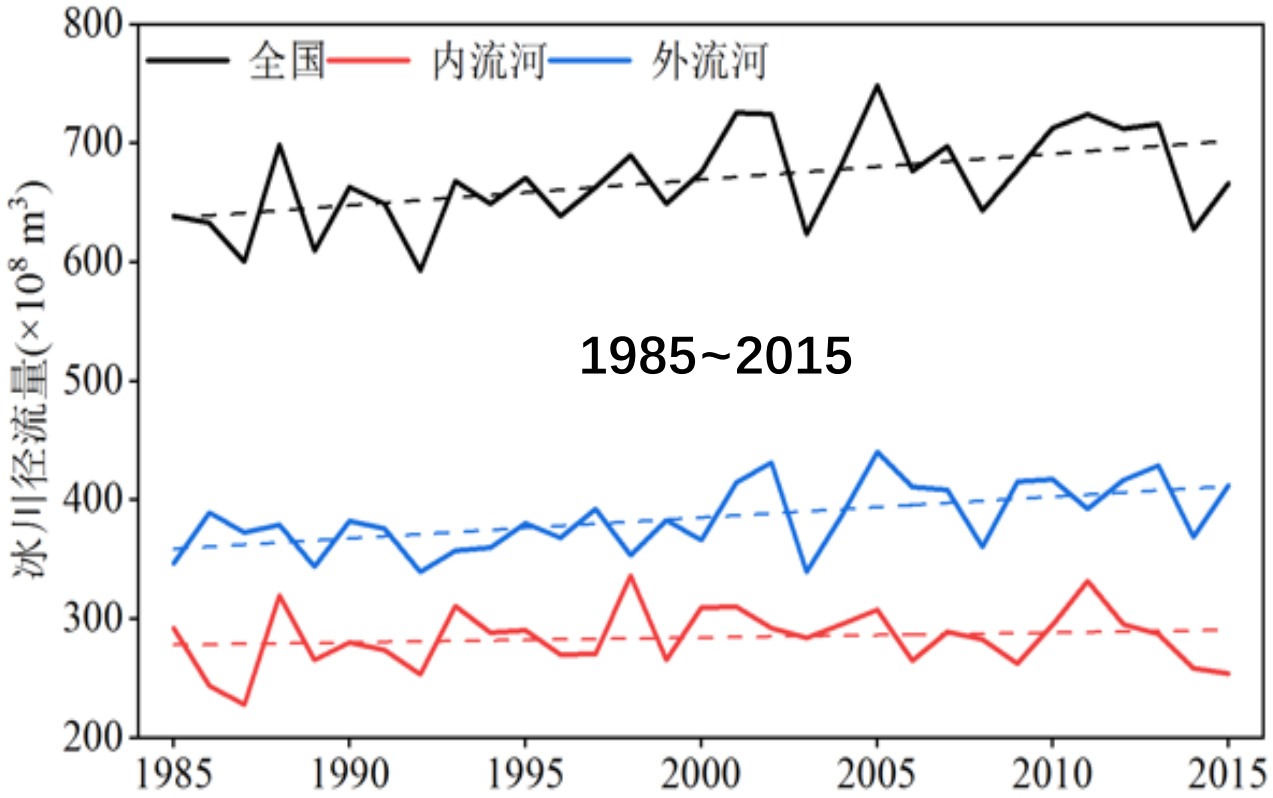


Glacial meltwater runoff depth



Ratio of glacial meltwater in basins

丁永建等，2017



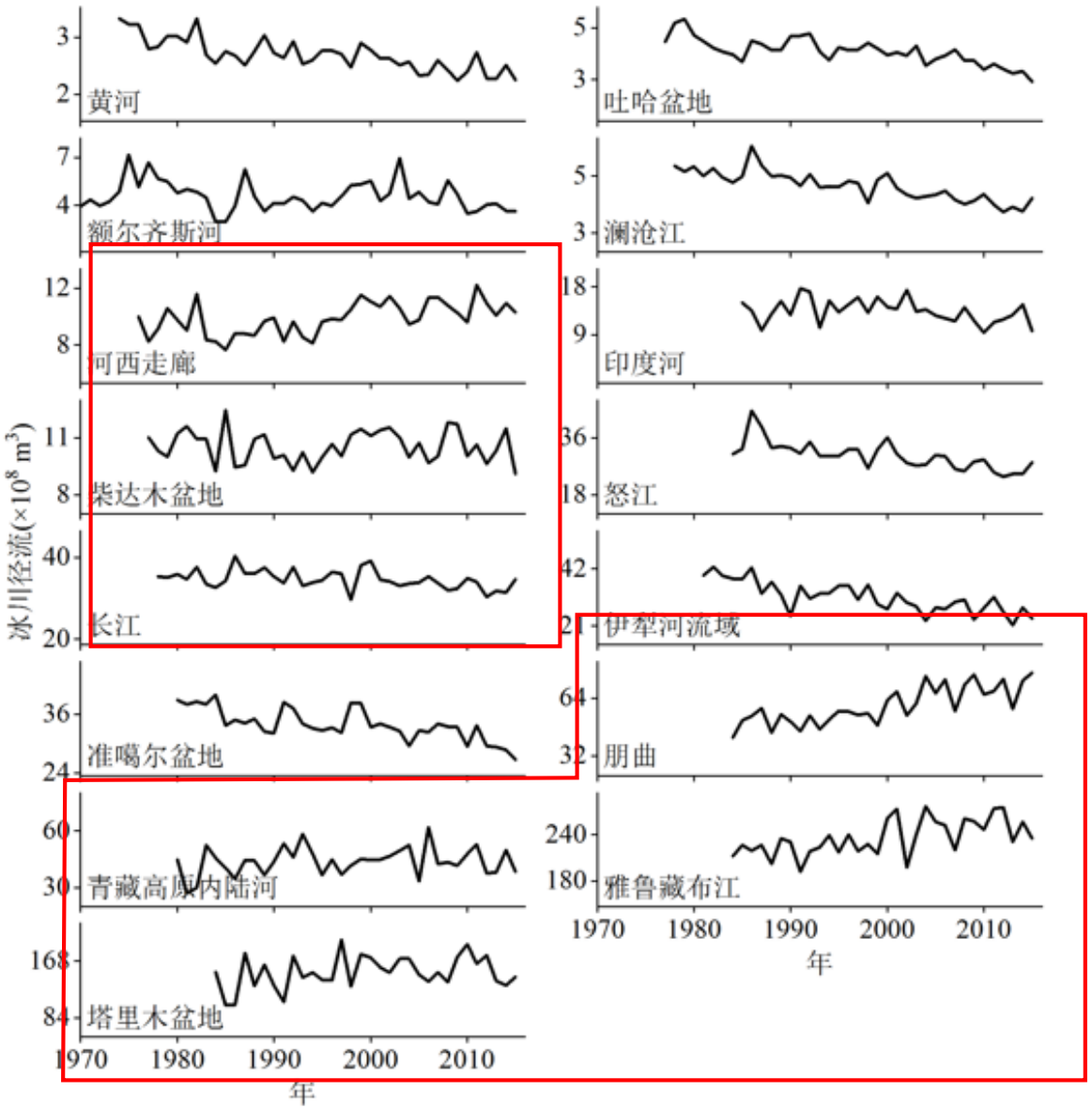
China: 669.43×10^8 m^3

Outflow basins: 385.15×10^8 m^3

Inland basins: 284.28×10^8 m^3

刘国华，2023

2. Glacial meltwater



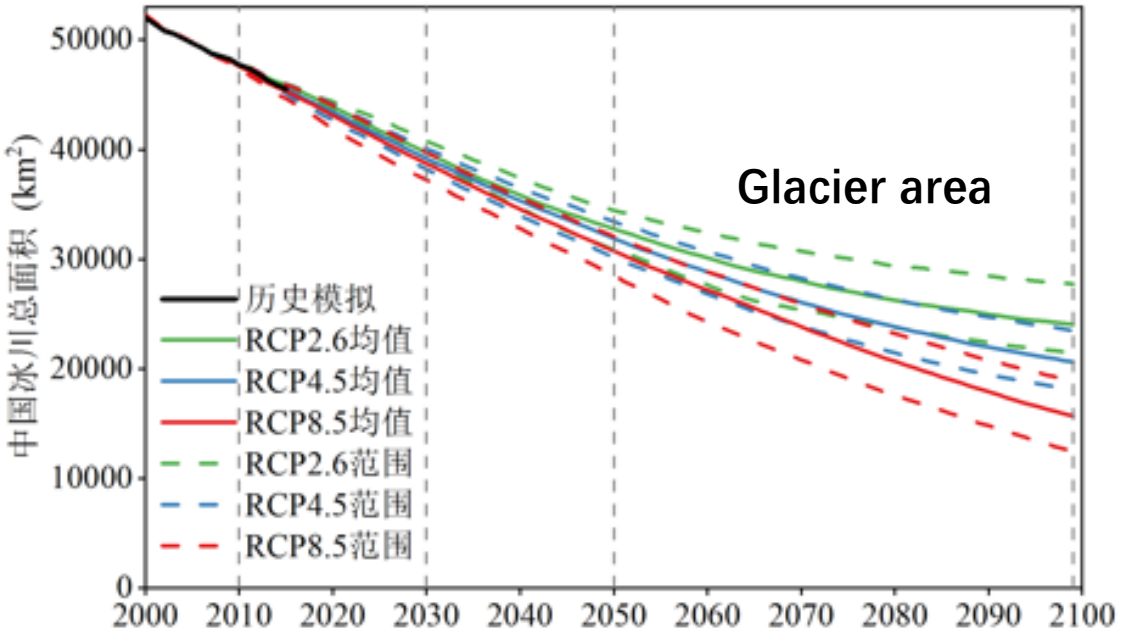
Changes of glacial meltwater in basins with different glacier coverage

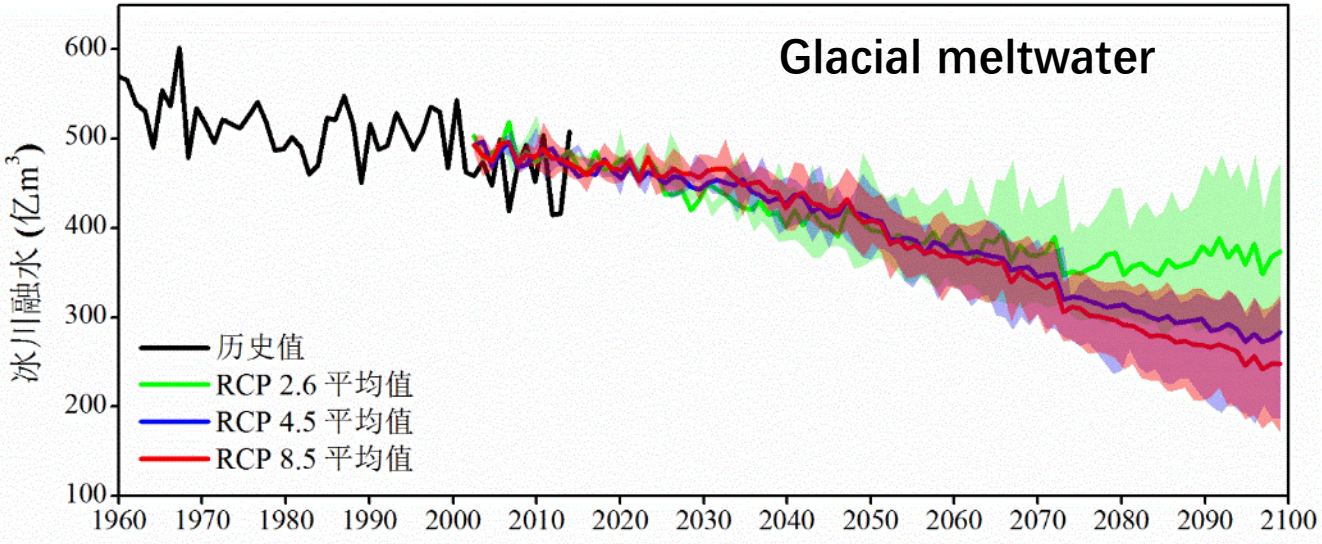
- increased in basins with a large number of glaciers and large glaciers
- decreased in basins dominated by small and dispersed glaciers

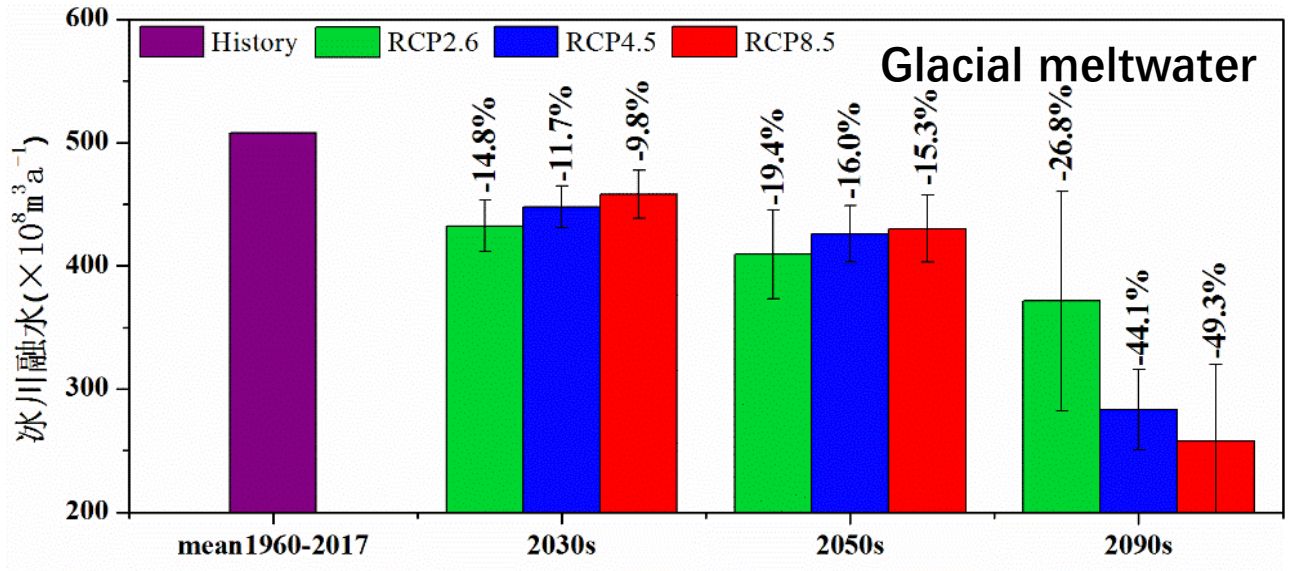
刘国华，2023

2. Glacial meltwater

Projected future changes in glacier in China





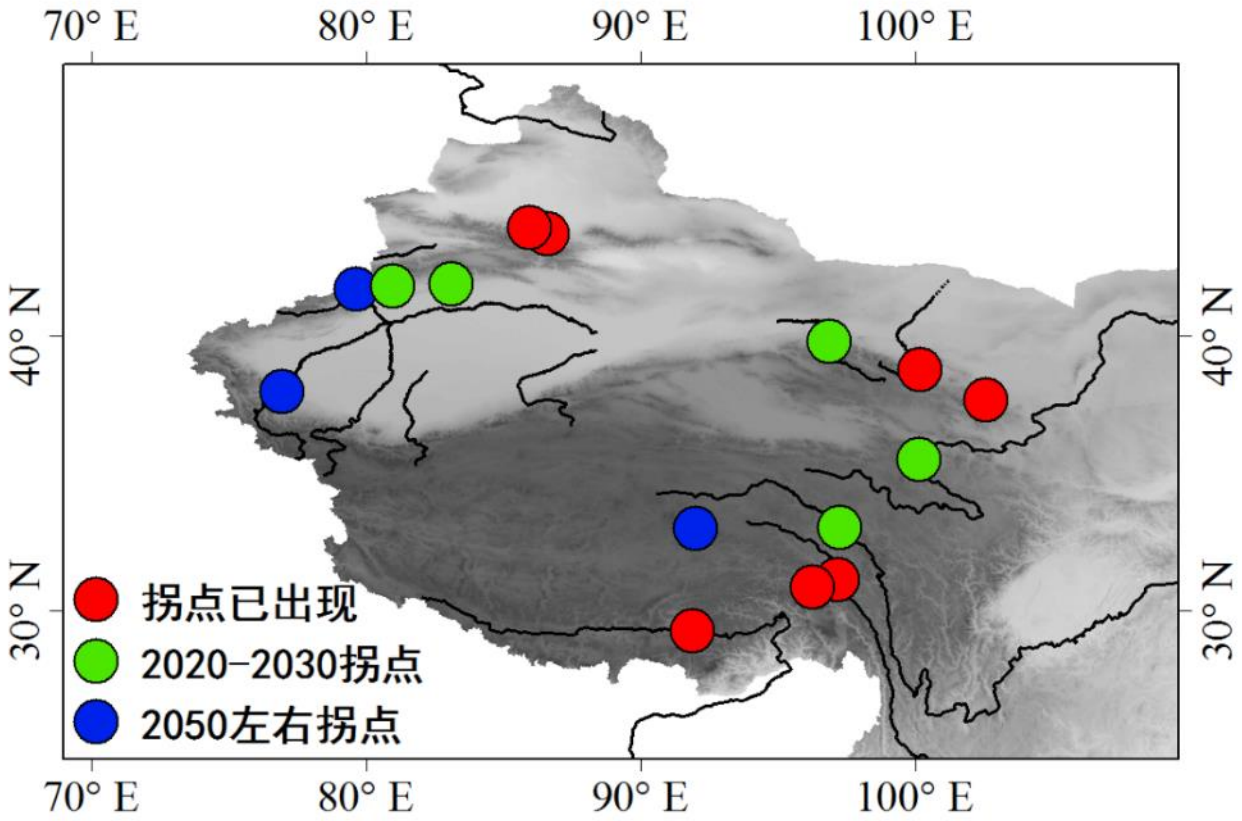


Glacial meltwater is projected to **decrease** in the future

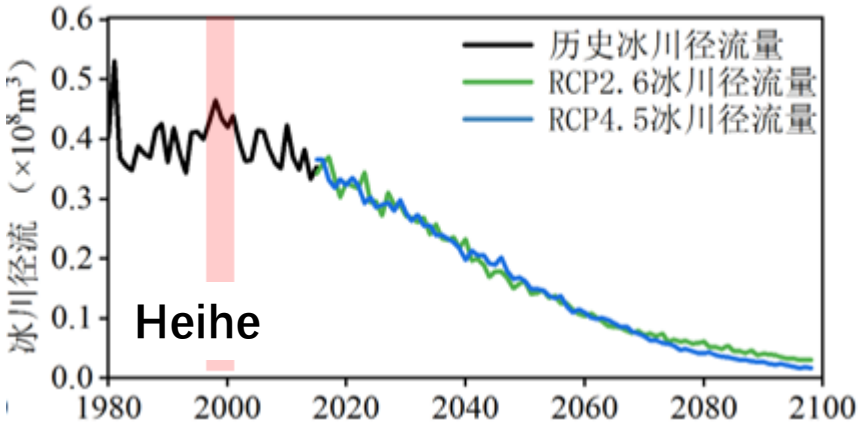
刘国华，2023

2. Glacial meltwater

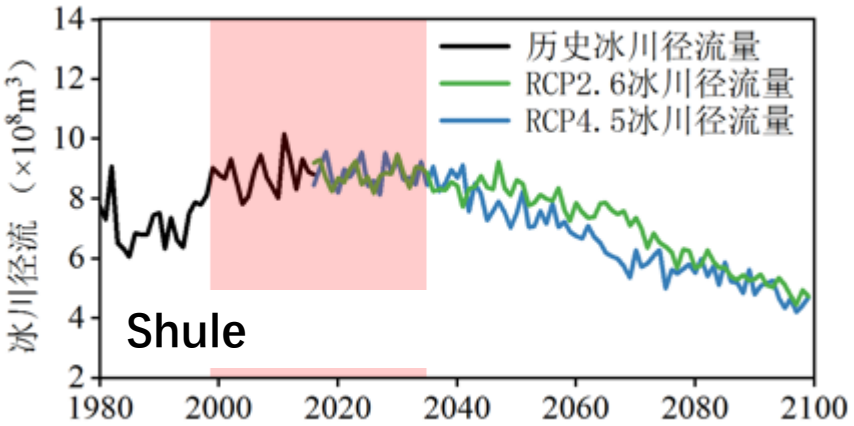
Time of Glacial meltwater reached peak



Reached (Heihe, Shiyang, Lantsang, Nujiang……)



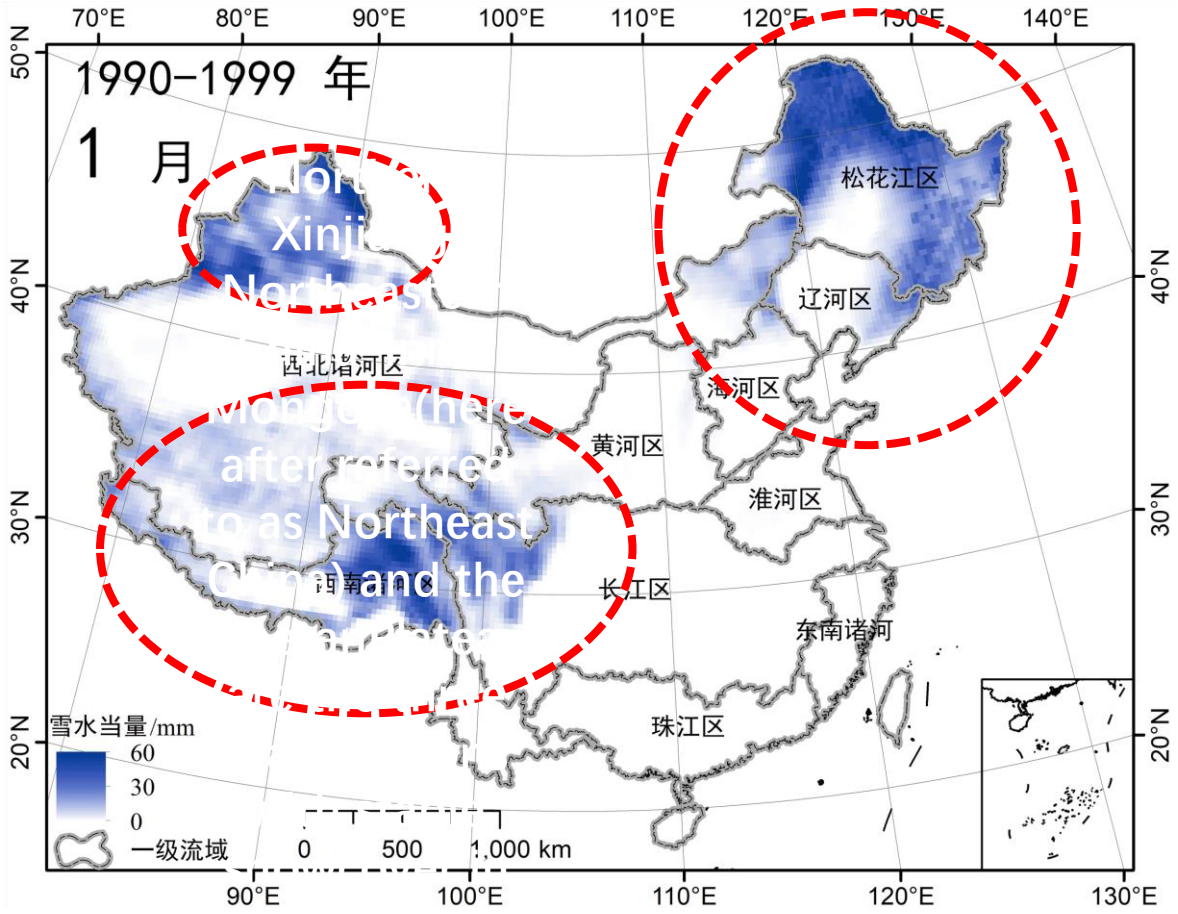
2020-2030 (Shule, Yangtze, Yellow……)

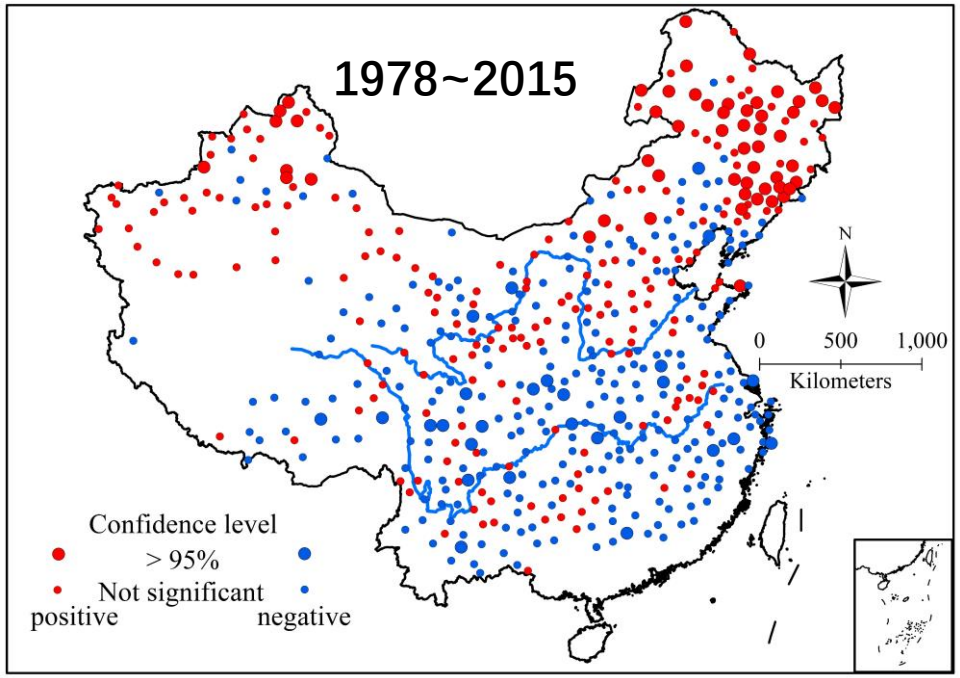


陈仁升等，2019；刘国华，2023

3. Snowmelt

Change of snow water equivalent （SWE）in China



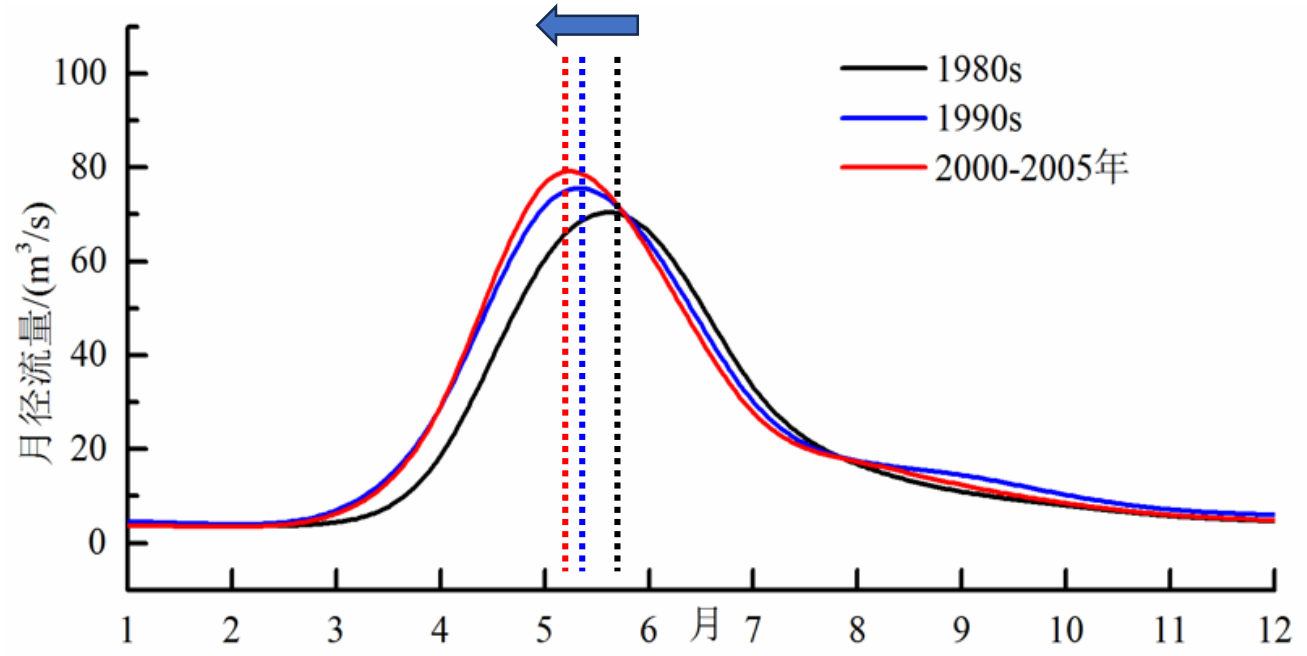


- SWE increased in North
- SWE decreased in South

Three main regions with stable snowcover: Northern Xinjiang, Northeast China and the Tibetan Plateau

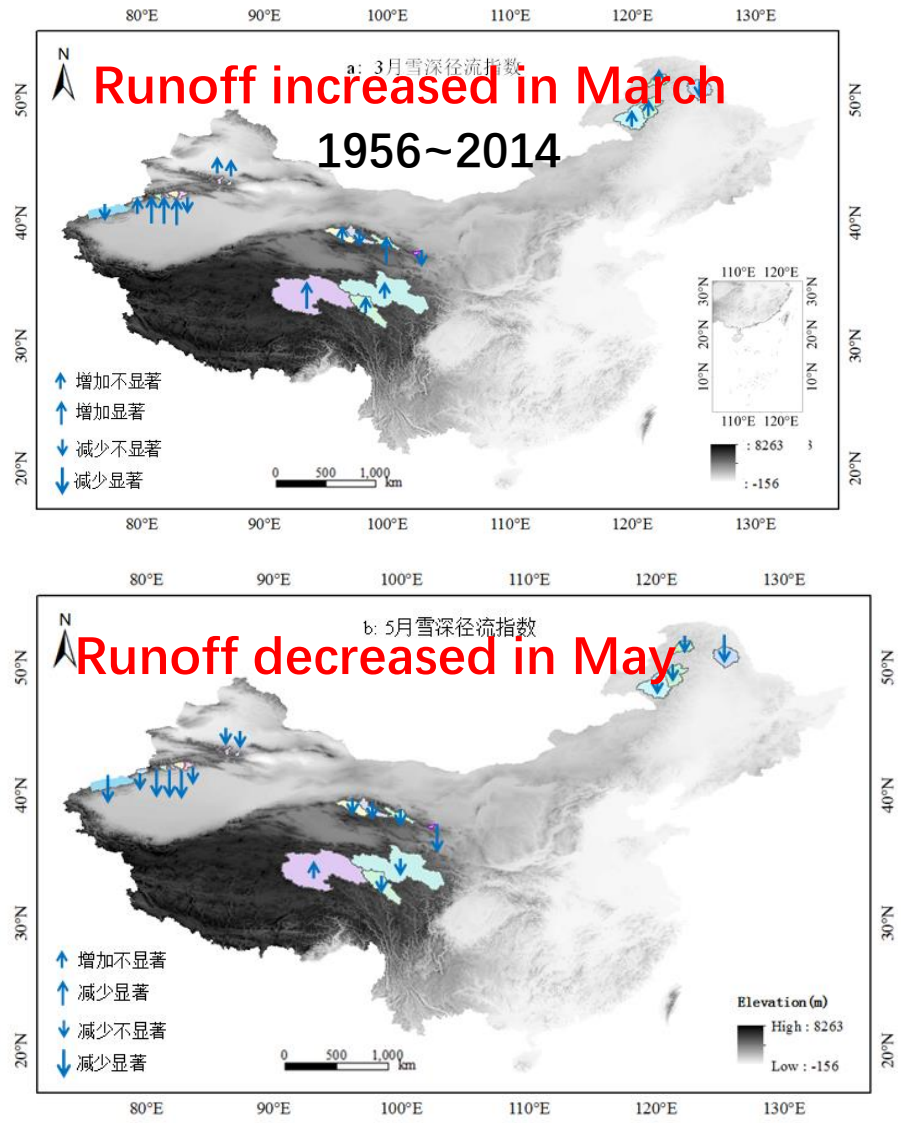
3. Snowmelt

Earlier onset of snowmelt



Variation of annual runoff
at Altai hydrologic station in Kelan River

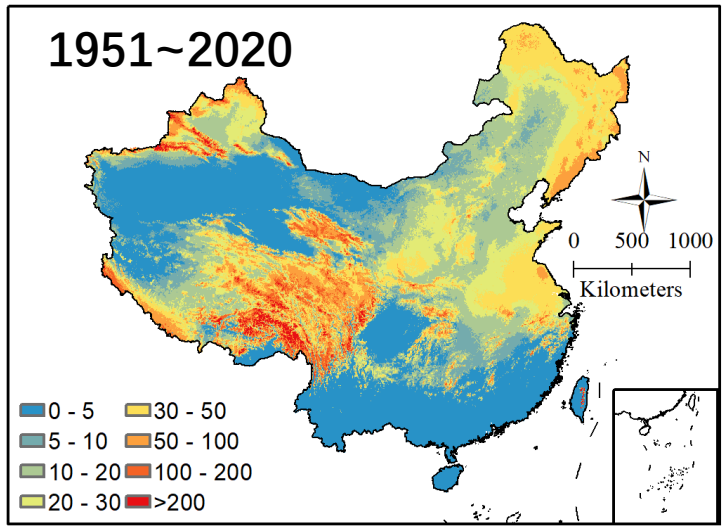
陈仁升等，2019



Liu et al，2019

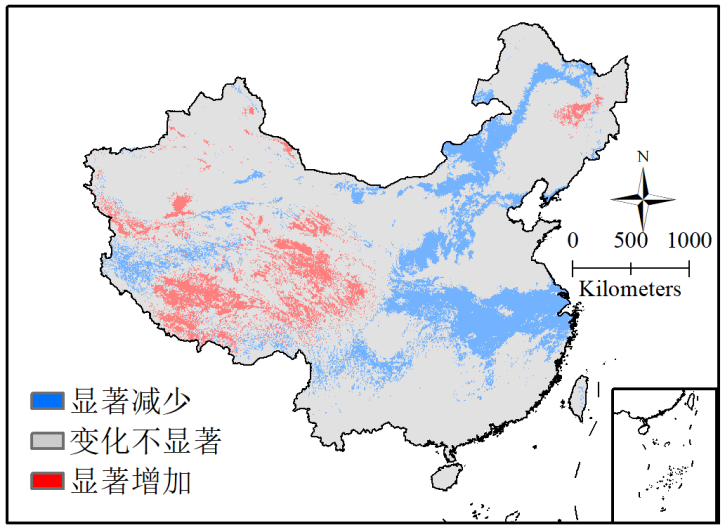
3. Snowmelt

Mean annual snowmelt

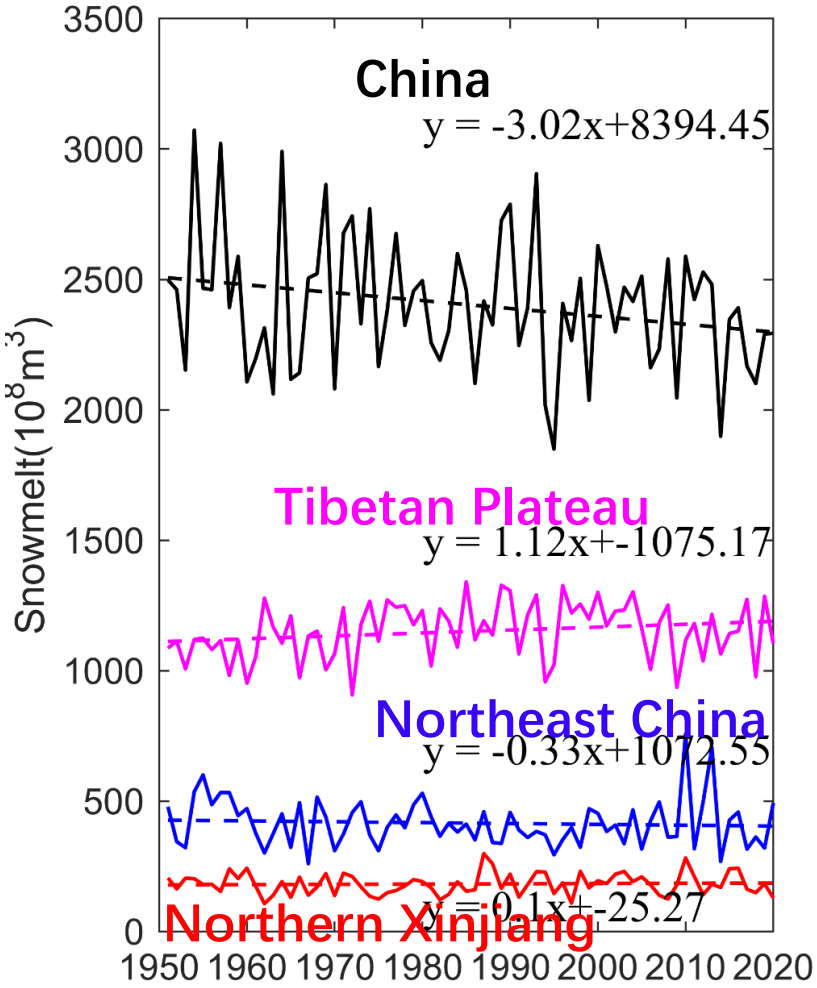


China: 2402 ×10^8 m^3
Northern Xinjiang: 182 ×10^8 m^3
Northeast China: 415 ×10^8 m^3
Tibetan Plateau: 1150 ×10^8 m^3

Change trends



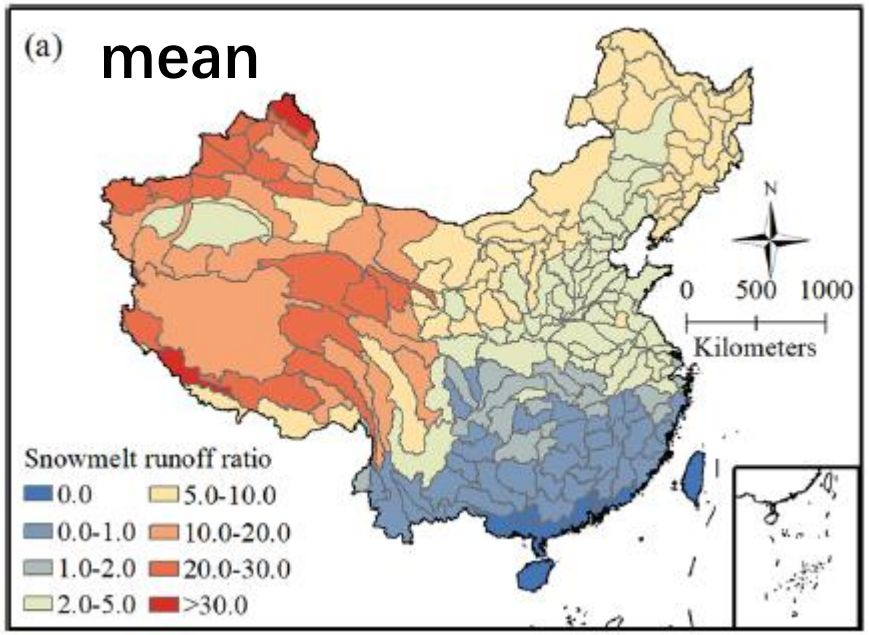
Increased: Tibetan Plateau
Decreased: middle and lower reaches of the Yangtze River, Northeast China……



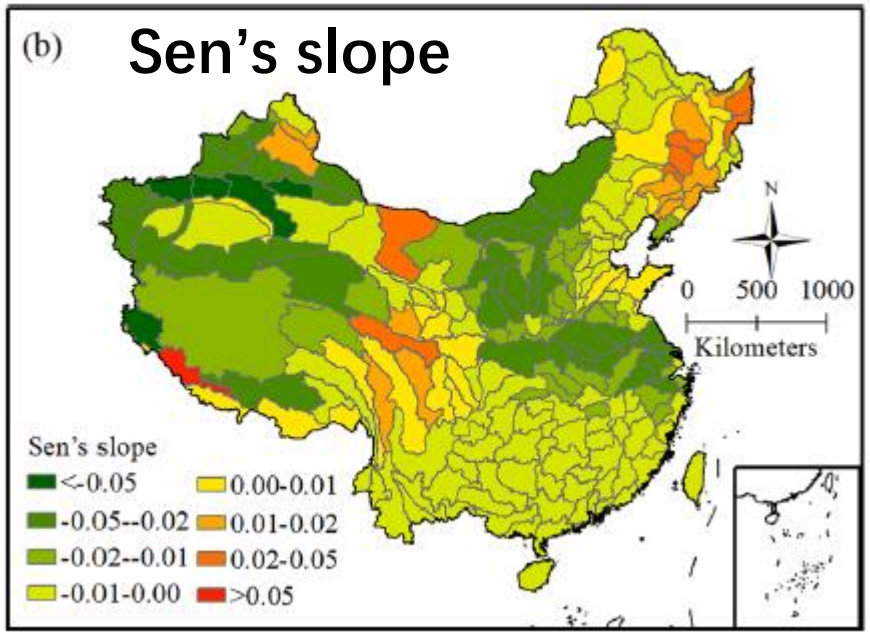
Yang et al，2022

3. Snowmelt

Snowmelt runoff ratio (1951~2017)



West China: >10%
North and Northeast China: >5%
South China: <2%



Decreased in most basins
Increased mainly distributed in the southeastern part of the Tibetan Plateau, the Heihe River, the Gurbantünggüt Desert, the Songhua River basin

Yang et al，2022

3. Snowmelt

Projected future changes in snowmelt (2006~2099)

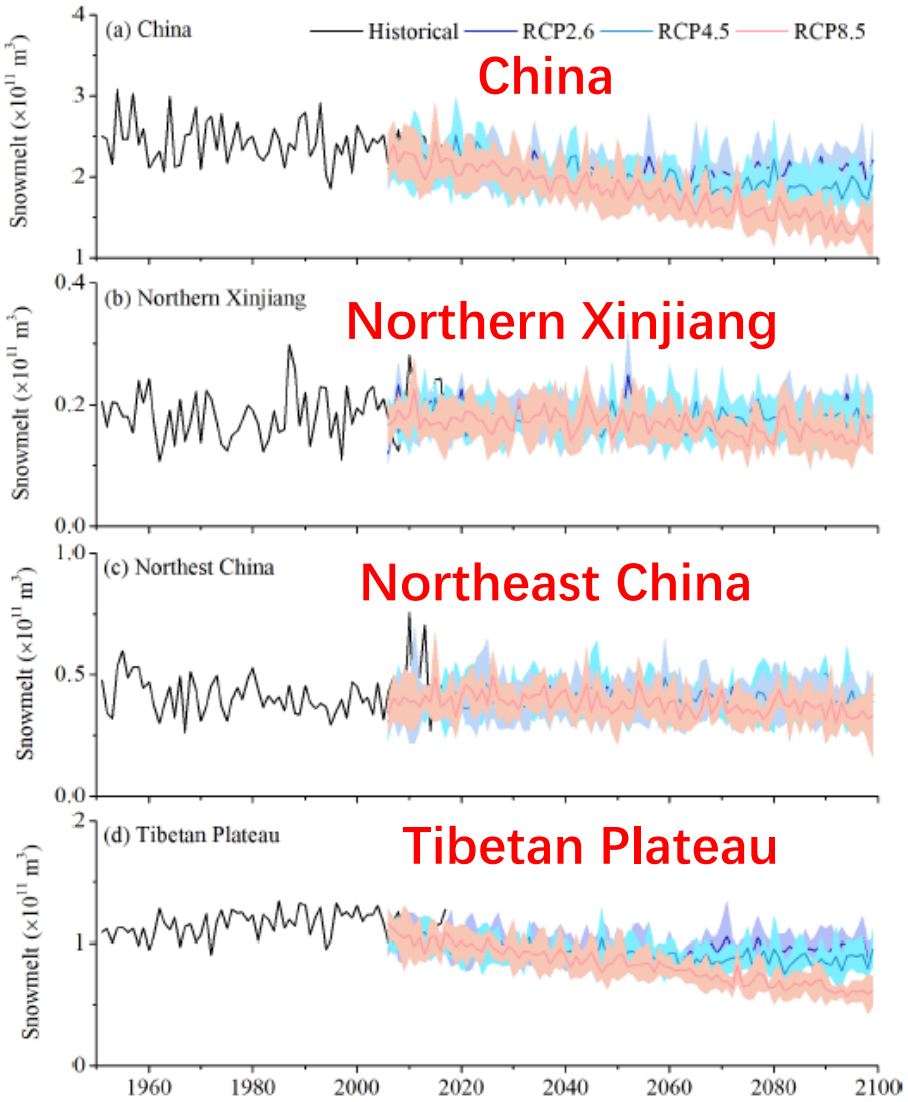
China, Tibetan Plateau

RCPs: significant decreasing trends

Northern Xinjiang, Northeast China

RCP8.5: significant decreasing trends

RCP2.6/4.5: no significant changes



Yang et al，2022

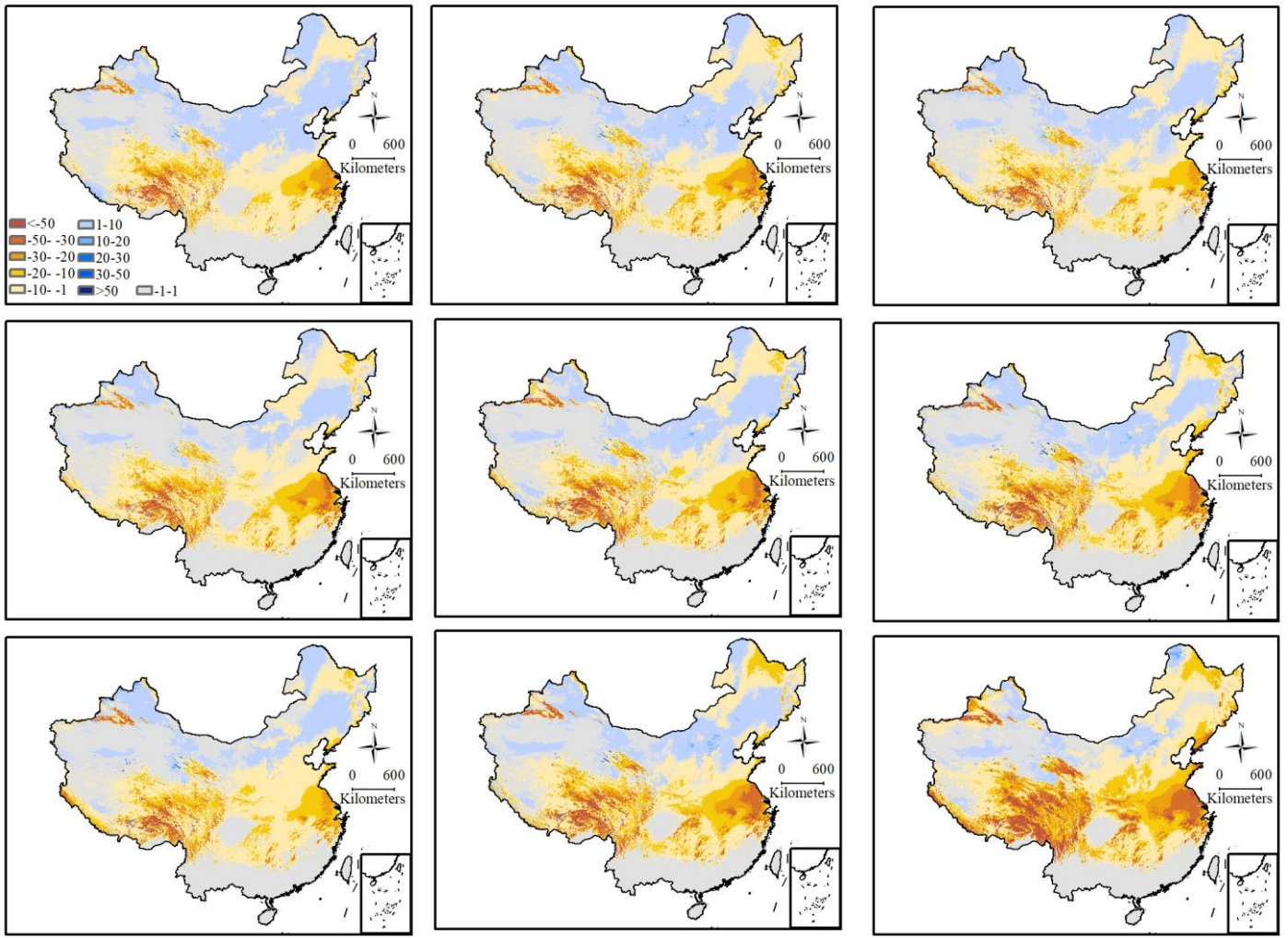
3. Snowmelt

Differences between the projected mean annual snowmelt and the reference period (1981-2010)

RCP2.6

RCP4.5

RCP8.5



2030s 2050s 2090s

- Northwest: increase in low-elevation arid areas and decrease in the higher elevation Tianshan and Altai Mountains
- Northeast: increase in the Greater Khingan Range and the Songliao Plain and decrease in the Lesser Khingan and Changbai mountains
- Tibetan Plateau/ Southeast China: large decrease

Yang et al，2022

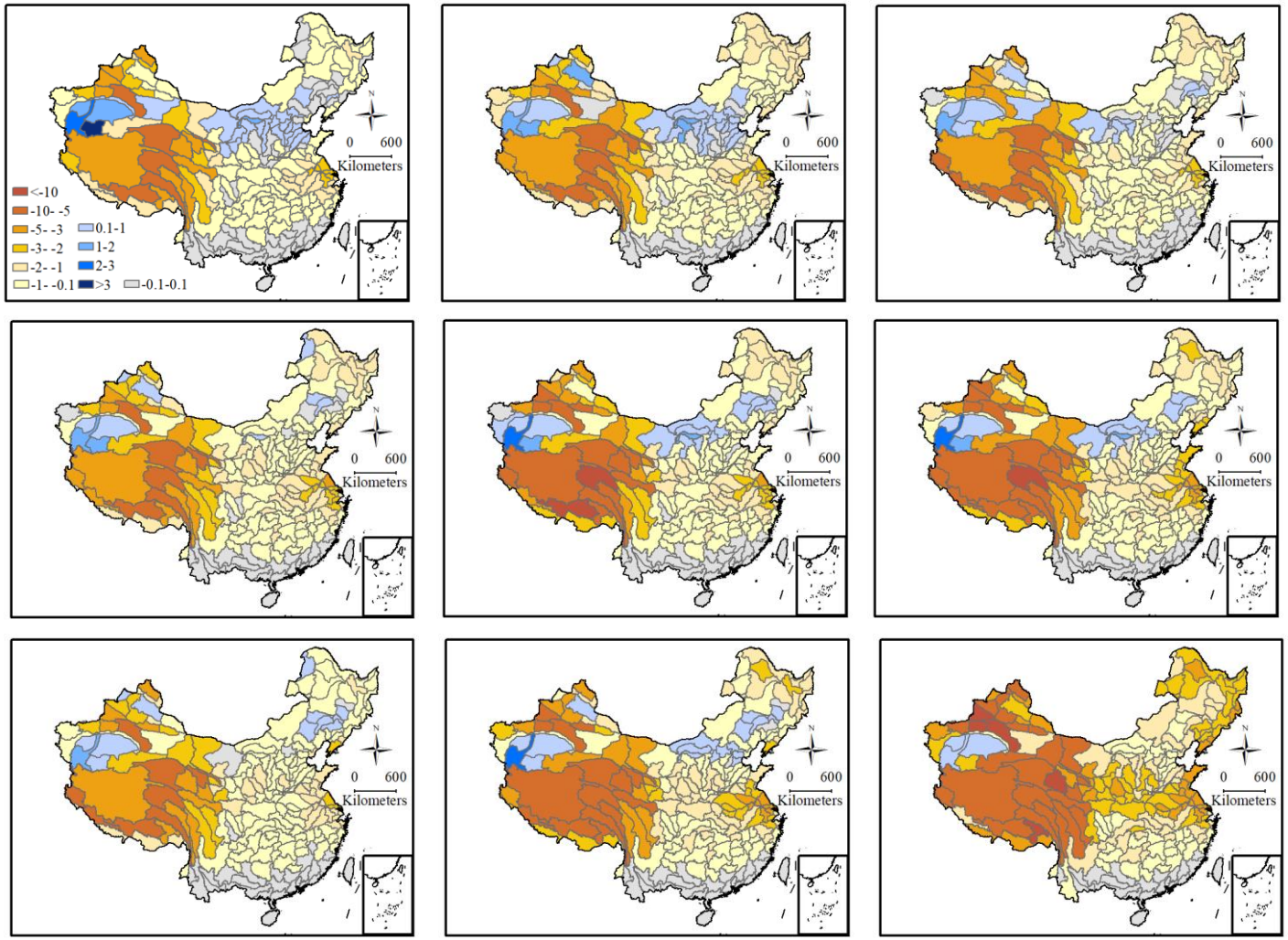
3. Snowmelt

Differences between the projected snowmelt runoff ratio and the reference period (1981-2010)

RCP2.6

RCP4.5

RCP8.5



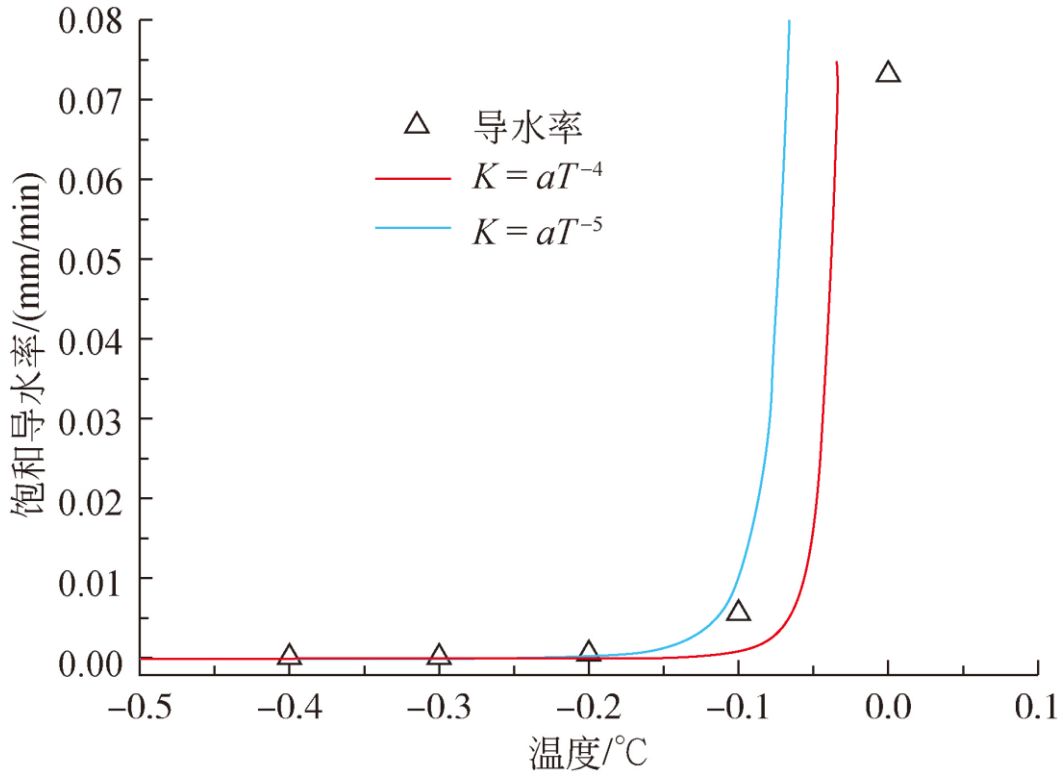
2030s 2050s 2090s

- The projected snowmelt runoff ratios are mostly smaller, except for a few basins in Xinjiang and North China
- The largest decreases are projected under RCP8.5, followed by RCP4.5, RCP2.6.
- Under RCP8.5, the snowmelt runoff ratios in the Tibetan Plateau and Tianshan Mountains are projected to decrease by more than 5% in most basins and by more than 10% in a few basins in the far-future.

Yang et al，2022

4. Hydrologic effects of permafrost degradation

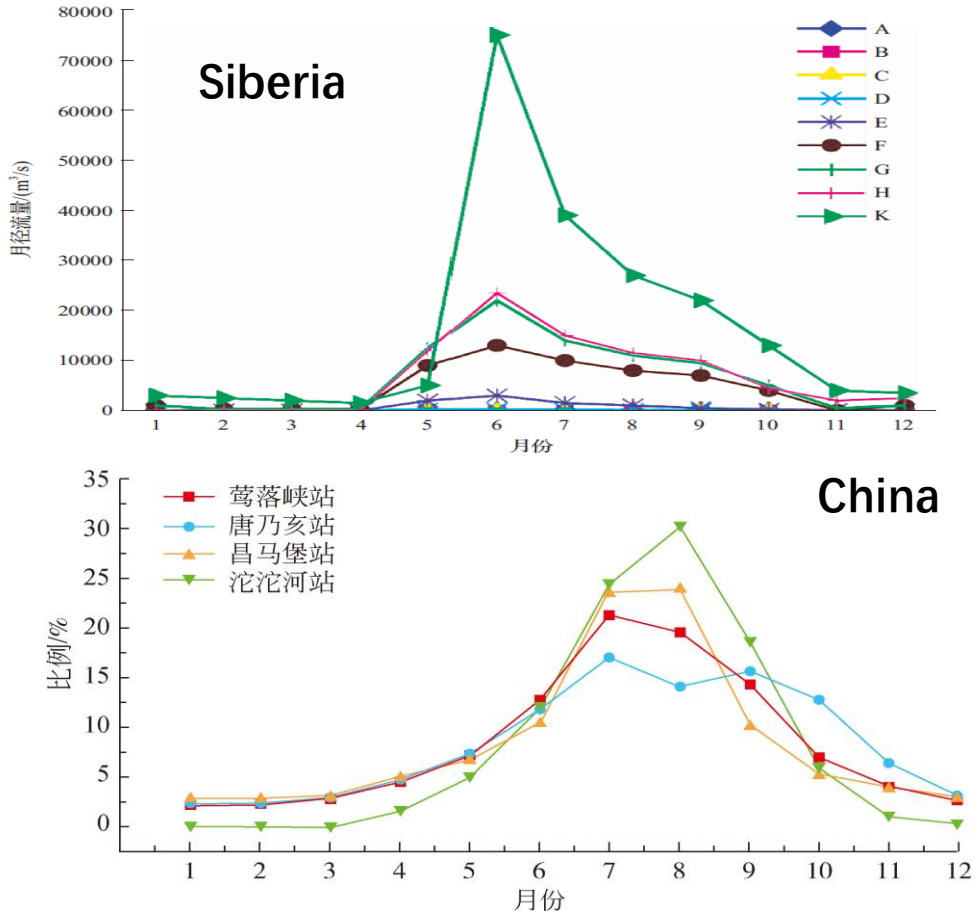
Limited permeability



Hydraulic conductivity of frozen soil is much lower than that of melted soil

陈仁升等，2019

Monthly hydrograph~Percentage of permafrost in basins

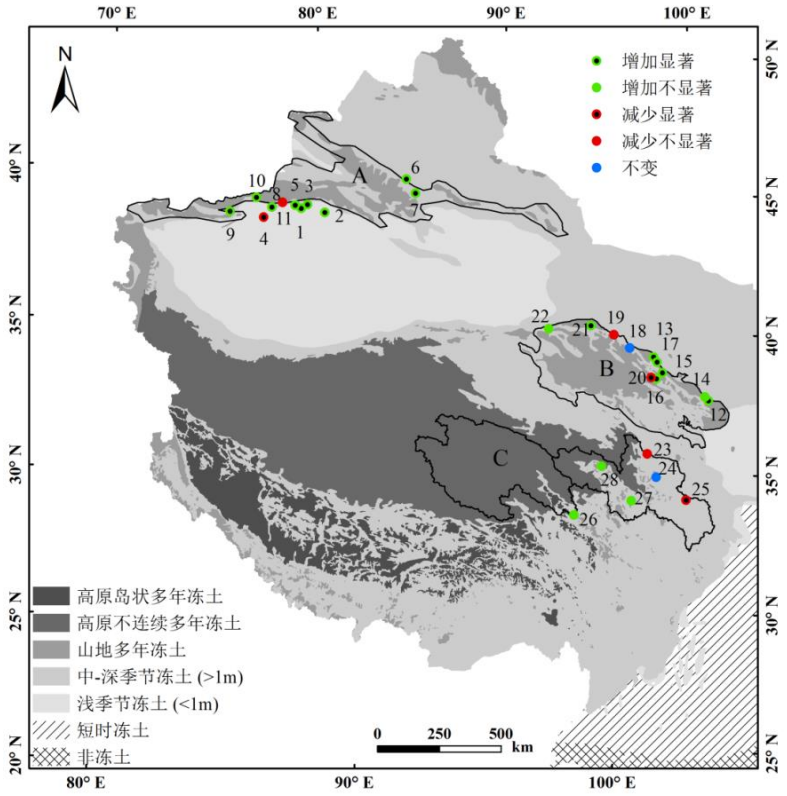


More permafrost/basin area
Larger Maximum/Minimum runoff

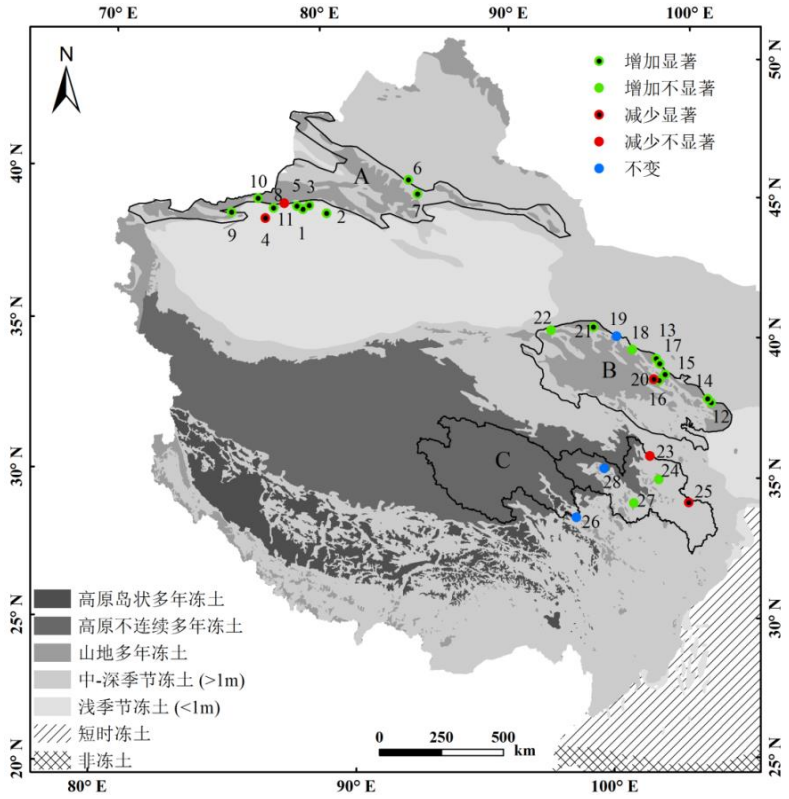
丁永建等，2017

4. Hydrologic effects of permafrost degradation

Change trends in winter discharge



Change trends in minimum monthly discharge



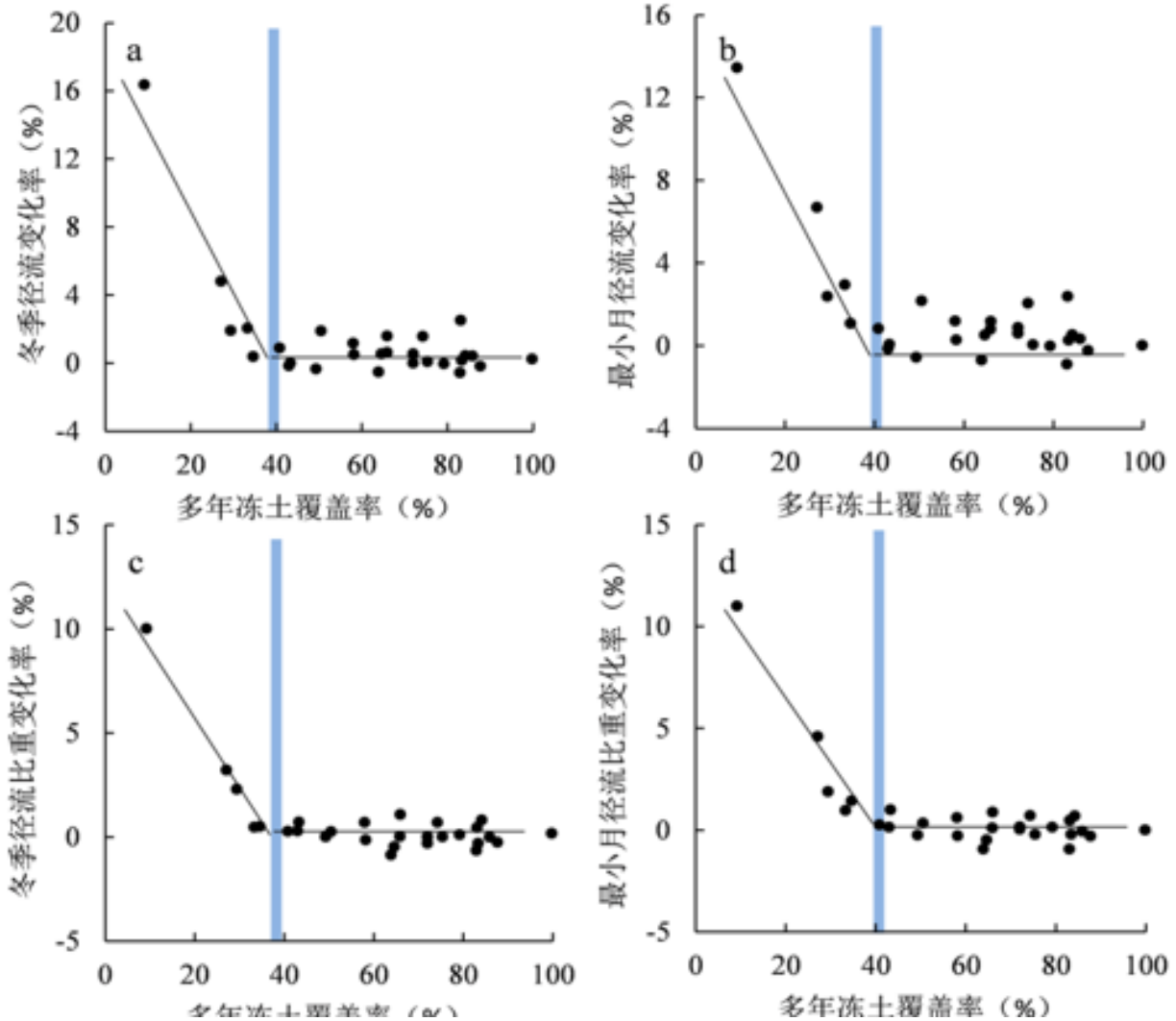
Thawing permafrost

Increase of infiltration and percolation

Increased winter discharge

Wang et al.，2018

4. Hydrologic effects of permafrost degradation



Threshold：40%

Permafrost coverage >40% :

Hydrological regime stable

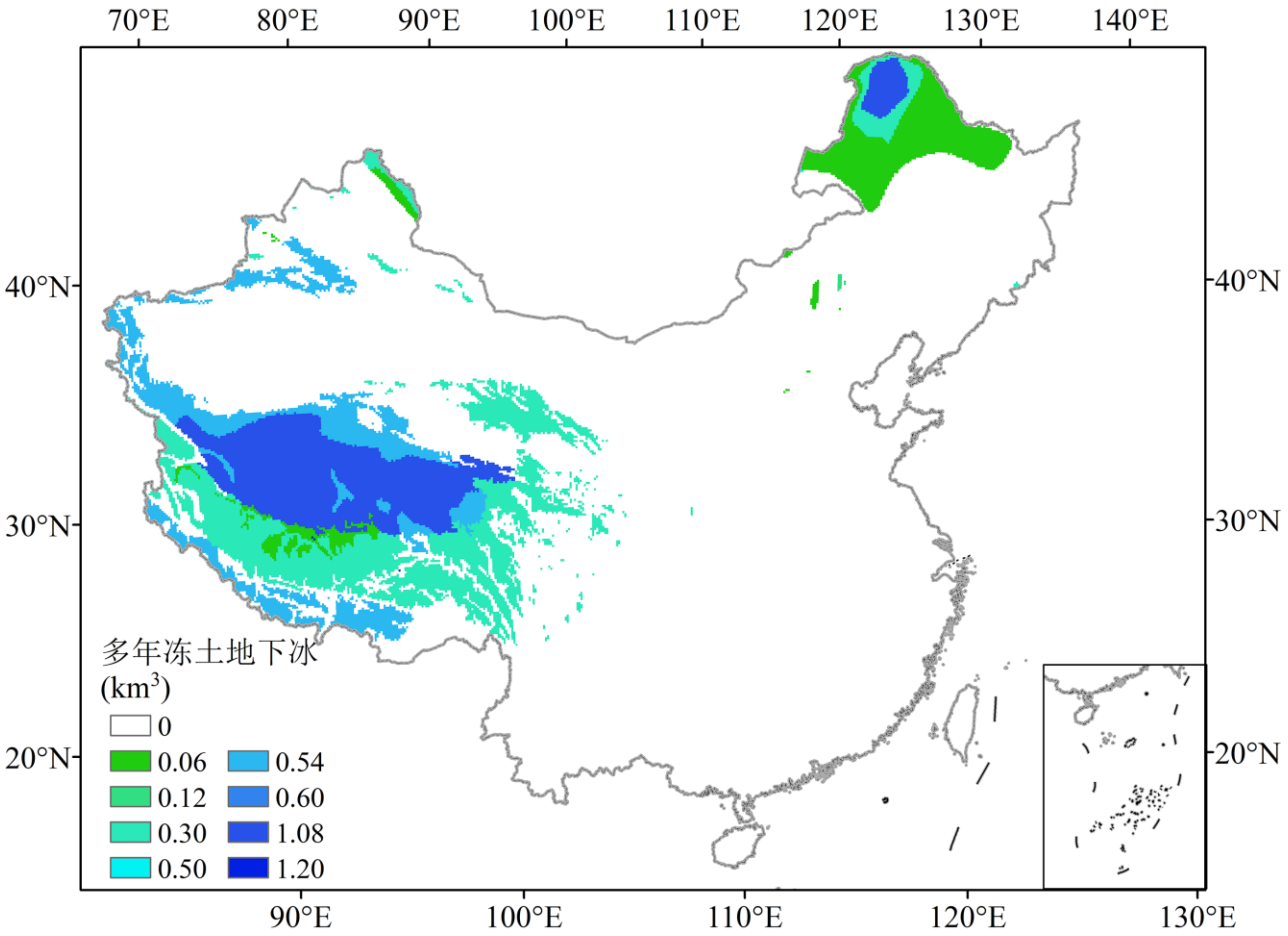
Permafrost coverage <40% :

Hydrological regime changed significantly

Wang et al.，2018

4. Hydrologic effects of permafrost degradation

Underground ice in permafrost regions



Total volume

China: 10820 km^3

Tibetan Plateau: 9492 km^3

Tianshan/Xinjiang: 515 km^3

Northeast China: 777 km^3

Meltwater from permafrost

5.5 cm/a

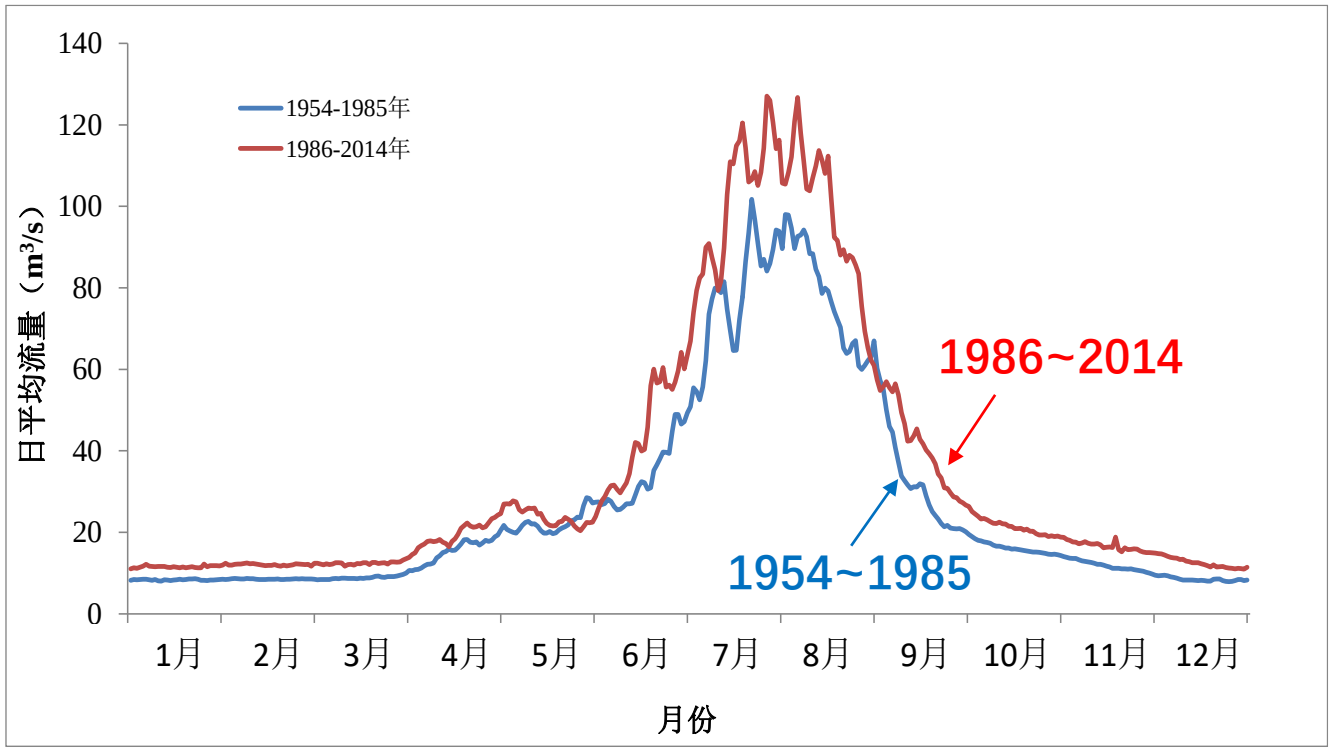
99×10^8 m^3 per year

Li et al.，2022

5. Comprehensive impacts on water resources

1) Basinal scale: hydrological observation in Shule River

The difference in annual precipitation is only 10mm



Glaciers shrinking: increased summer runoff

Change of snowmelt: advanced spring flood peak; shortened snowmelt period

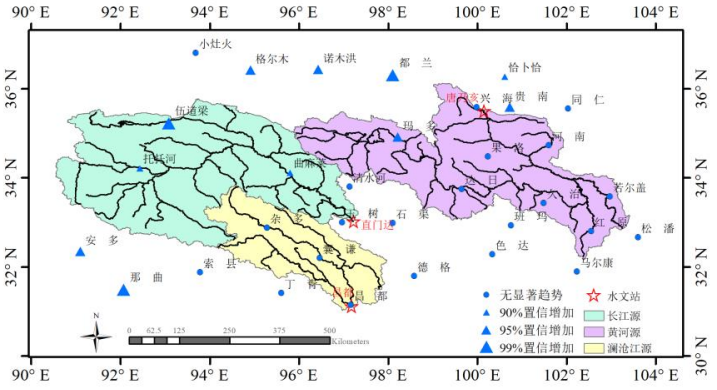
Permafrost degradation: increased winter runoff

陈仁升等，2019

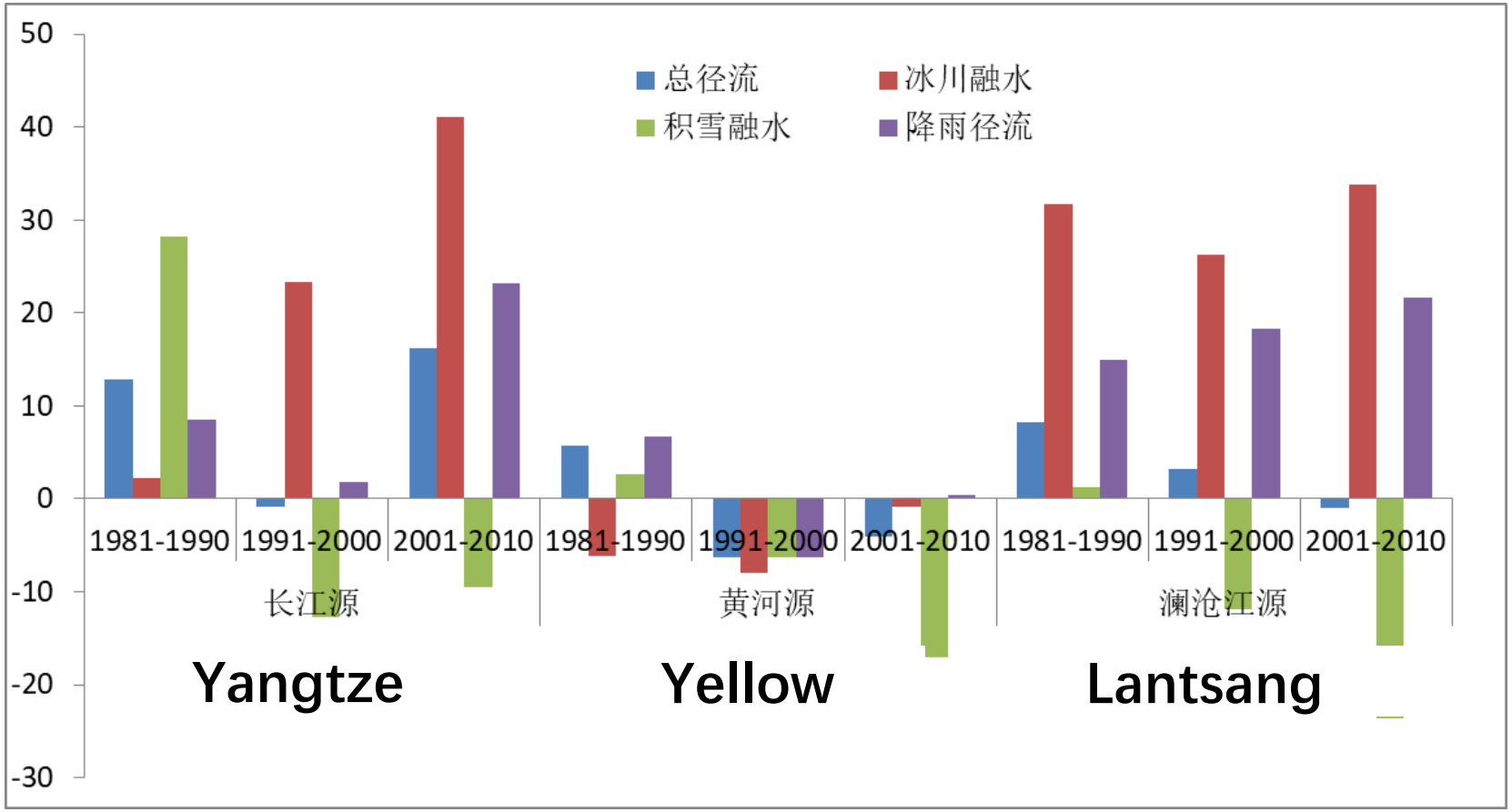
5. Comprehensive impacts on water resources

2) Regional scale

Three-River Headwaters Region



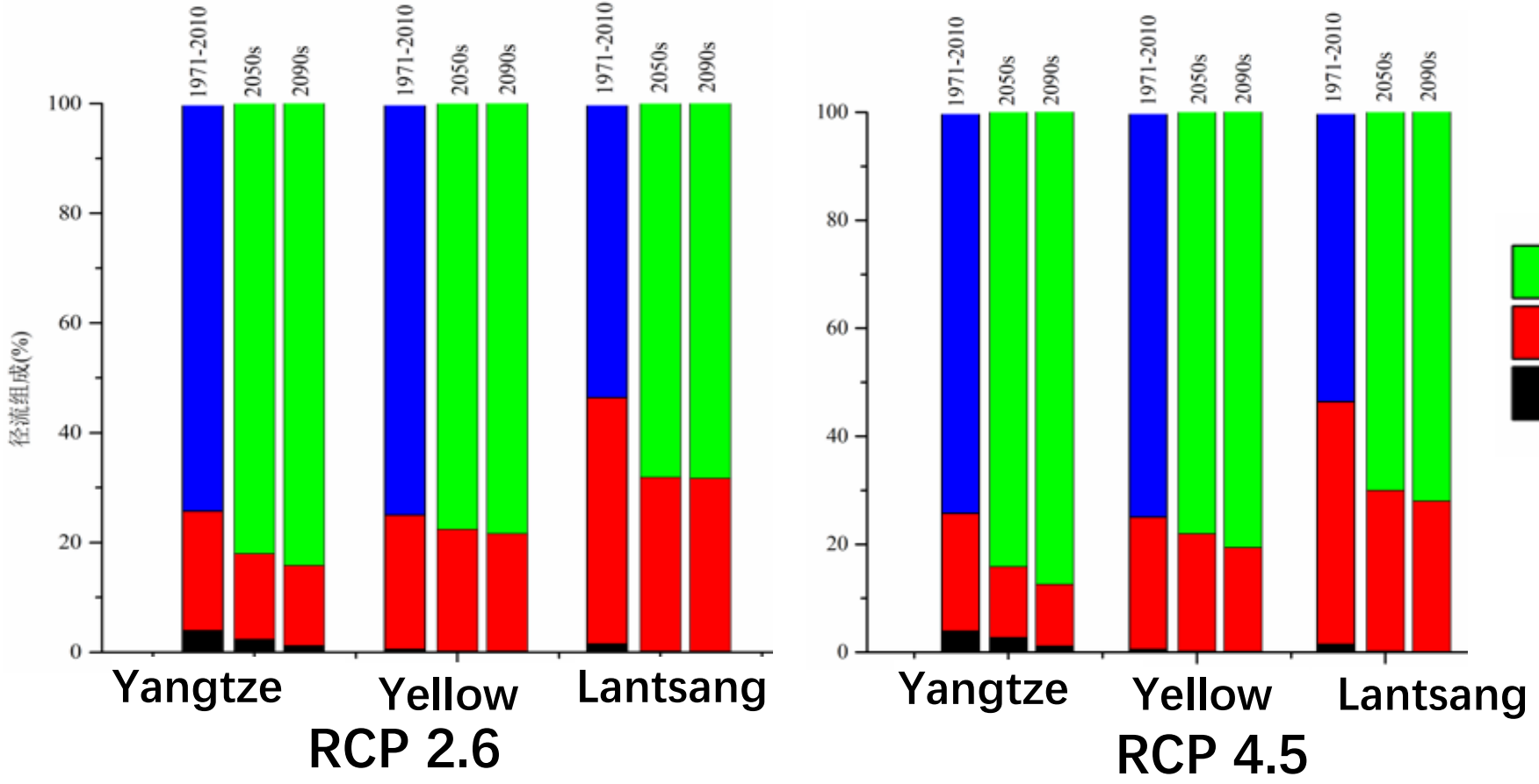
Interdecadal variation of total runoff, glacial melt, snowmelt and rainfall runoff: relative to 1970s (%)



- Glacier melt increased, except for the Yellow River
- Snowmelt decreased

5. Comprehensive impacts on water resources

2) Region scale: projected runoff component

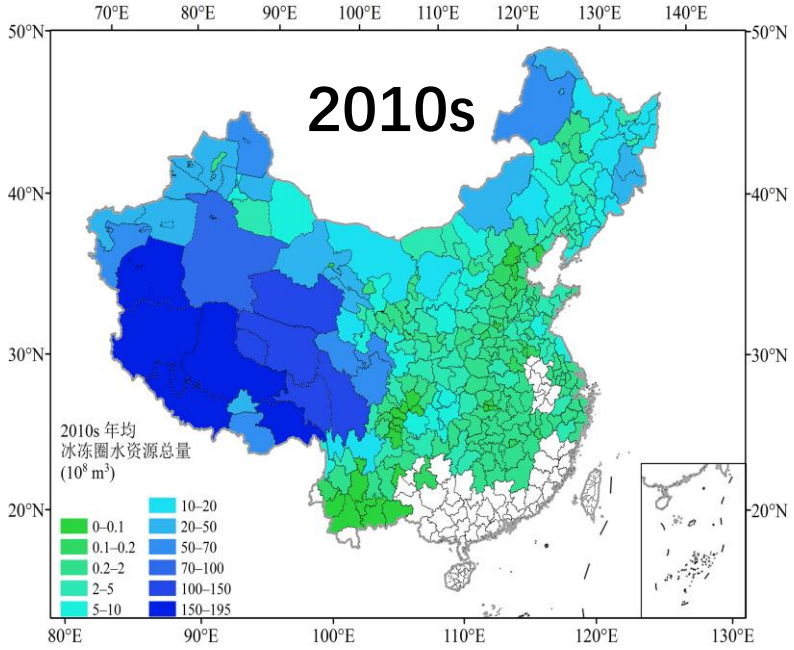


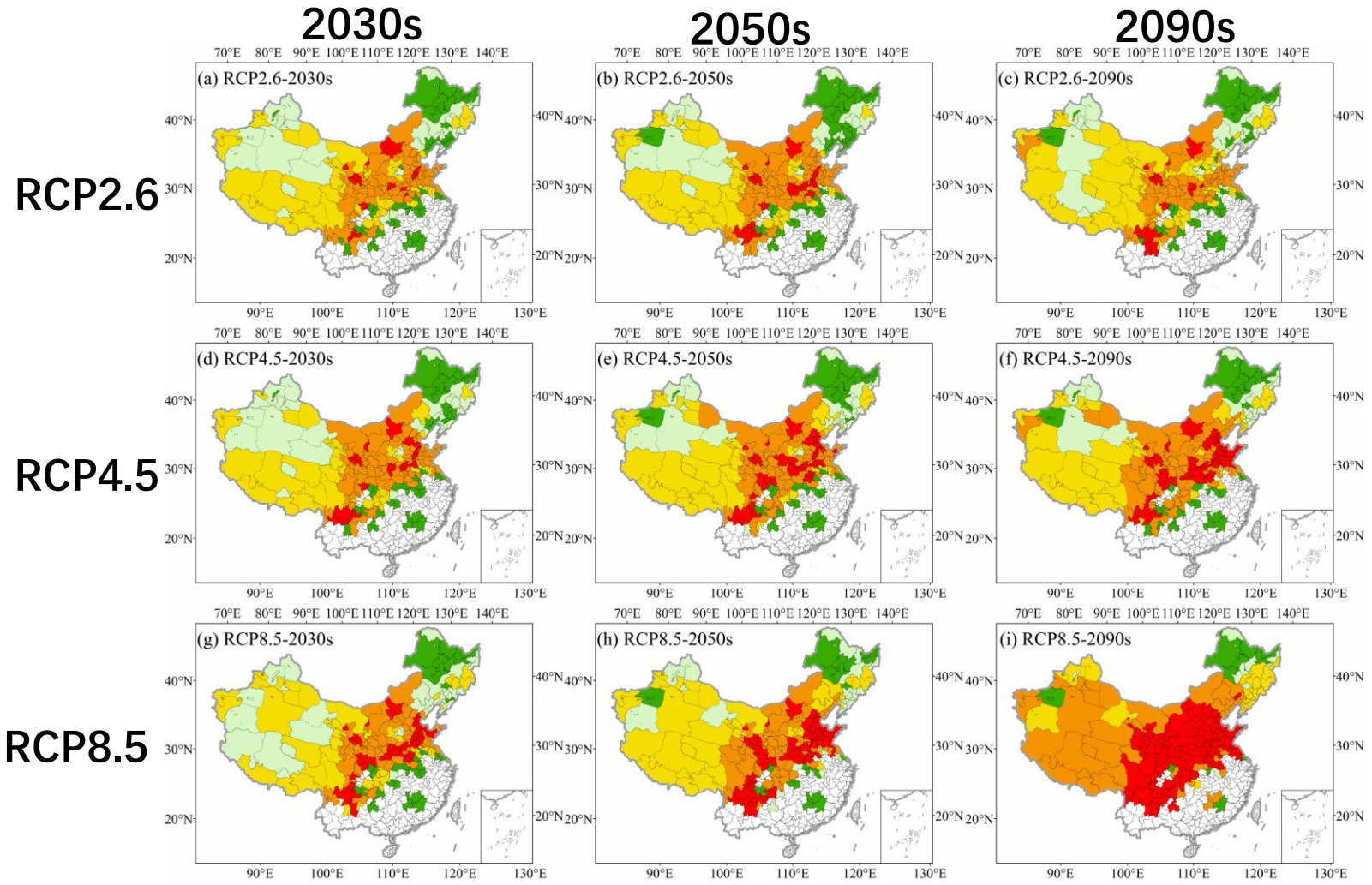
Glacier melt decreased, snowmelt decreased

5. Comprehensive impacts on water resources

3) National scale

Cryosphere water resources





Potential loss zone (−100% – −80%)
Rapid decline zone (−80% – −50%)
Medium speed weakening zone (−50% – −20%)
Relatively stable zone (−20% – +20%)
Significantly enhanced zone (> +20%)

Li et al.，2022

Thanks for your attention!