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TPCF-3 and TPRCC-Network Task Team

Increasing disaster risks over High Mountain Asia under warming climate

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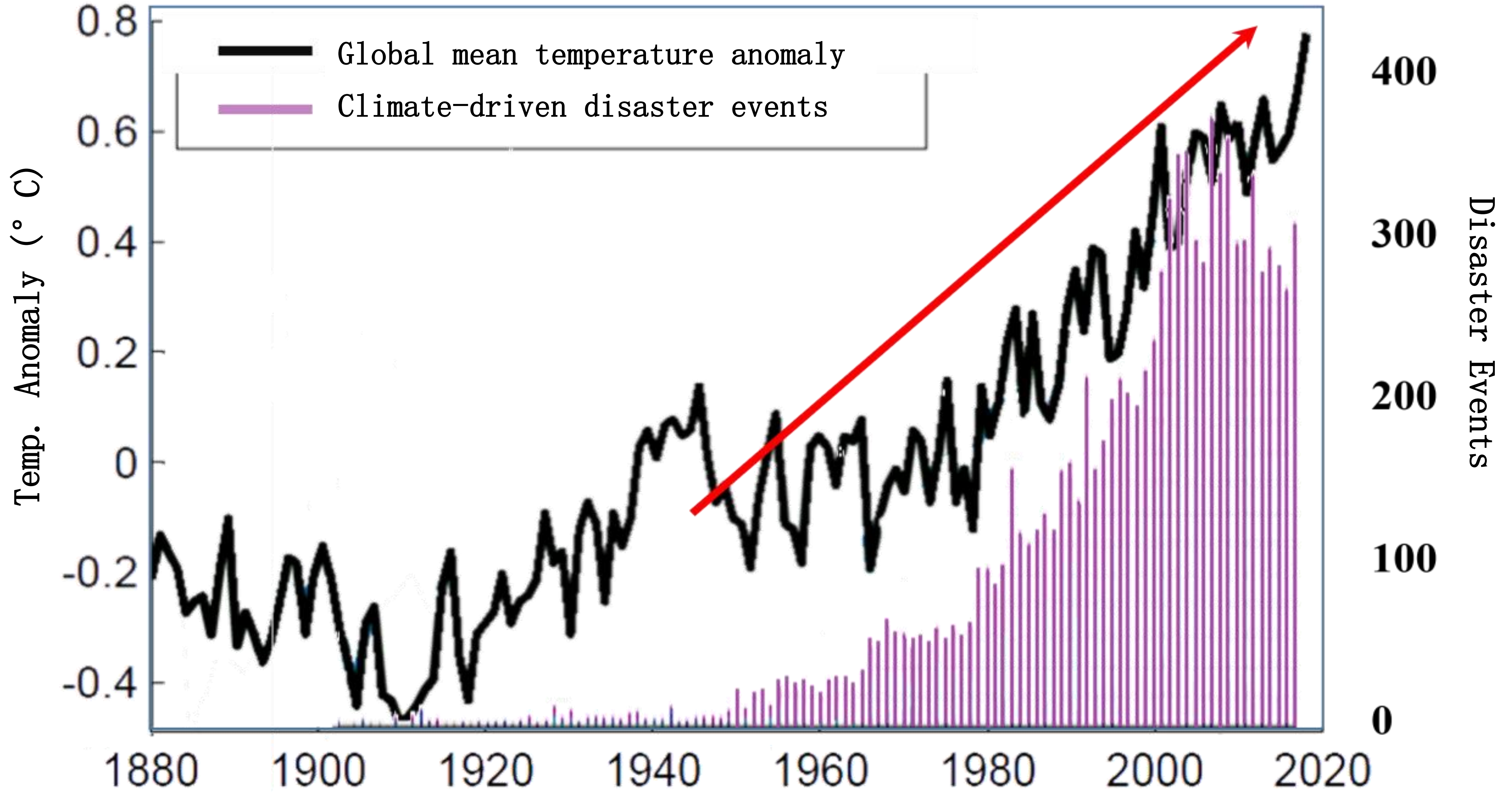
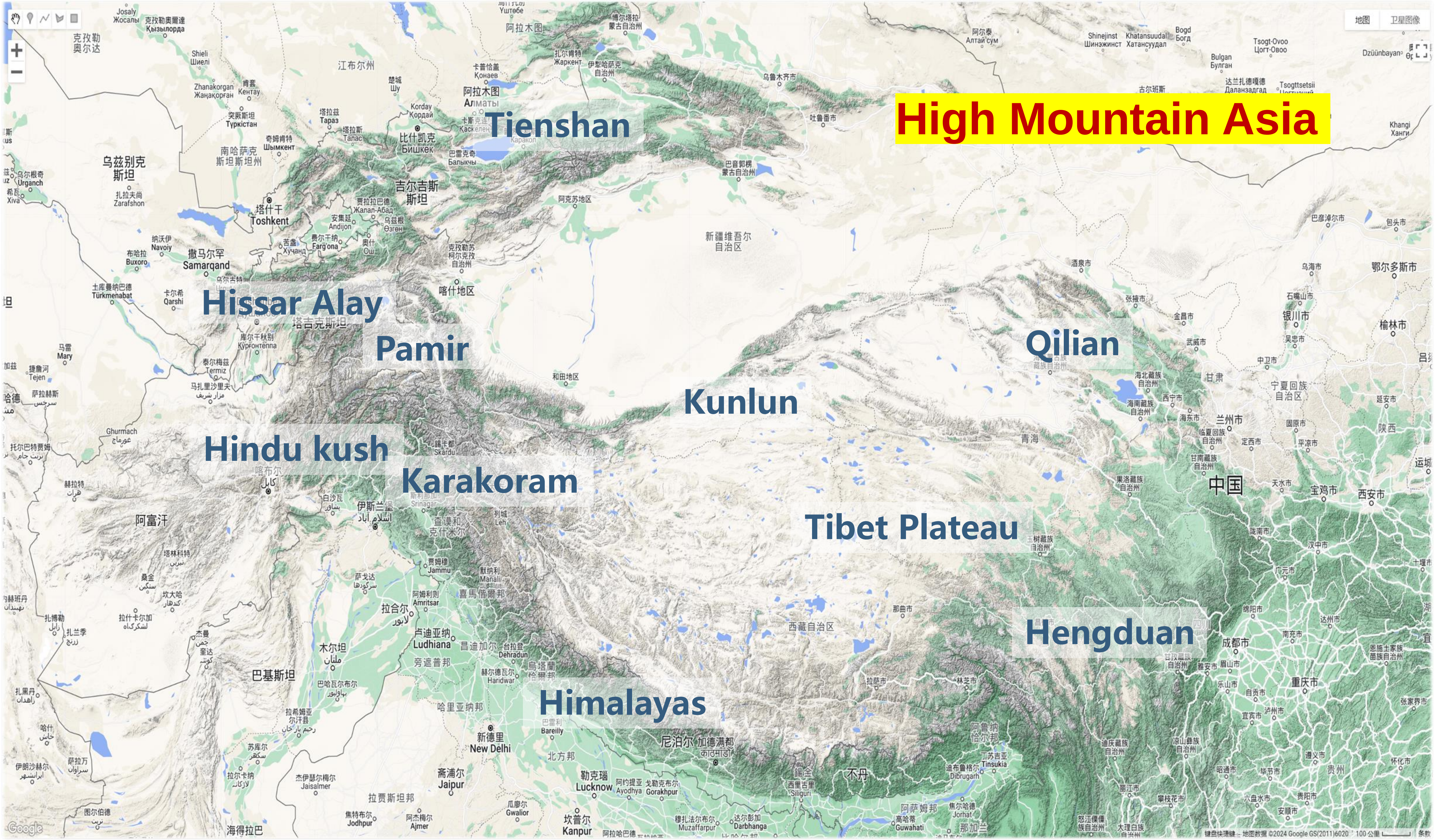
ESPDRR

Outline

- Climate change over High Mountain Asia (HMA)
- Increasing floods risk over HMA
- Cryospheric tipping point and impacts

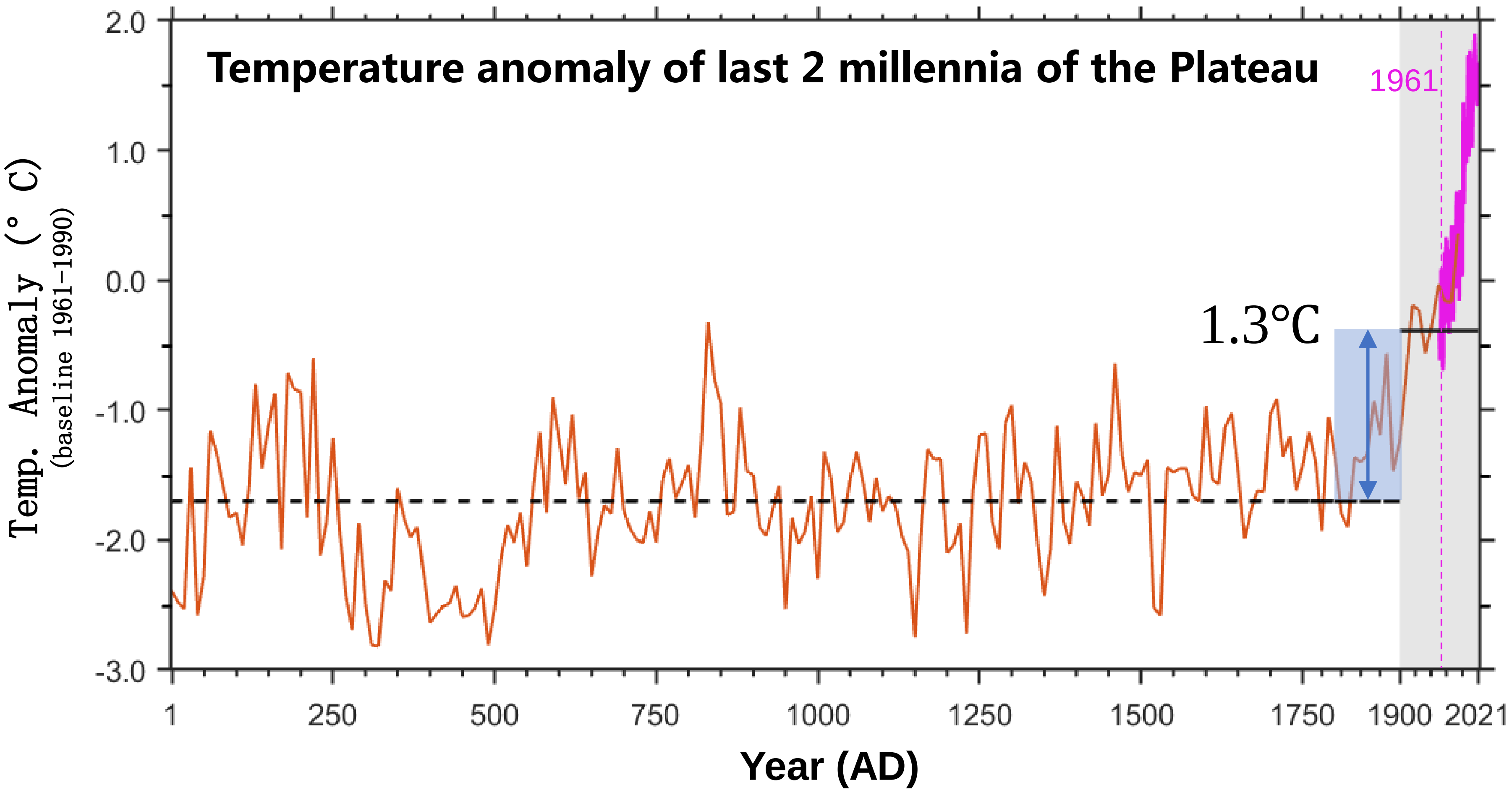


(H. Wang, Personal Comm)


High Mountain Asia
Tienshan
Hissar Alay
Pamir
Kunlun
Qilian
Hindu kush
Karakoram
Tibet Plateau
Hengduan
Himalayas

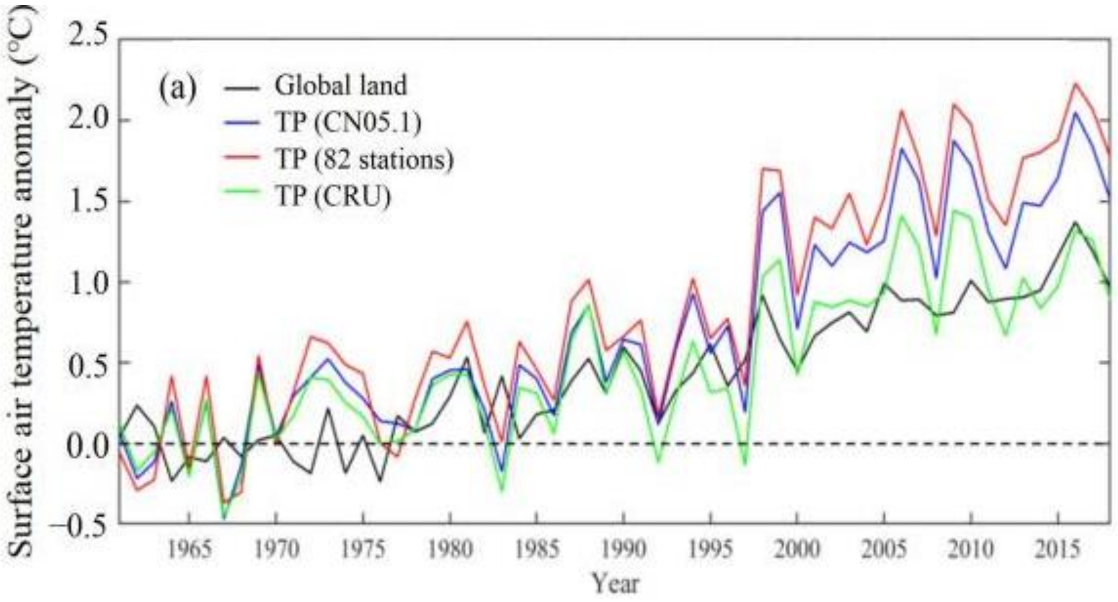
Temperature change

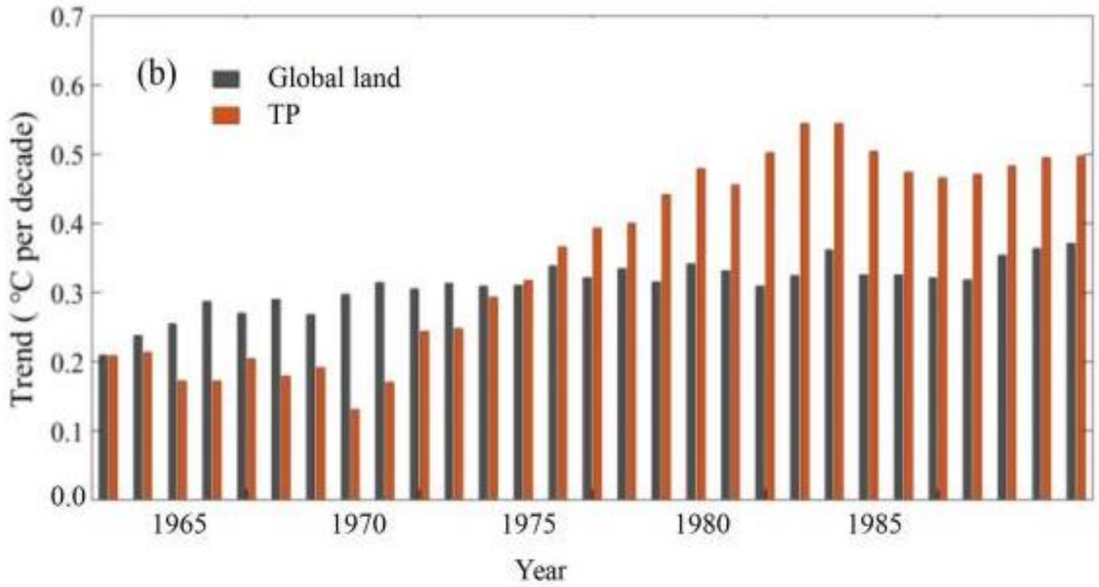
The warming rate over HMA since 1961 is unprecedentedly high



(After Yao et al., 2019)

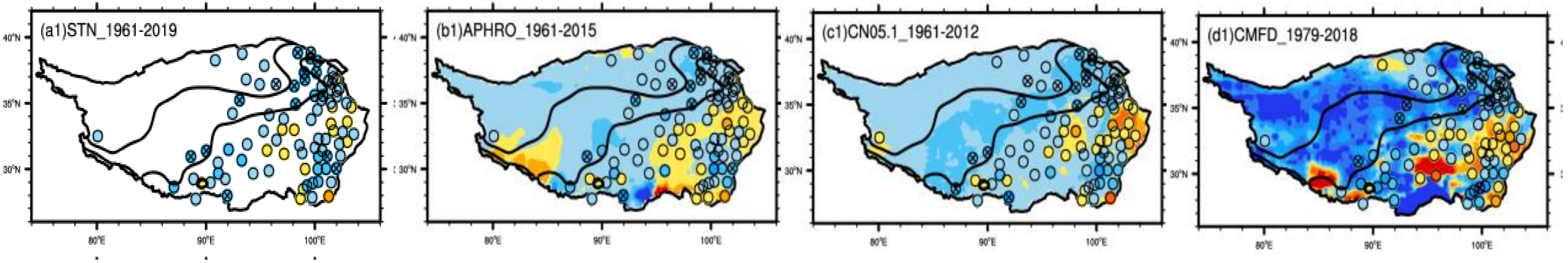
Amplified warming



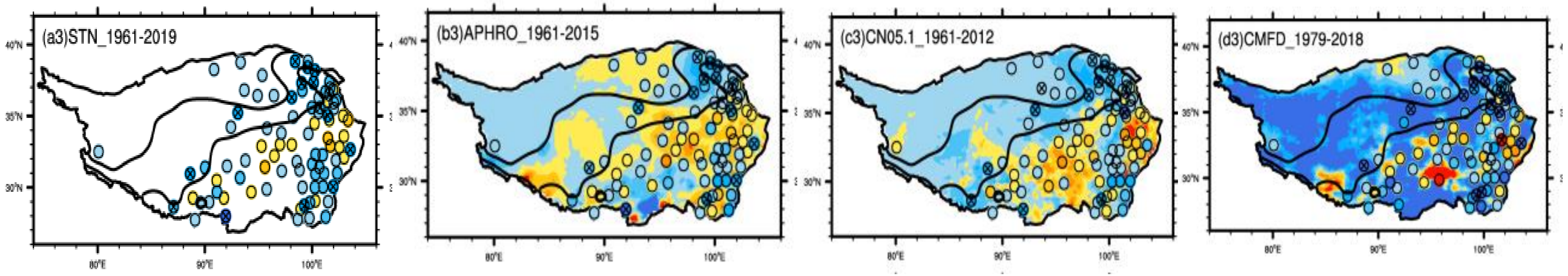


Based on observational data, multiple sets of reanalysis data have revealed the **amplified warming** effect over the Tibetan Plateau(TP), compared with global land

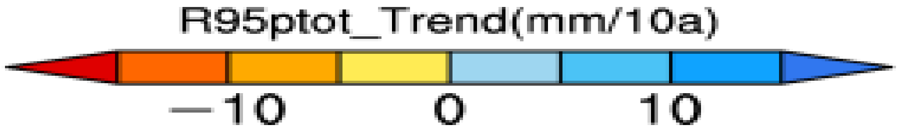
increased wetting



Total precipitation



Extreme precipitation



（Luan and Zhai, ACCR, 2022）

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Introduction

- **Compile an inventory of historical flood events in HMA.**
- **Analyze their distribution, trends, drivers, and impacts.**
- **Provide an important scientific basis for further evaluating and mitigating flood risks.**

Floods inventory

STEP 1

Flood events data collection

- Public databases,
- Yearbooks,
- Media reports,
- Literature.

Analyze data

STEP 2

Spatiotemporal distribution analysis

- Spatial and seasonal distribution analysis,
- Trend analysis using Bayesian regression.

STEP 3

Driver and impact analysis

- Driver identification using machine learning,
- Conceptual driver mapping,
- Impact analysis.

Runoff and Climatic-Environmental Factors

Propose adaptive measures.

Flood types

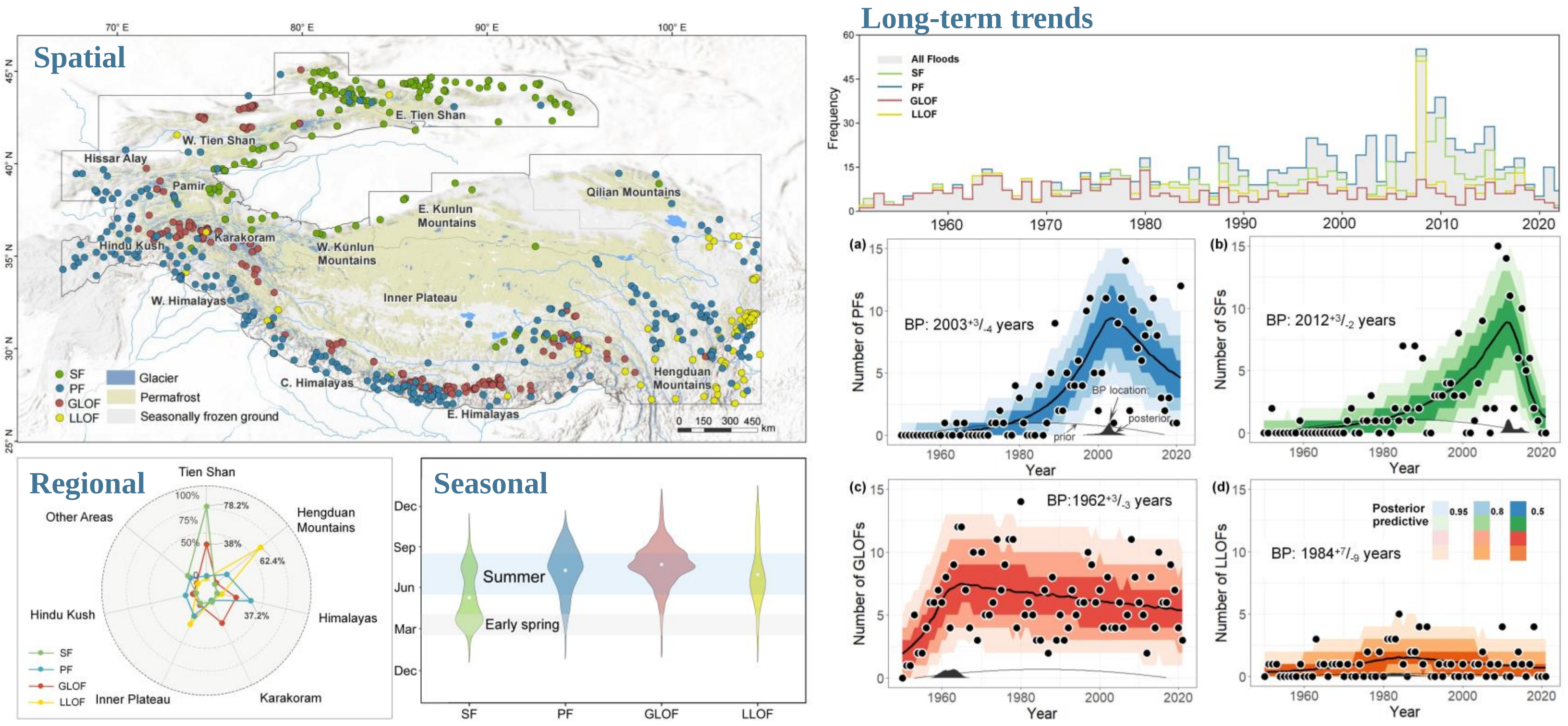
① Pluvial floods (PFs), ② Snowmelt floods (SFs)

③ Glacial lake outburst floods (GLOFs), ④ Landslide-dammed lake outburst floods (LLOFs)

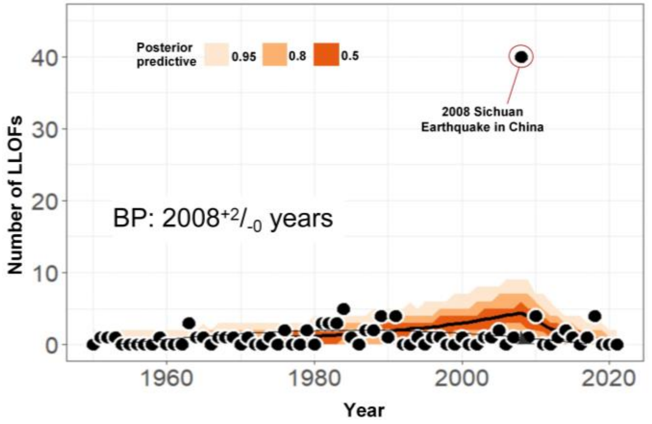
Observations

- Flood frequency exhibits complex, nonlinear trends and distinct spatial and seasonal patterns.

Historical Flood Events in High Mountain Asia (1950-2023)



Total: 1015 events

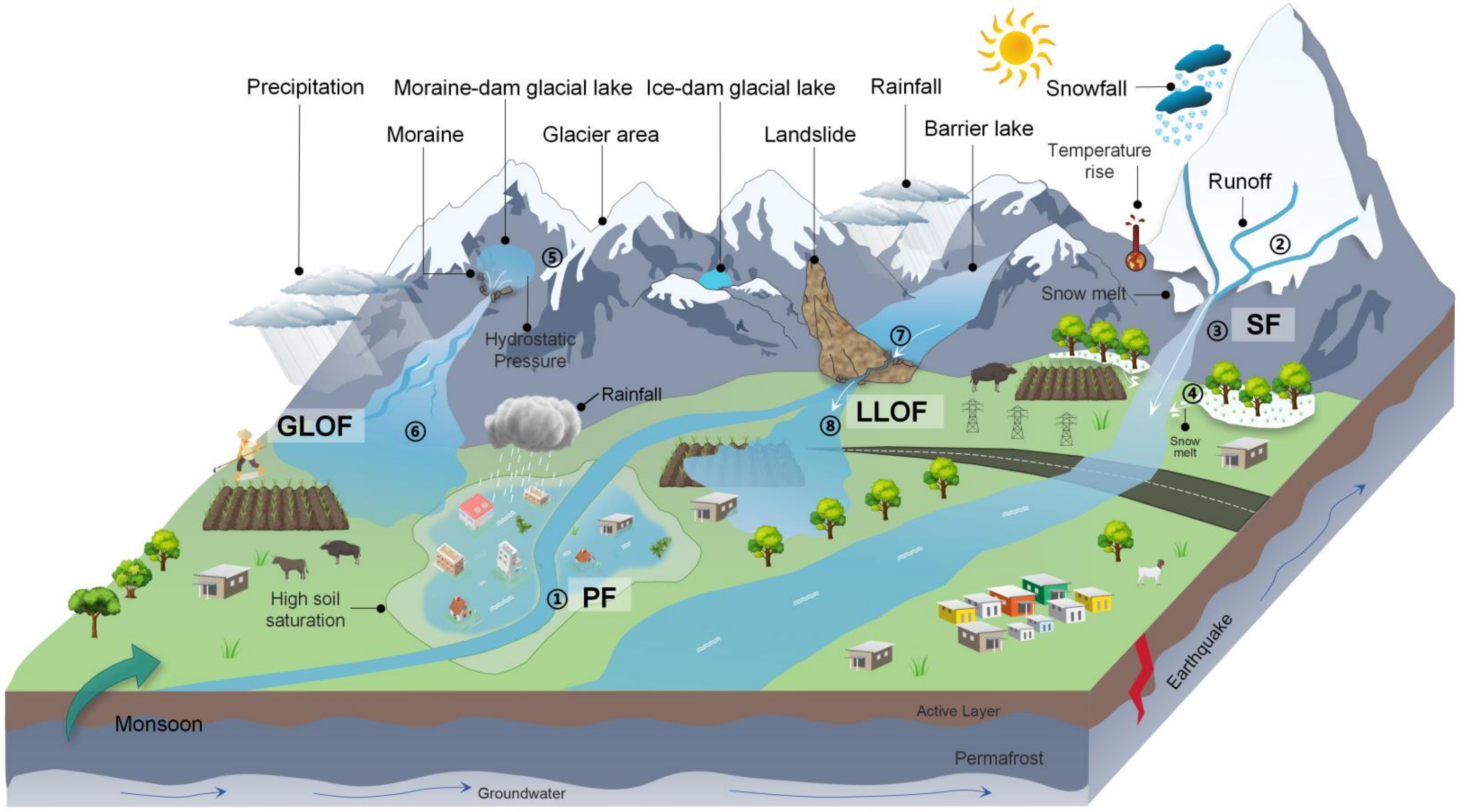


PFs: 261 events; summer; southern. **SFs:** 220 events, early spring & Summer, north-western.

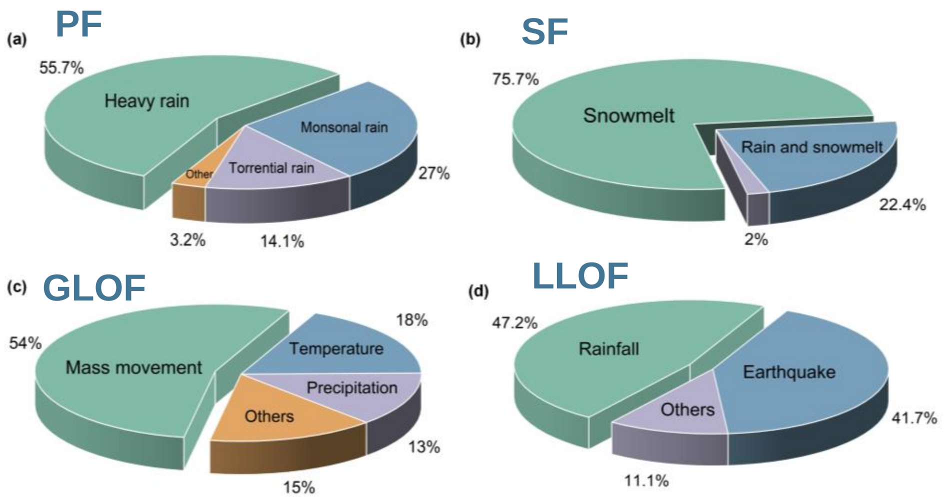
GLOFs: 427 events, summer, northern & southern. **LLOFs:** 107 events, southeastern.

Drives

- The mechanisms driving different types of flood events vary, yet all are impacted by the combined effects of climatic conditions and geographical environments.



Driving factors of floods in in High Mountain Asia. Schematic diagram of the mechanisms of four types of flood formation, where gradient blue indicates the flood inundation extent, and white arrows show the direction of water flow.



Classification of different types of floods in HMA.

Drives

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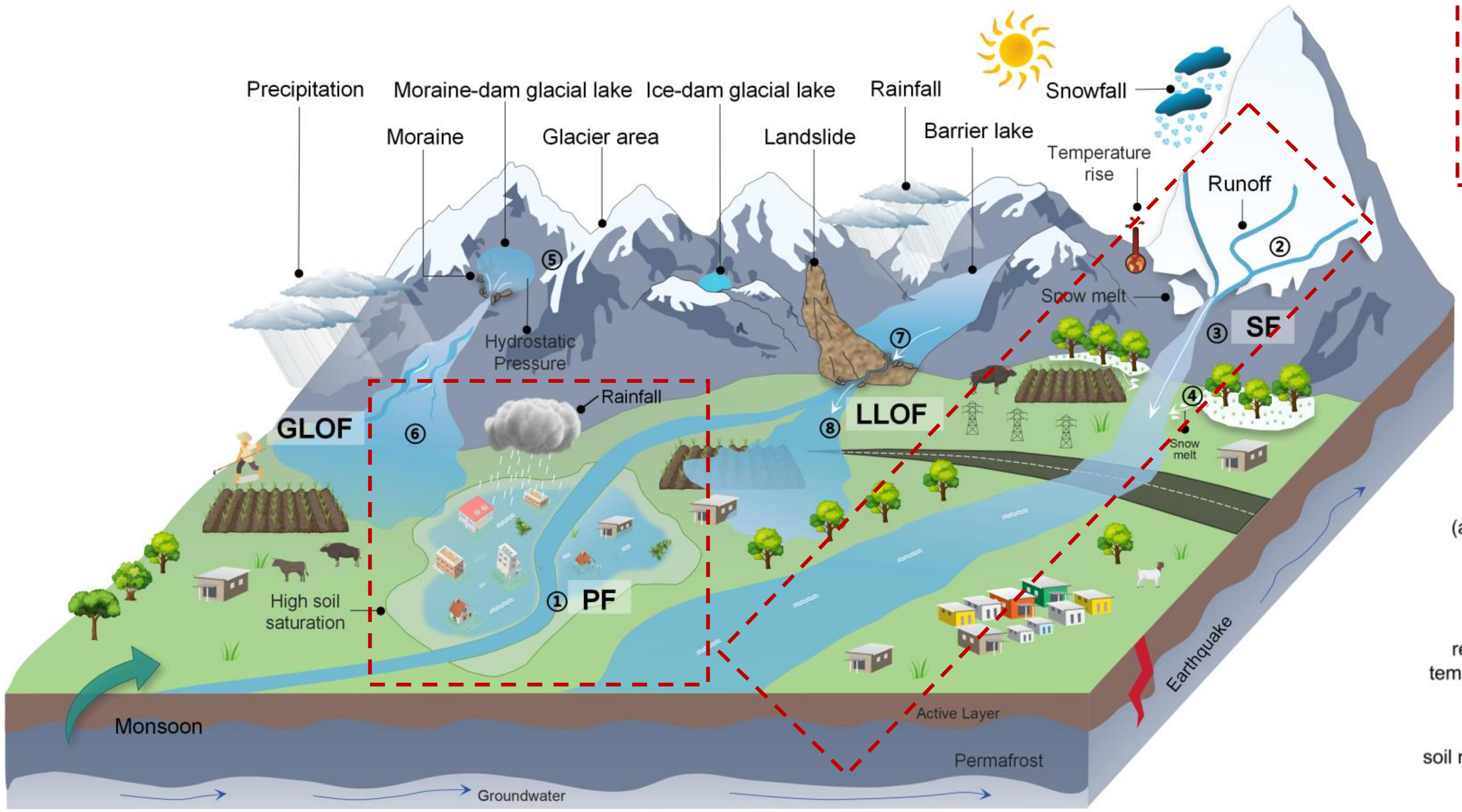

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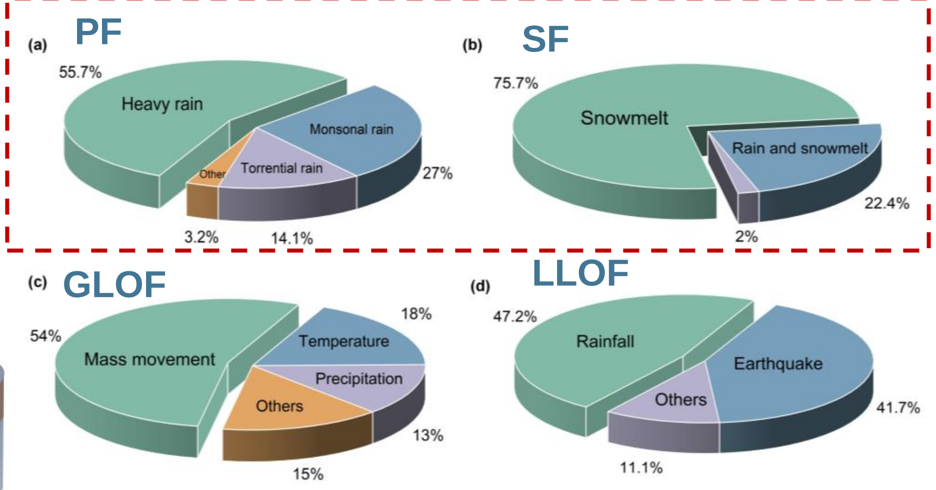
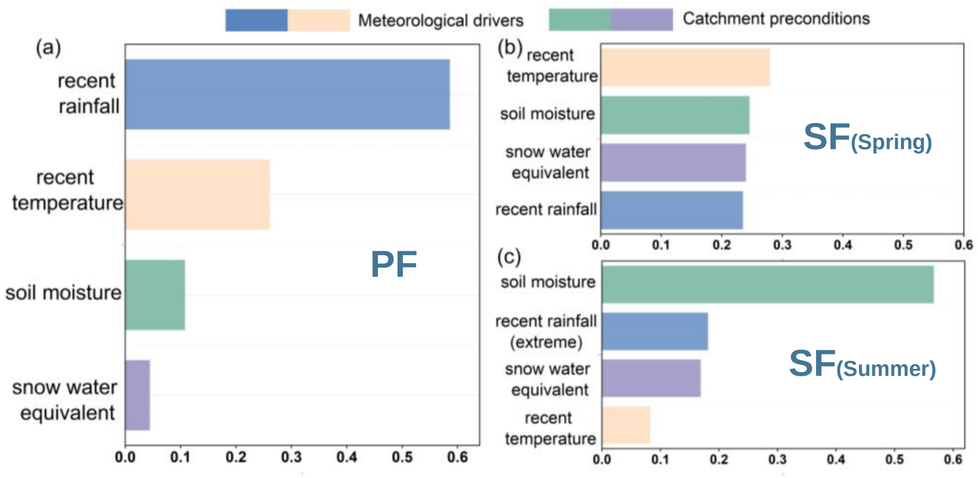


Triggering factors of different flood types in HMA.



Importance of flood impact factors in HMA

Impacts

□ Floods have caused devastating human and infrastructure losses in HMA.

- **PFs** have the broadest impact, causing at least **23 900** deaths and displacing **105 million** people from 1950 to 2023.
- Each **SF,** on average, results in **18** deaths, affects around **128 000** people, and causes damage to 3,377.52 hectares of crops and 553.7 heads of livestock.
- **GLOFs** have a wide-reaching impact, often causing significant devastation downstream. (June 2013,Chorabari , western Himalayas, **6 000** fatalities)
- **LLOFs** also cause catastrophic effects.

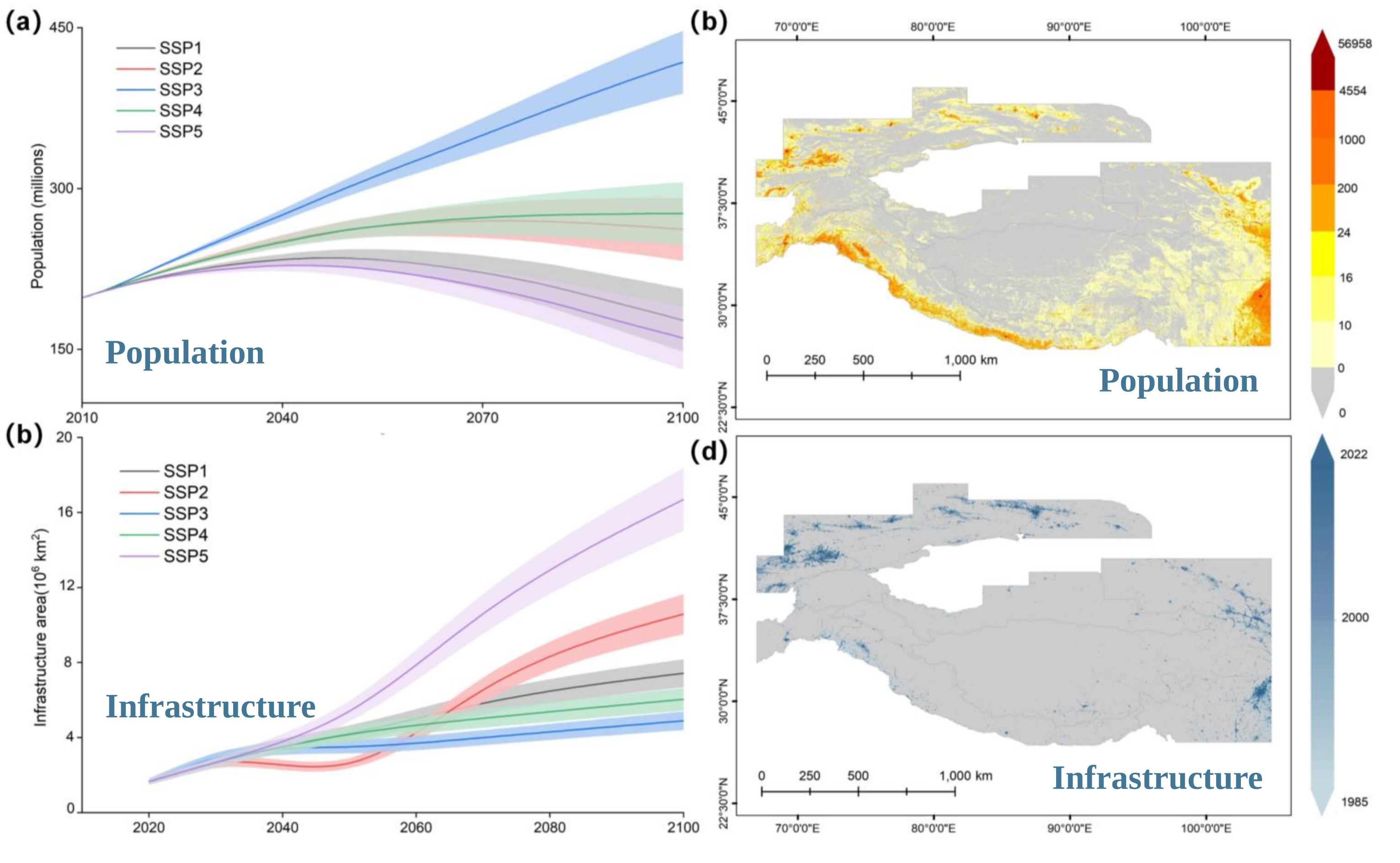
(Image source from Internet)

Impacts

◻ Population and infrastructure growth has heightened HMA′ s disaster exposure.

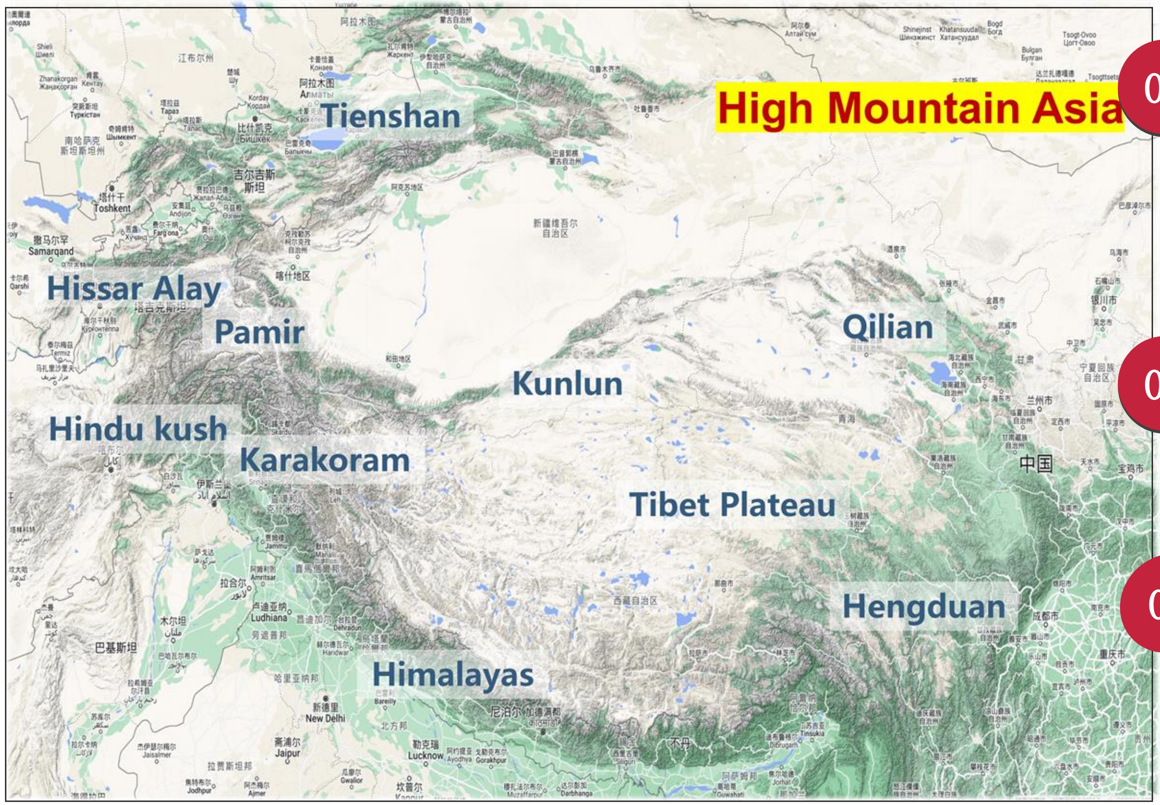
- Average annual growth rates of **1.53%**(Population) and **7.11%** (Infrastructure)
- Increasing are expected to **continue** in the future

Flood exposure



Population and Infrastructure in HMA. a. Average annual population under SSP scenarios in the future. **b.** Average population density from 2000 to 2020 (people / km^2). **c.** Future infrastructure area under SSP scenarios. **d.** Spatial distribution of infrastructurfrom 1985 to 2022.

Adaptation



01 Enhance Risk-Sensitive Spatial Identification

Identifying risk-sensitive areas and adjusting the spatial distribution of population and socio-economic activities are essential in the future.

02 Strengthen international cooperation

Promoting Stronger Regional Cooperation and Effective Information Sharing.

03 Leverage Indigenous Knowledge

Encouraging local people, especially the youth, to participate in local flood mitigation efforts.

白远远, 李东锋. (2024). 青藏高原及周边山区历史洪水灾害分布数据集（1950-2023）. 国家青藏高原科学数据中心. *https://doi.org/10.11888/HumanNat.tpdc.301724*.

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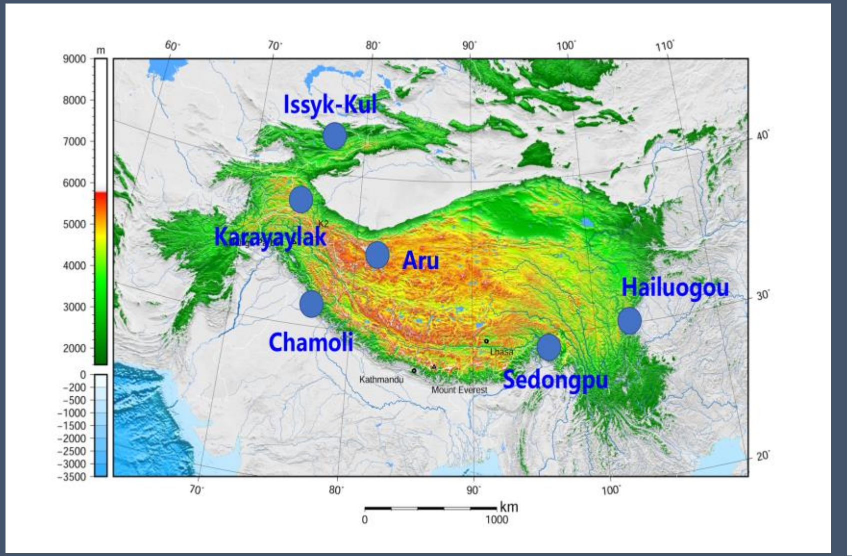
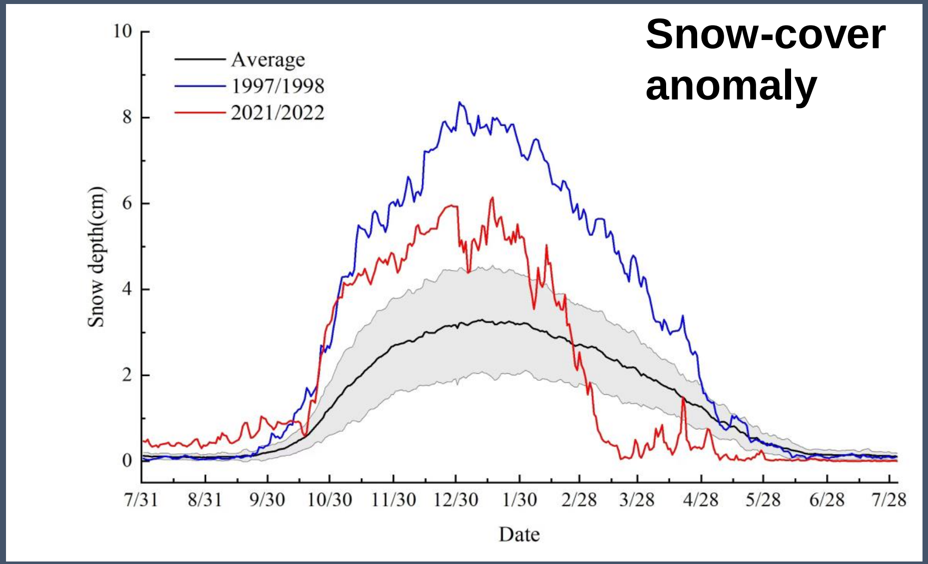
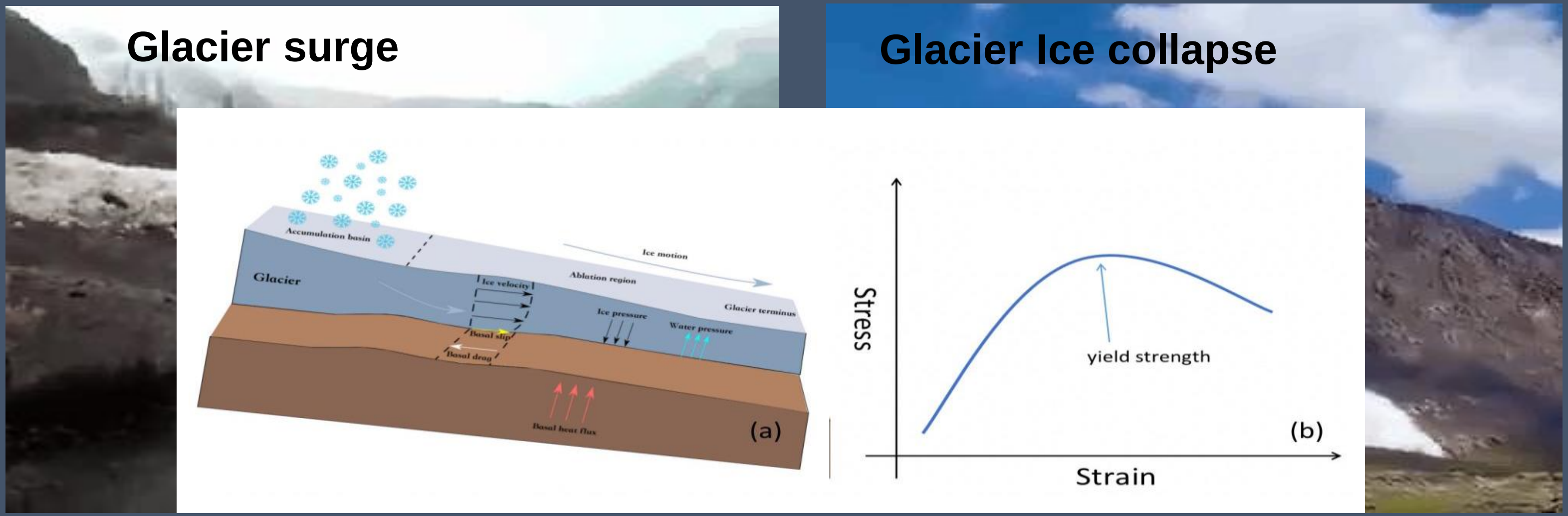
Abrupt cryosphere events (ACEs) in High Mountain Asia (HMA) region

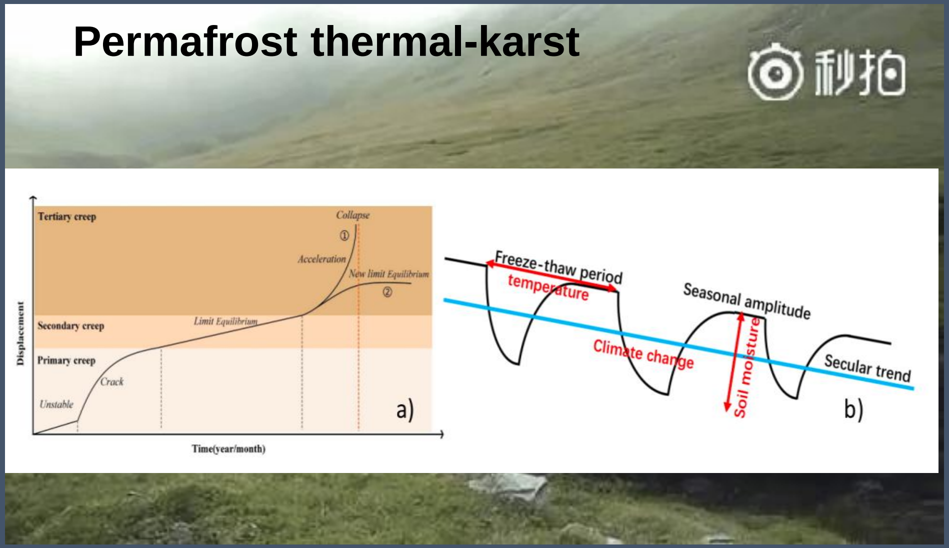
Frequent occurrence of abrupt massive collapse of glacier mass, widespread thermal-karst of permafrost and snow cover anomaly

Cryosphere over HMA reach tipping point at 1.1° C GWL

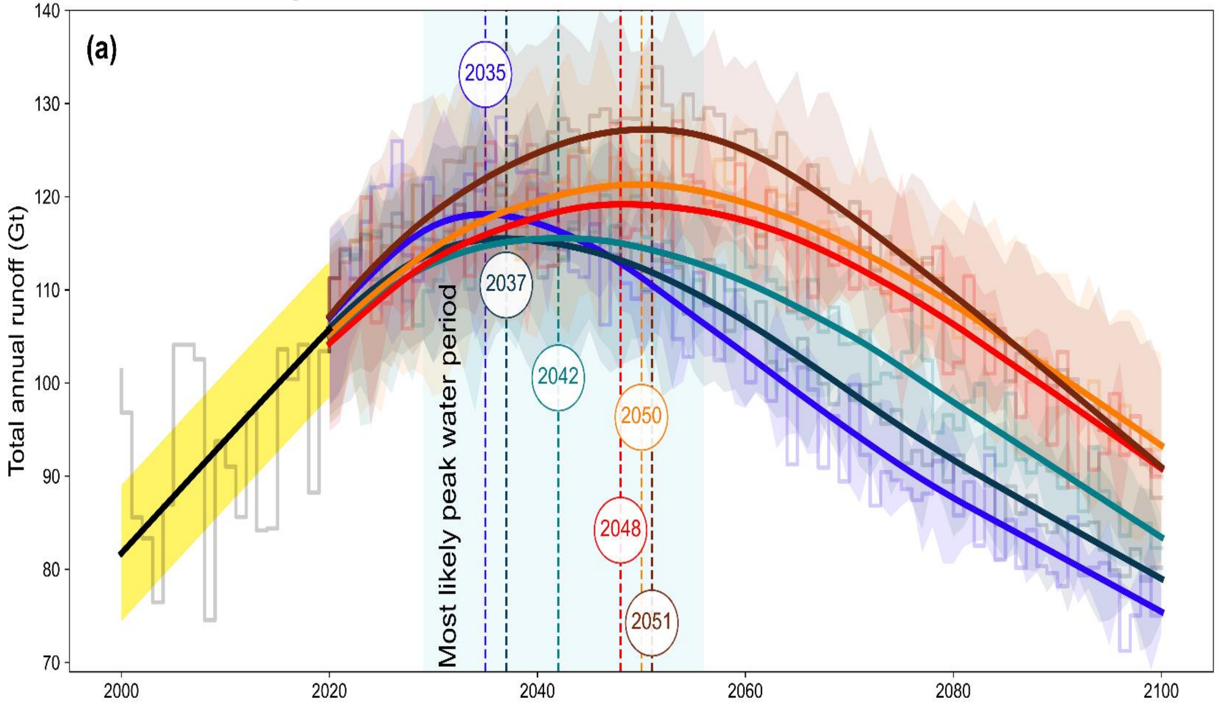


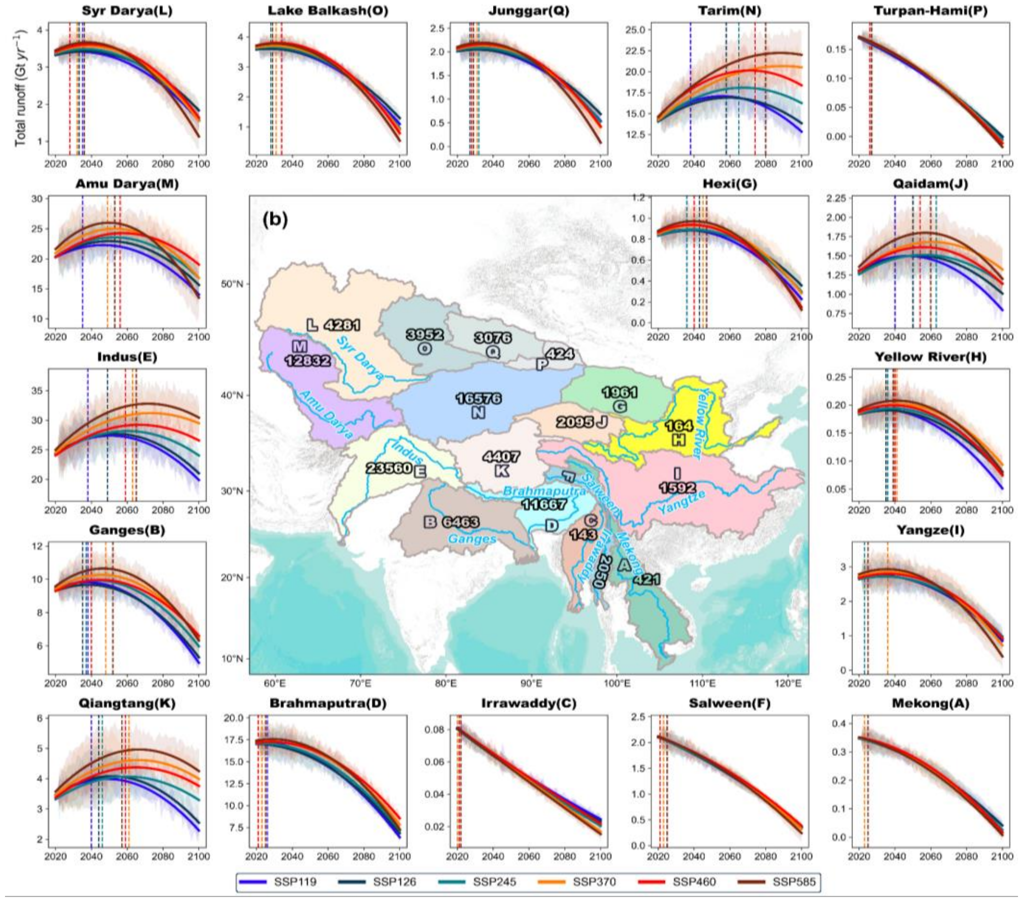






Projected peak-water over HMA drainage basins



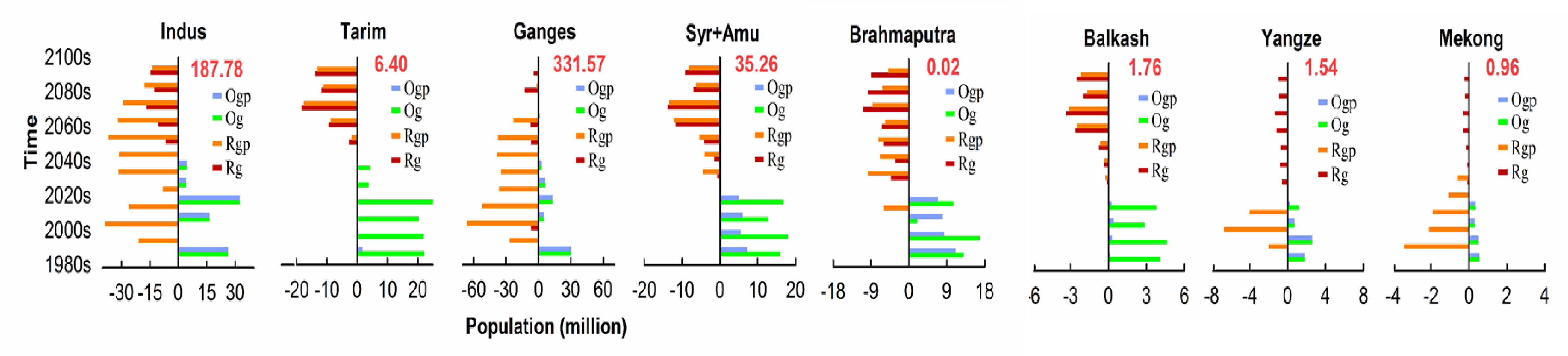


(a) Glacier total runoff change under different climate scenarios;

(b) Glacier runoff change in major drainage basins over HMA

- Glacier evolution model integrated the ice flow dynamics is employed to project the peak water of glacier runoff in major drainage basins. The most drainage basins (14/17, SSP245) will reach peak water before 2050s.

(Zhao, Zhang, Xiao* et al., 2023)*



Opportunities (green bar) and risks (red bar) associated with changes in the service potential of glacial meltwater and population in the Asia's important water tower units

Su, Xiao and Chen et al., 2021

- Both meltwater supply and demand (population) are expected to continue to rise for a certain period, but after the "peak", they will steadily decrease.
- There is a mismatch between the peak times of meltwater and population, which further creates both opportunities and risks that vary with the basin and time.
- Both opportunities and risks are the greatest in the Indus River basin.

Cryosphere

Oasis

Desert

Eurasian inland oasis ecosystem

Fuchenggou village, Minqin of Shiyang River, August 2019

冰退沙进，沙进人走

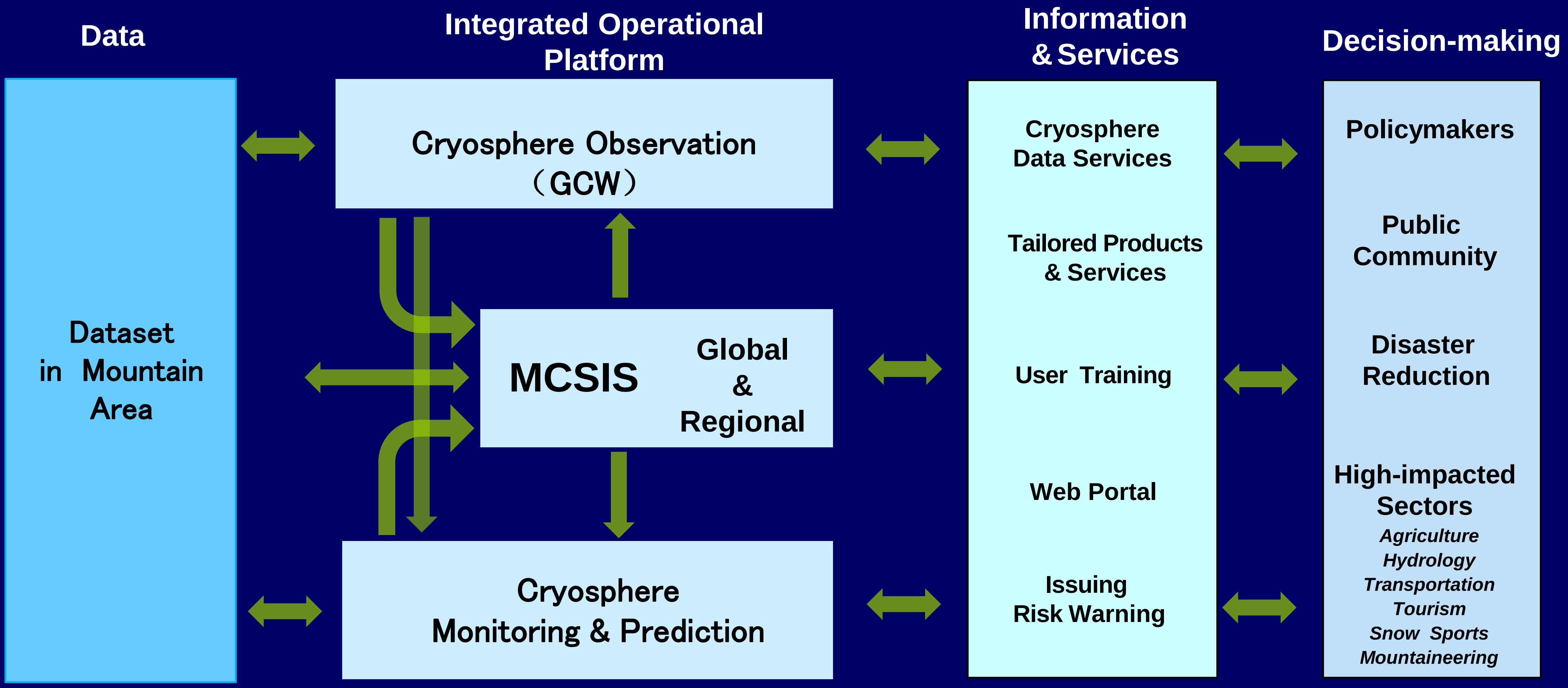
(By Dahe Qin)

- Our Safe boundaries have been defined to safeguard the ability of the Earth's biophysical systems to continue to function and provide services to all living beings on Earth. Meltwater is a fundamental wellbeing to many arid and semi-arid regions such as in northwest China. Climate warming accelerates human and nature's exposure to significant harm.

- When meltwater crossing tipping points for the region, eco-refugees and poverty is unavoidable. Actions must be taken for climate mitigation so that Intergenerational justice and intra-generational justice being achieved.

Suggestion: International Operation Framework on High Mountain Cryosphere Service

(All high mountains)



MCSIS: *M*ountain *C*ryosphere *S*ervices *I*nformation *S*ystem

Thanks for your attention

References

1. Qin D.H., Zhai P.M, Xiao C.D., et al., 2025. Assessment Report of Climate Change, Impacts and Adaptation of Qinghai-Xizang Plateau. Beijing, Science Press.
2. Bai Y. Y., Li D. F., Wangchuk S., et al., 2025. Flood complexity and rising exposure risk in High Mountain Asia under climate change, Science Bulletin, https://doi.org/10.1016/j.scib.2025.01.055
3. Xiao, C.D., Zhang, T., Che, T and others, Qin, D.H.*, 2023. Do abrupt cryosphere events in High Mountain Asia indicate earlier tipping point than expected? Advances in Climate Change Research, 14(6): 873-883.

Bayi Glacier, Mt. Qilian

Courtesy: Y. Zheng