



中国科学院 青藏高原研究所

Institute of Tibetan Plateau Research
Chinese Academy of Sciences

Advancing Data for Periglacial Environment with Remote Sensing Big Data

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Institute of Tibetan Plateau Research, Chinese Academy of Sciences



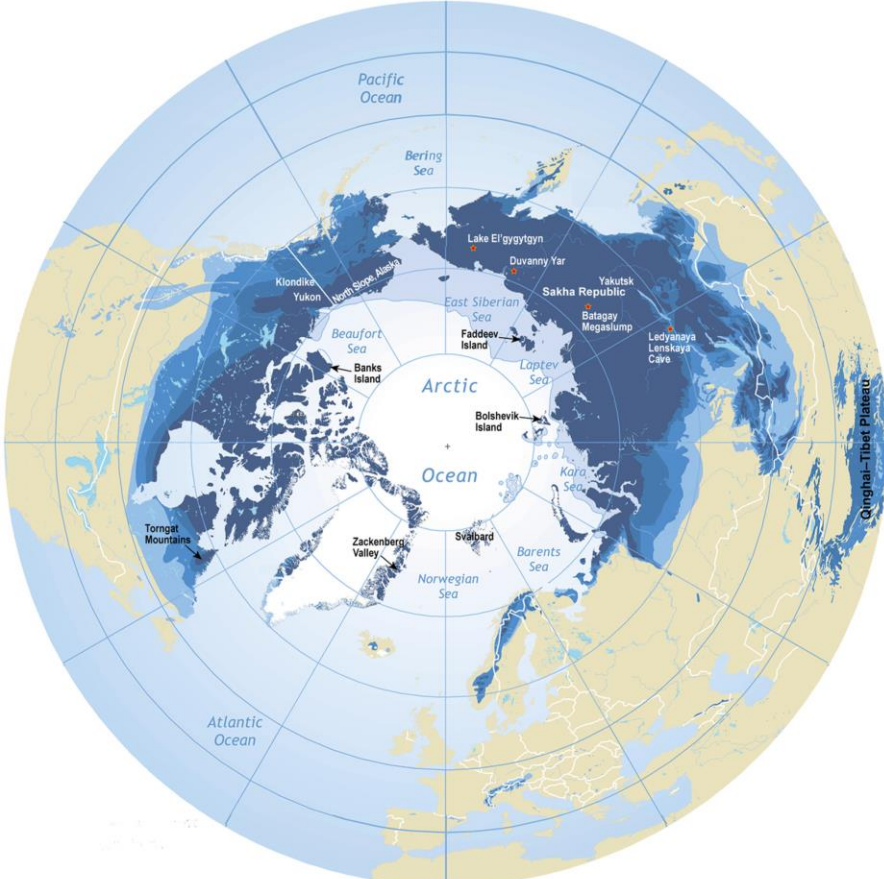
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Key Laboratory of Tibetan Plateau Earth System, Environment and Resources

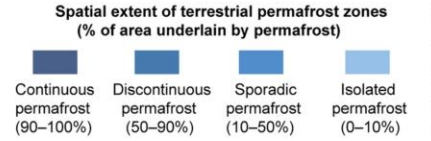


TPDC 国家青藏高原科学数据中心

Periglacial environment



Permafrost in the Northern Hemisphere



Subsea permafrost

Source: Brown et al. (1997)
© International Permafrost Association

(Murton, 2021 PPP)

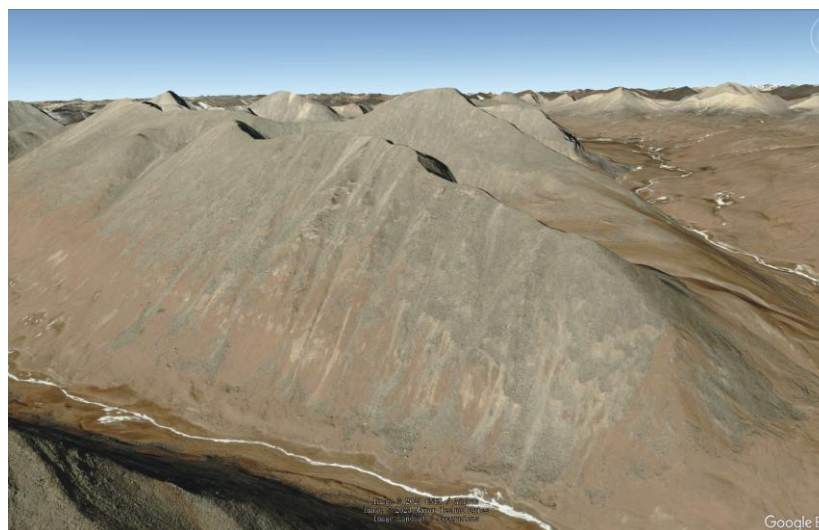
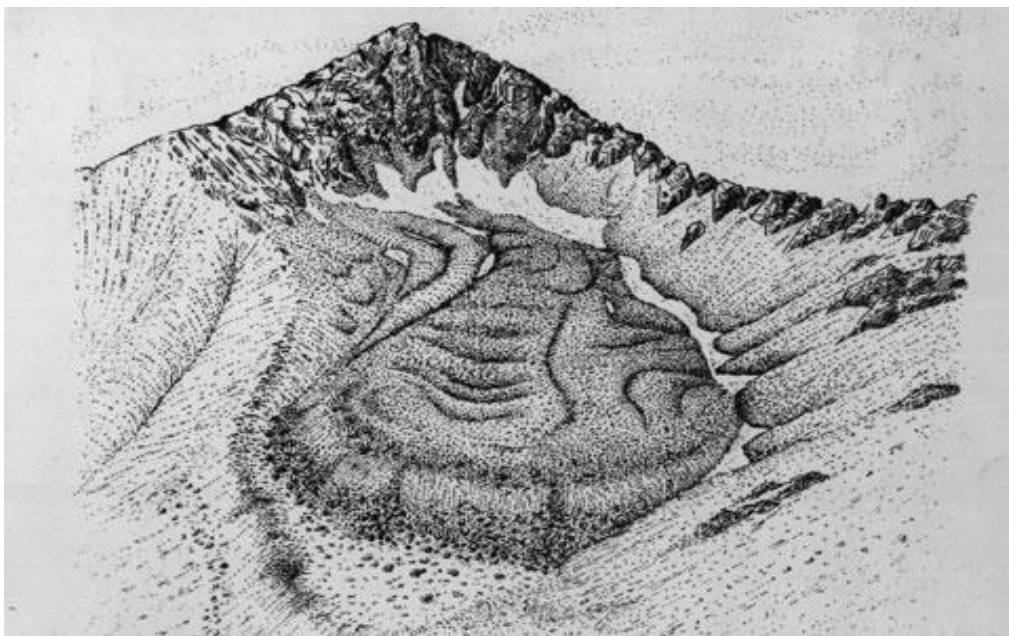


20% the Earth’s land surface lies under periglacial conditions, with the Tibetan Plateau being one of the key distribution regions.

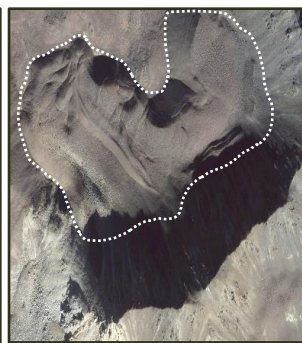
- ❑ Sensitive Indicators of Climate Change
- ❑ Regulation of the Global Carbon Cycle
- ❑ Unique Landforms and Landscapes
- ❑ Impact on Human Activities

Periglacial landforms

Periglacial landforms such as rock glaciers are key elements in understanding the periglacial environment and its changes, holding significant implications for climate indication, disaster initiation, and water resources.



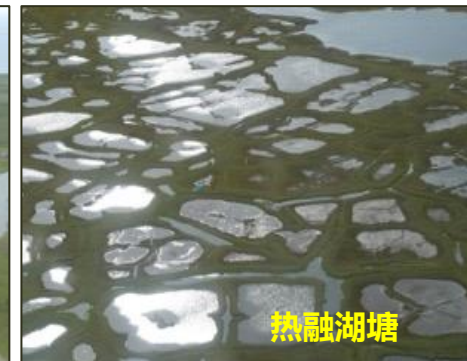
Talus



Rock glacier



冻胀丘



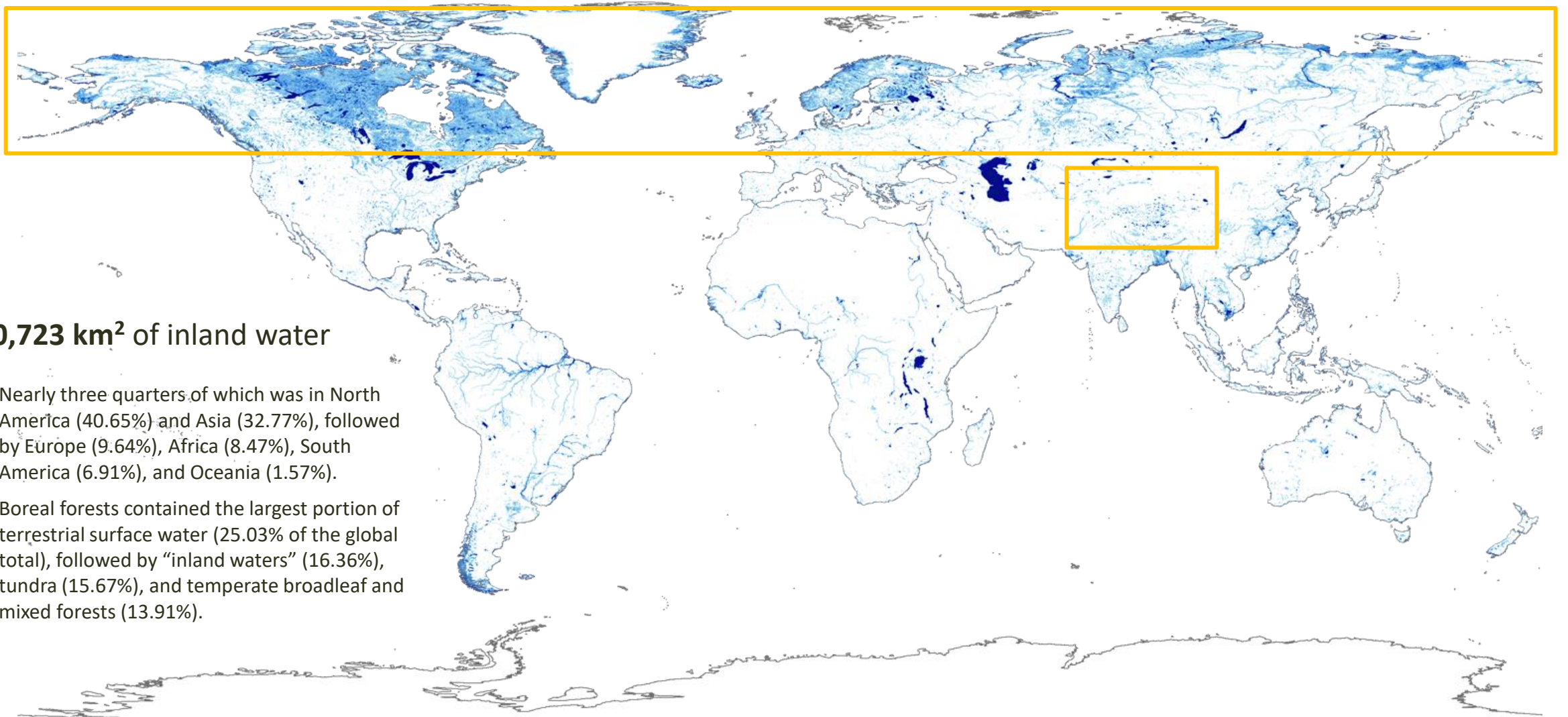
热融湖塘



石环

Other landforms: Thermokarst lakes, stone circles, stone seas, frost mounds

Distribution of surface water

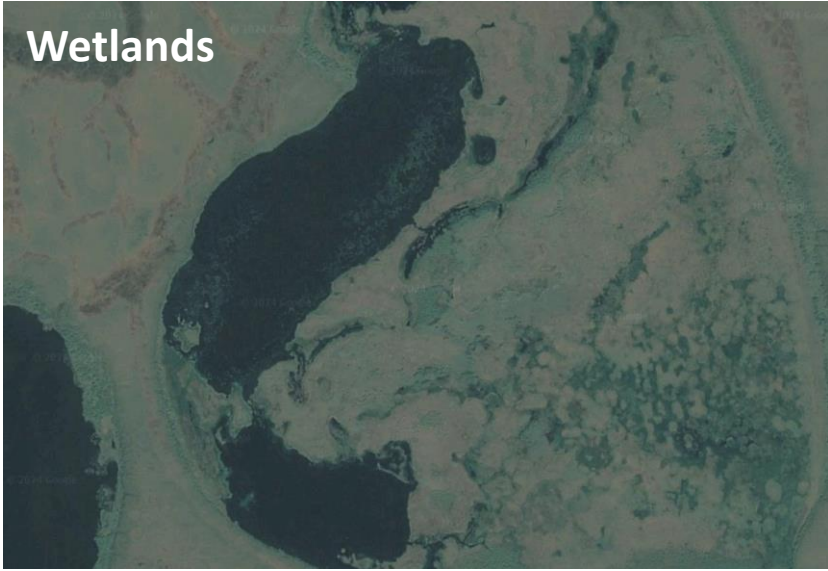


3,650,723 km² of inland water

- Nearly three quarters of which was in North America (40.65%) and Asia (32.77%), followed by Europe (9.64%), Africa (8.47%), South America (6.91%), and Oceania (1.57%).
- Boreal forests contained the largest portion of terrestrial surface water (25.03% of the global total), followed by “inland waters” (16.36%), tundra (15.67%), and temperate broadleaf and mixed forests (13.91%).

Small water bodies

Wetlands



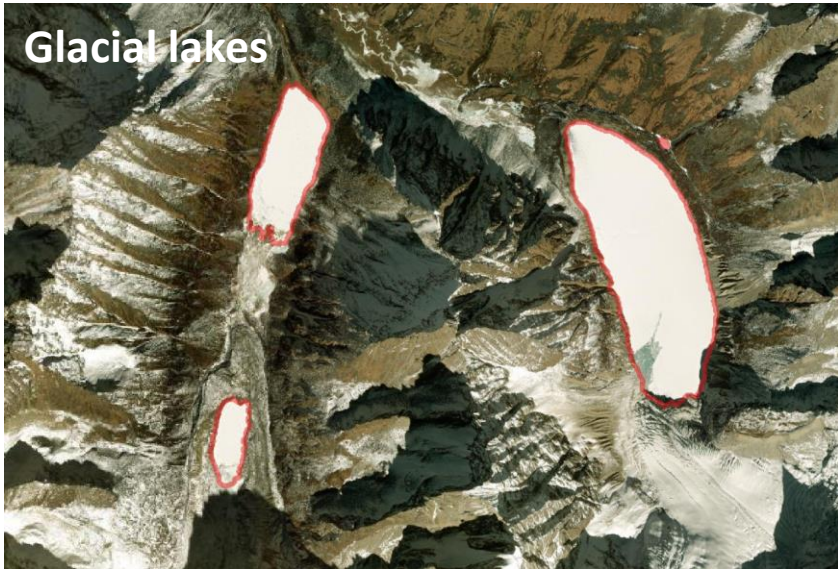
Reservoirs



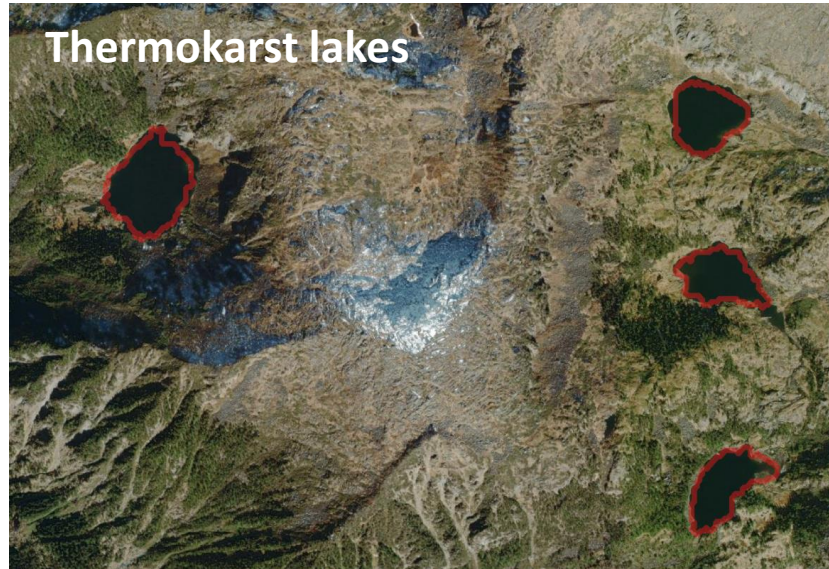
Water ponds



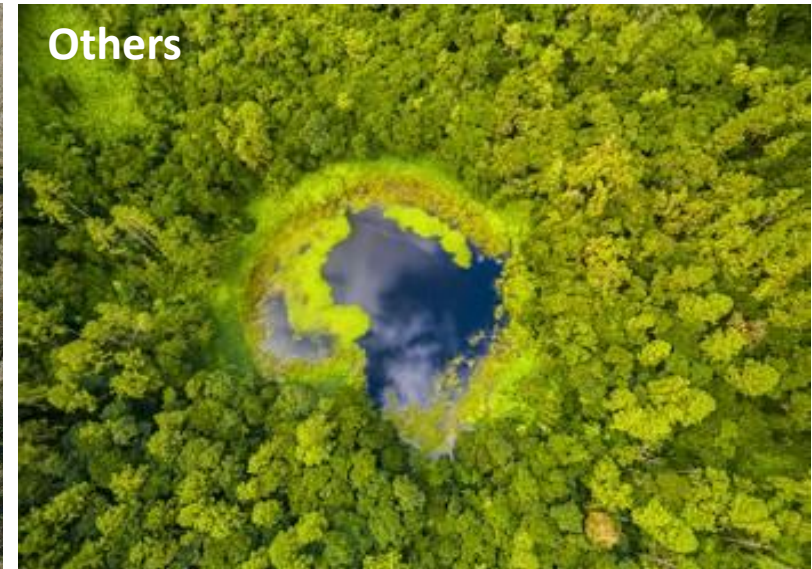
Glacial lakes



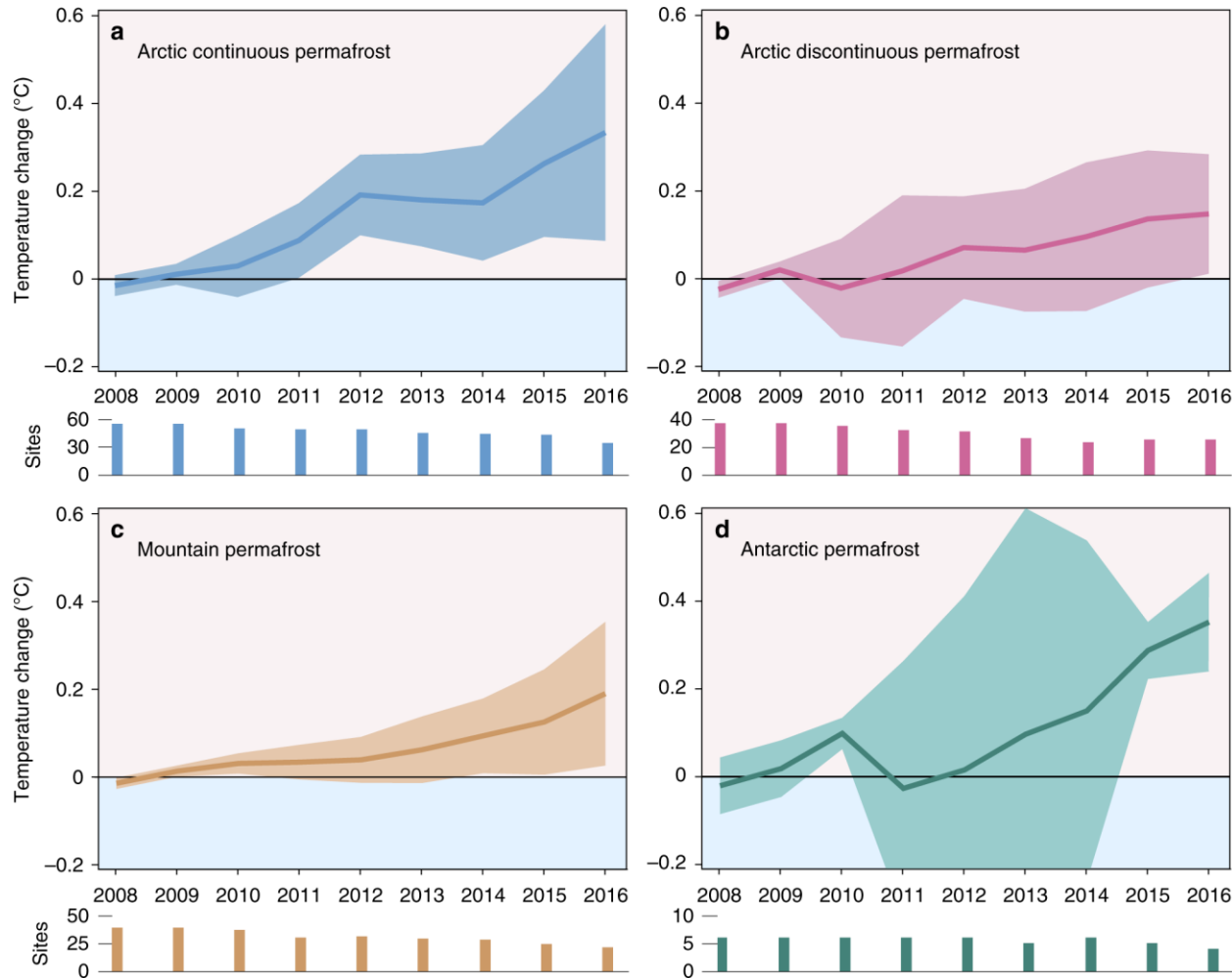
Thermokarst lakes



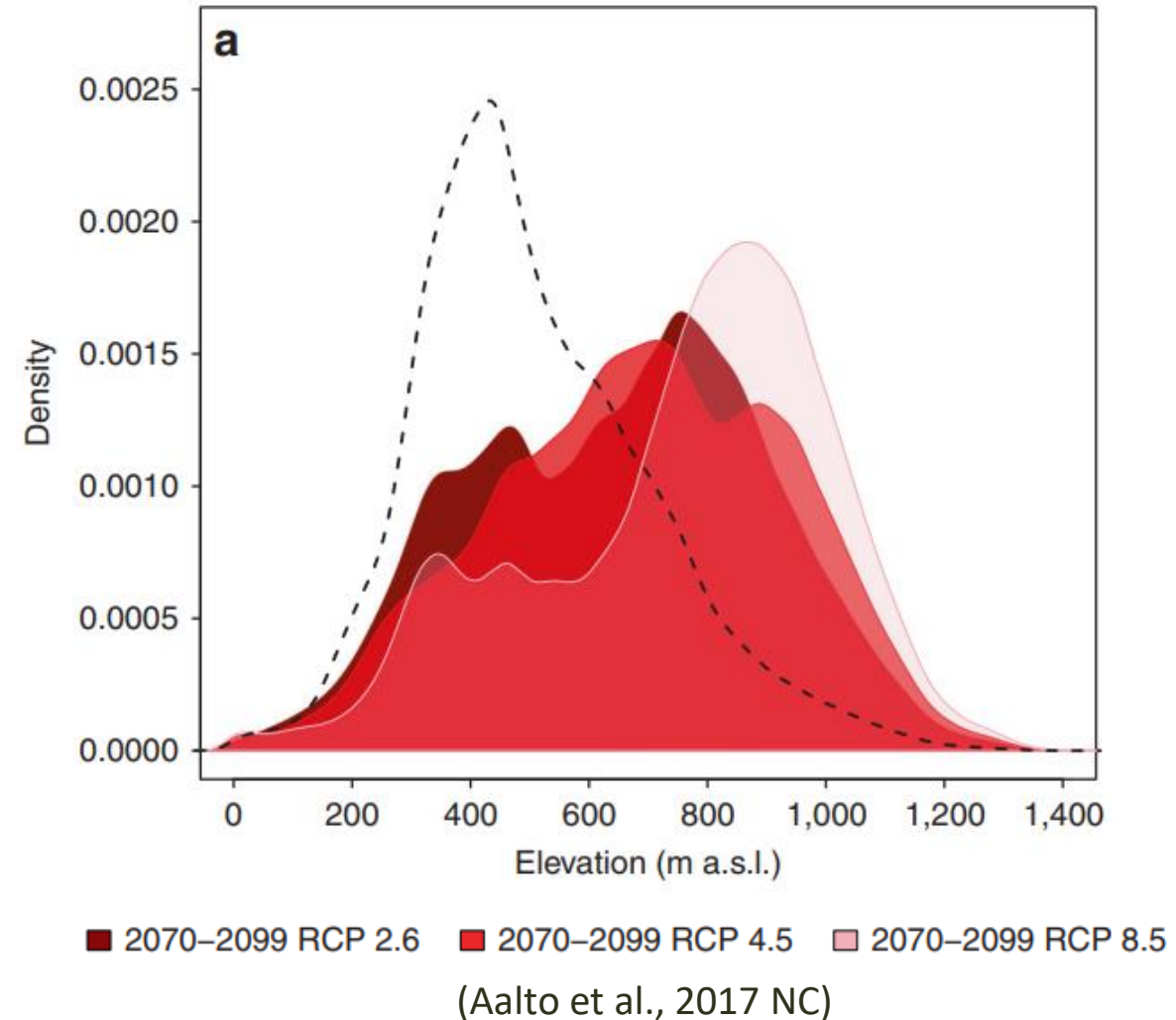
Others



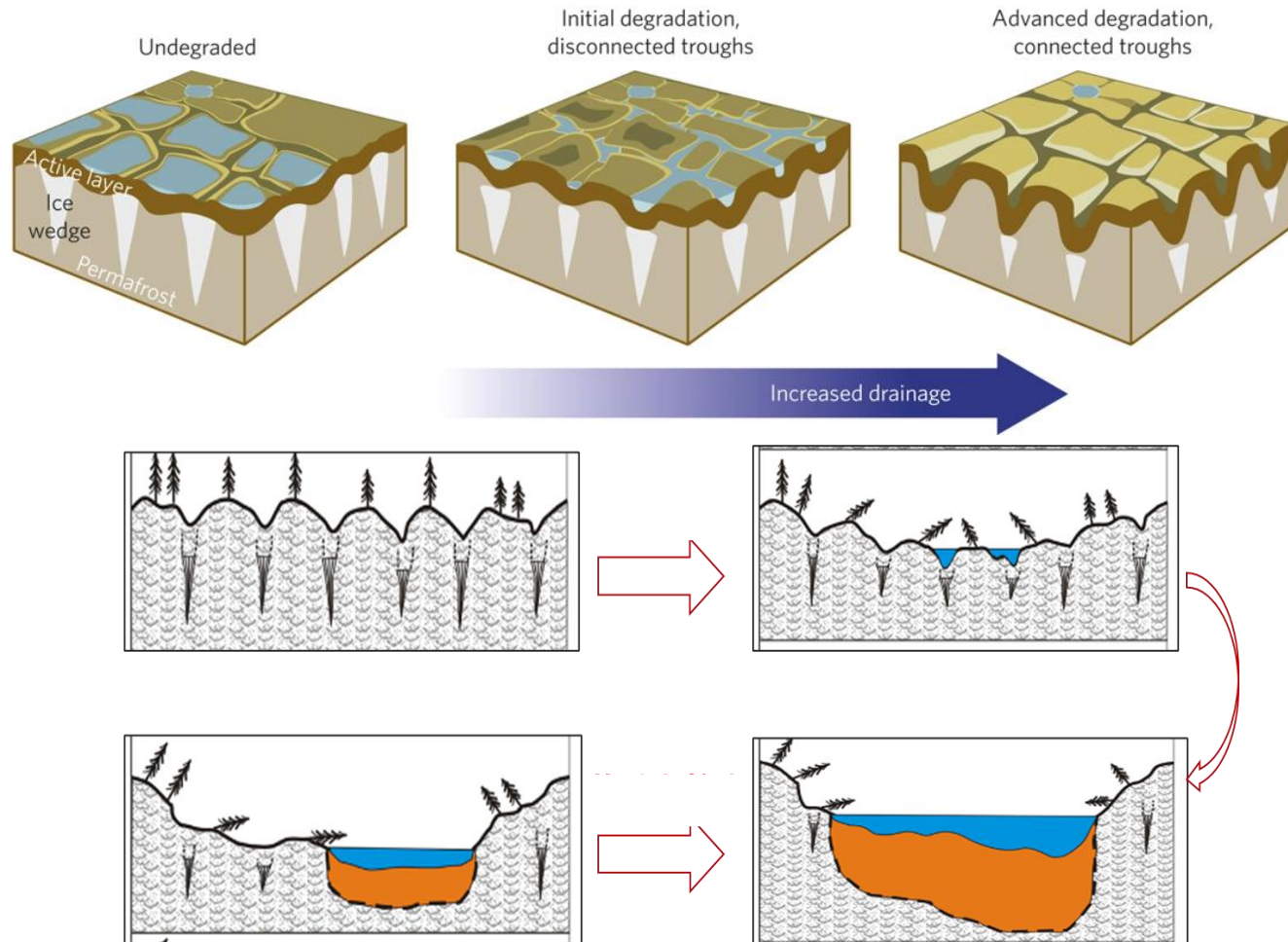
Rapid changes in global permafrost response to climate change



(Biskaborn et al., 2019 NC; Smith et al., 2022 NREE)

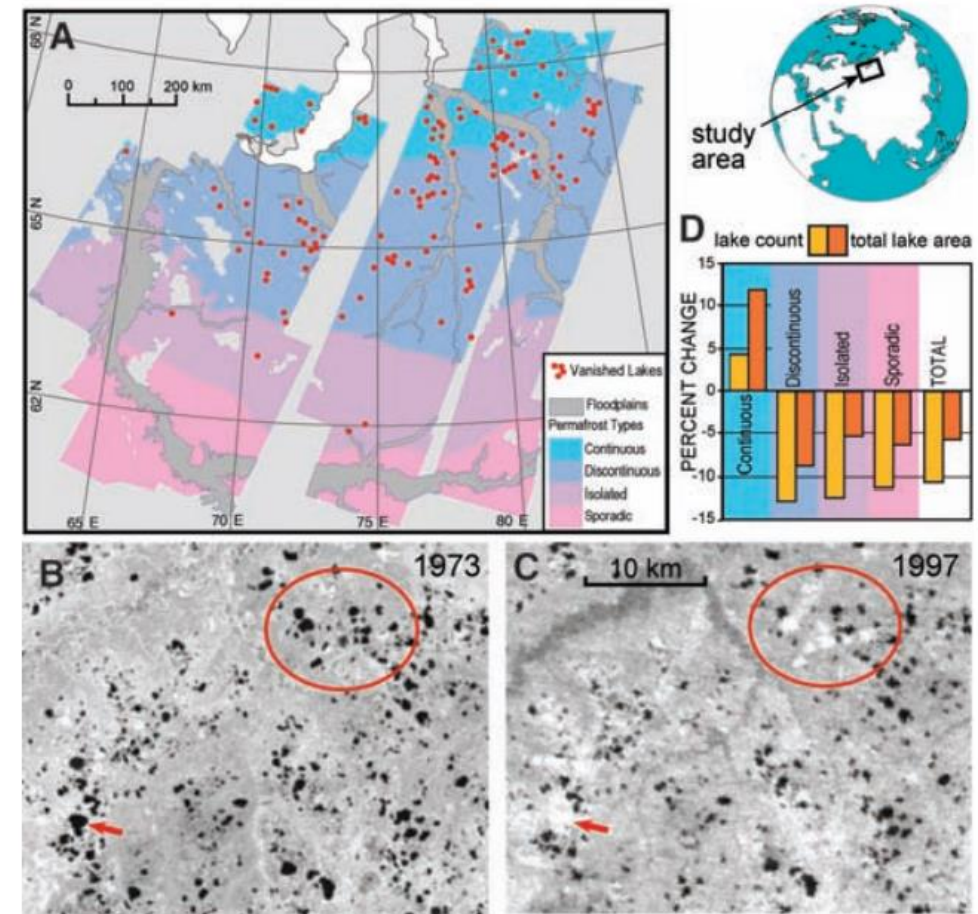


Small lakes and other periglacial landforms are indicators and have experienced substantial changes



Formation of thermokarst lakes in response to changing permafrost

Grosse et al., 2013



Shrinkage and disappear of thermokarst lakes

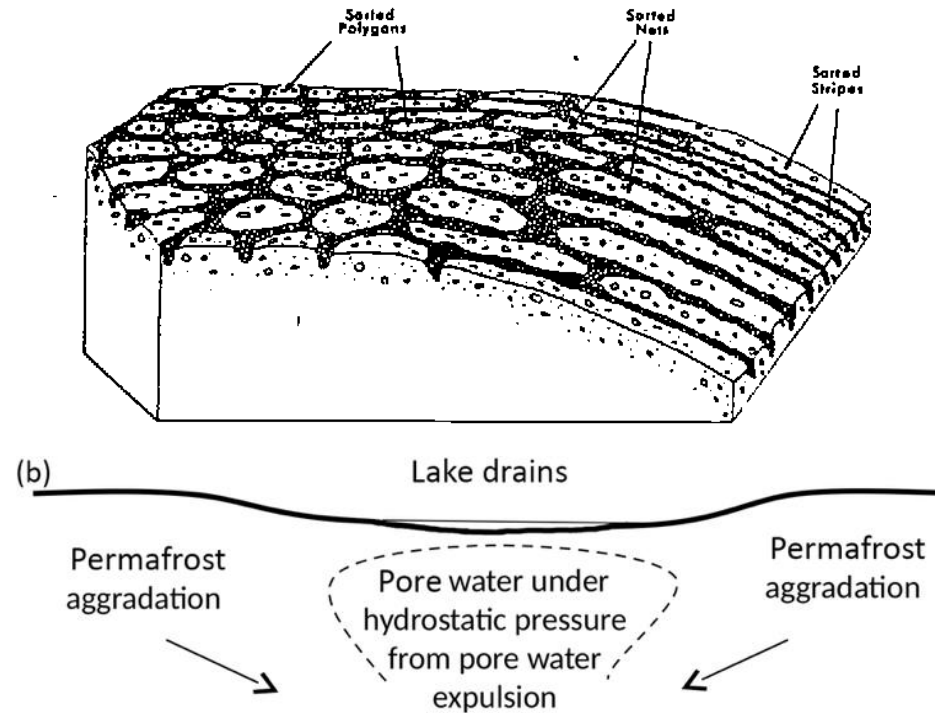
Smith et al., 2005 Science

Challenges

Traditional survey methods are difficult to support the study of periglacial landforms.



Weak spectral characteristics



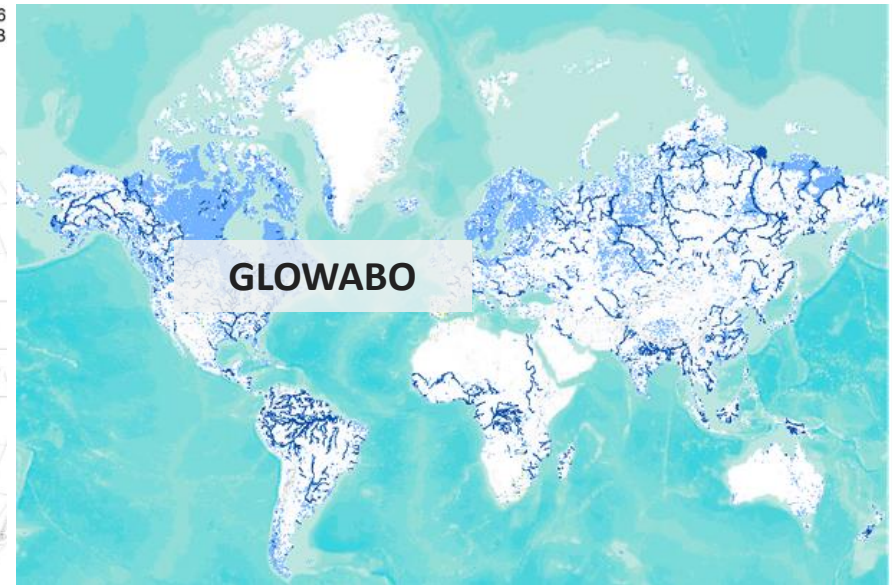
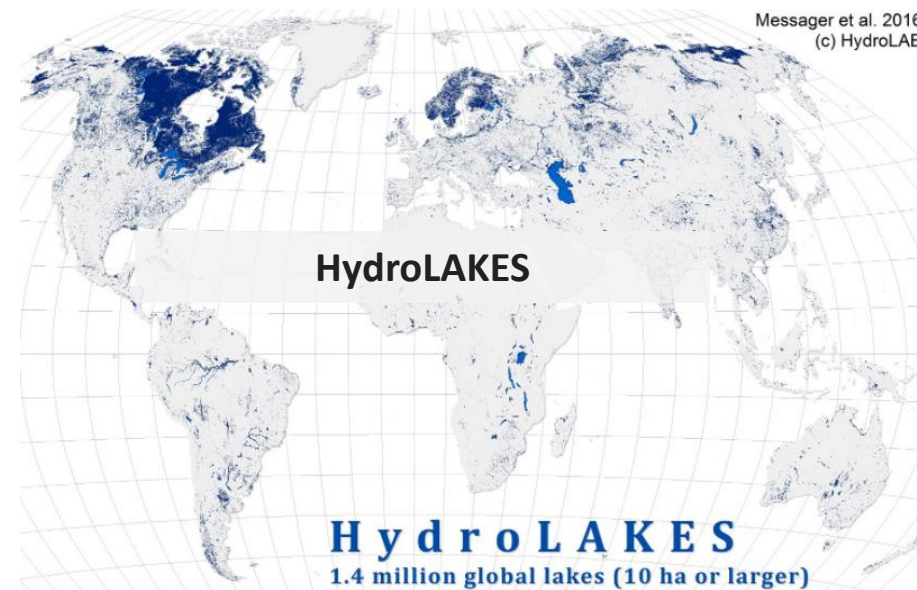
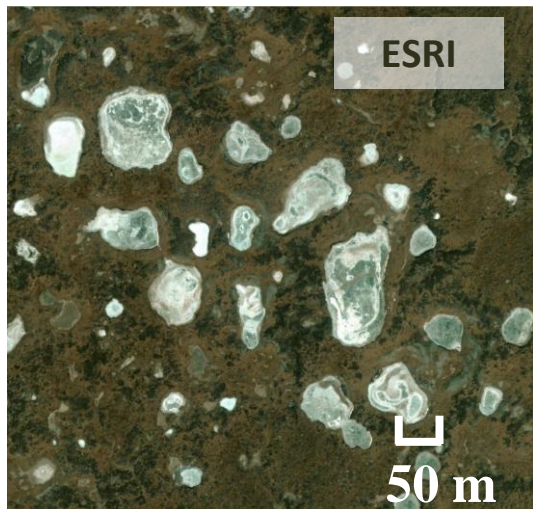
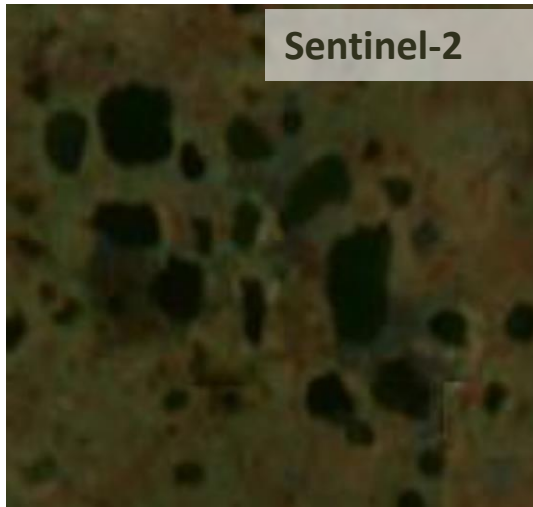
Complex periglacial processes and periglacial landscapes



Periglacial landscapes are small in scale and difficult to observe using medium-to-coarse resolution satellite data.

Challenges

Our understanding is limited for small water bodies that are usually also shallow and sensitive to environment changes

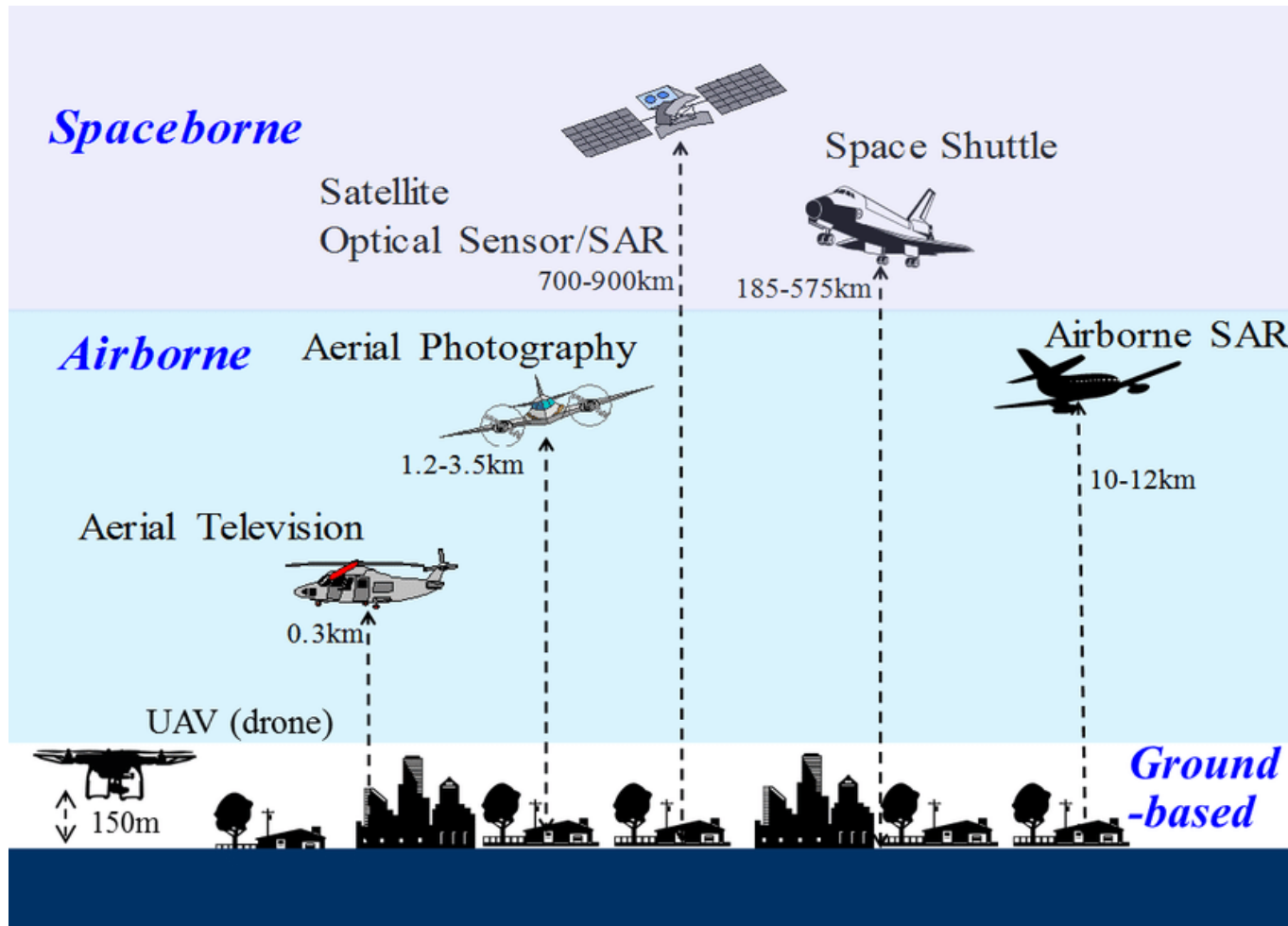


Global surface water research and datasets focus on large or medium water bodies (> 0.1km²)

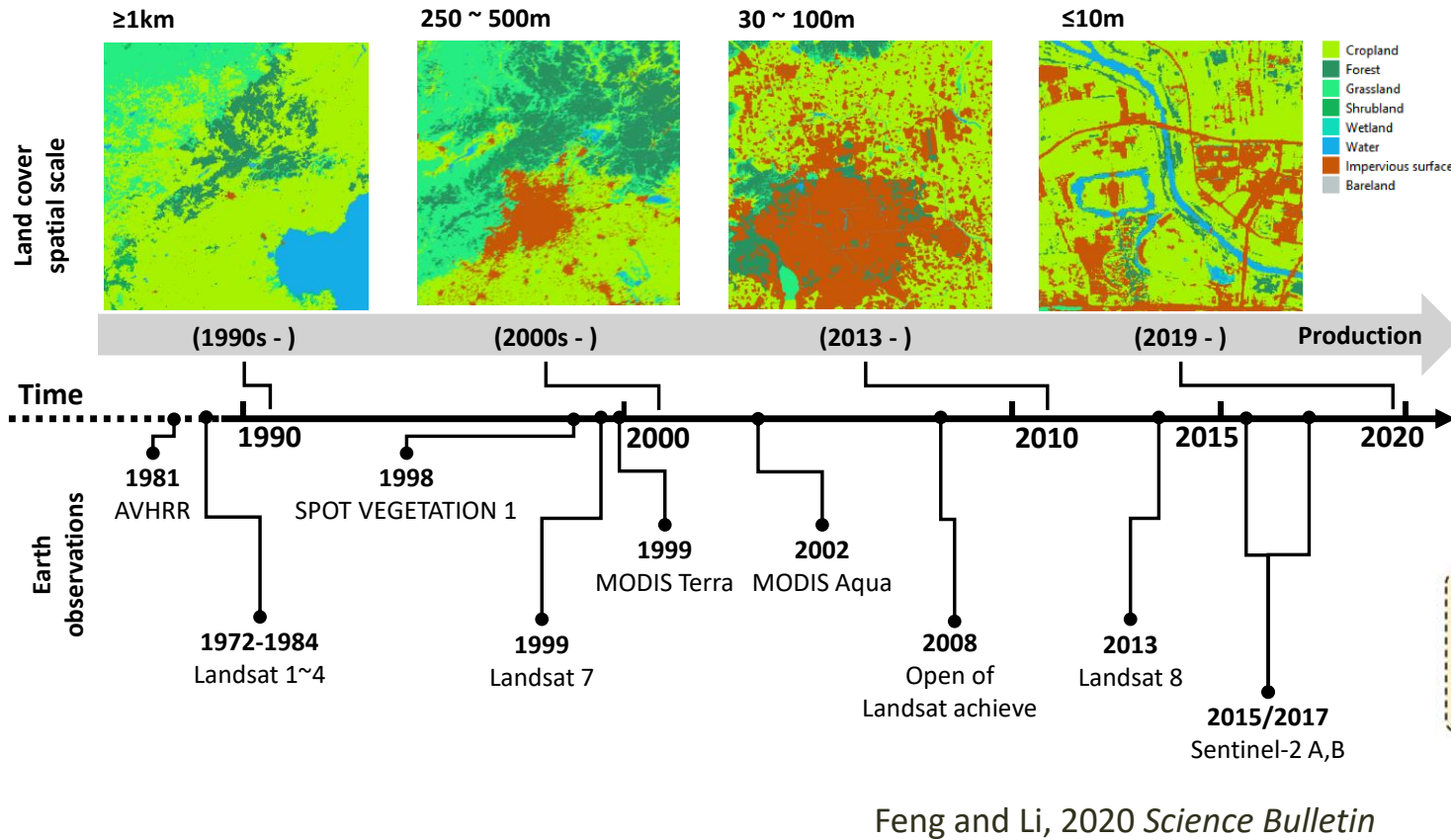
Weaker signals and higher uncertainty

Big data of Earth

The explosion of Earth observations provides the data possible for exploring small water bodies



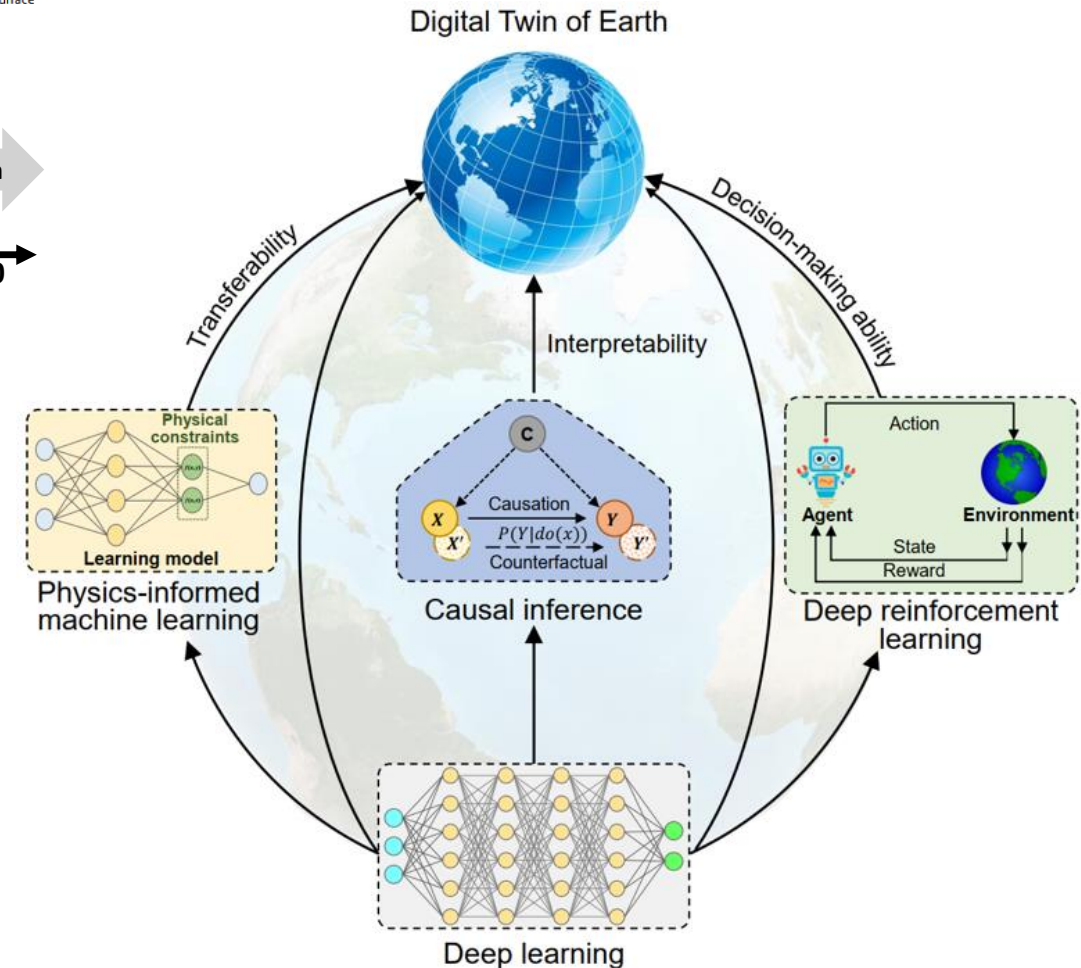
Data driven geoscience



Big Data in Earth system science and progress towards a digital twin

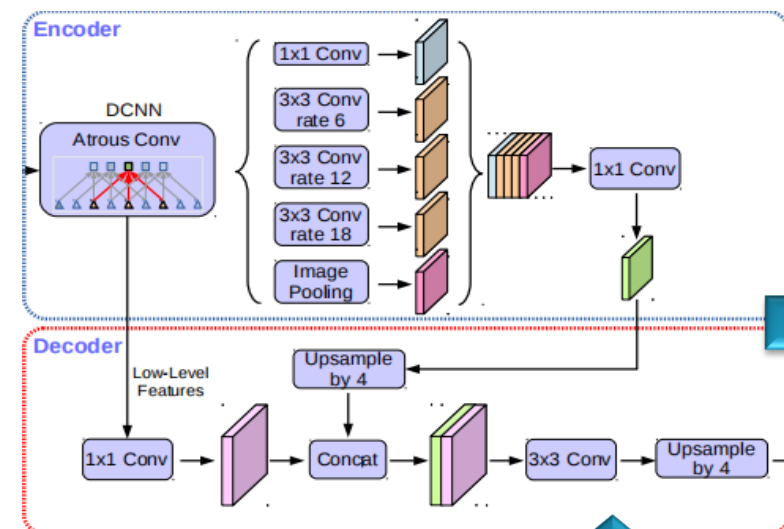
[Xin Li](#) ✉, [Min Feng](#) ✉, [Youhua Ran](#), [Yang Su](#), [Feng Liu](#), [Chunlin Huang](#), [Huanfeng Shen](#), [Qing Xiao](#),
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Nature Reviews Earth & Environment 4, 319–332 (2023) | [Cite this article](#)



Periglacial landform identification

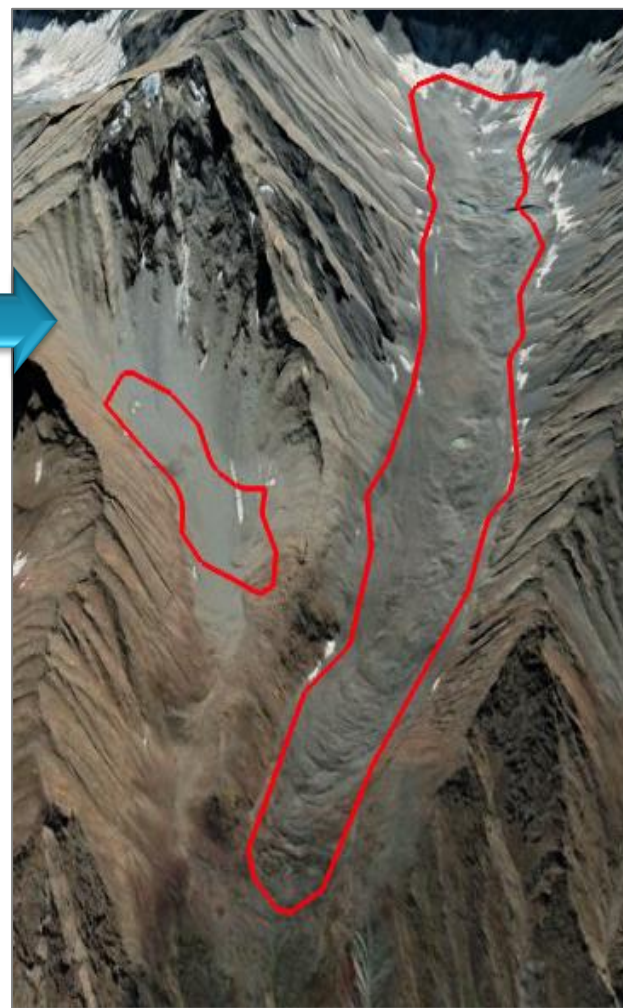
A deep-learning (DeepLab v3+) and MT-InSAR method for identifying rock glaciers



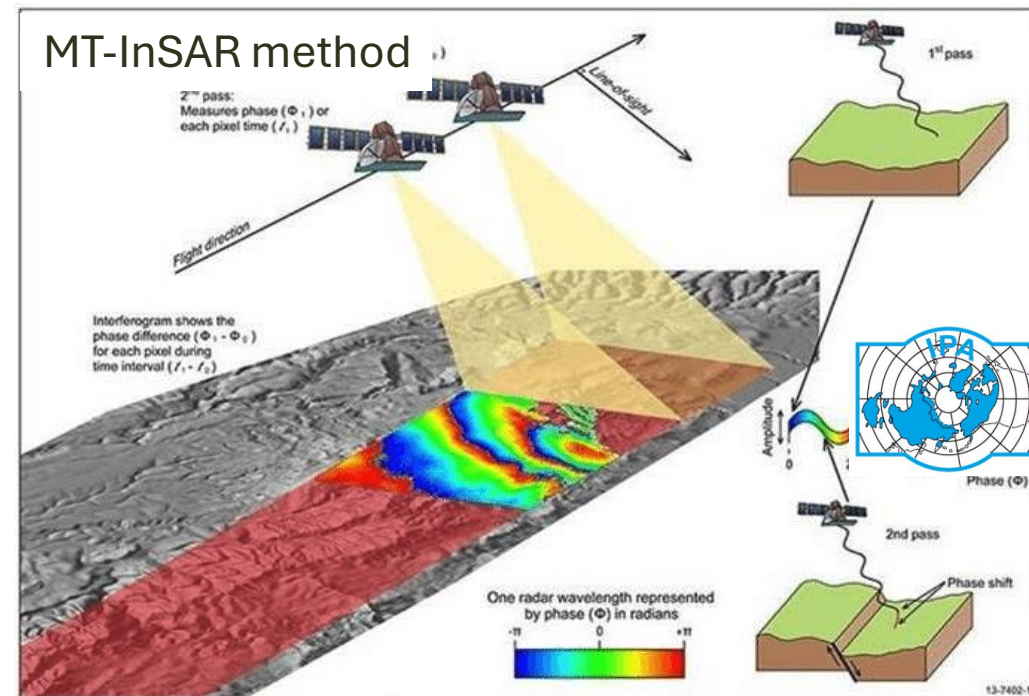
DeepLab v3+



Millions of satellite images



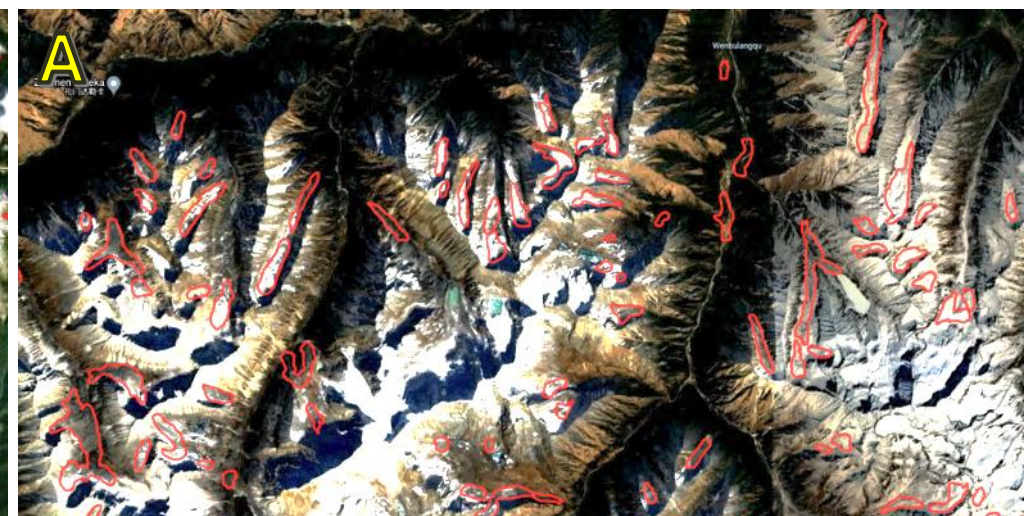
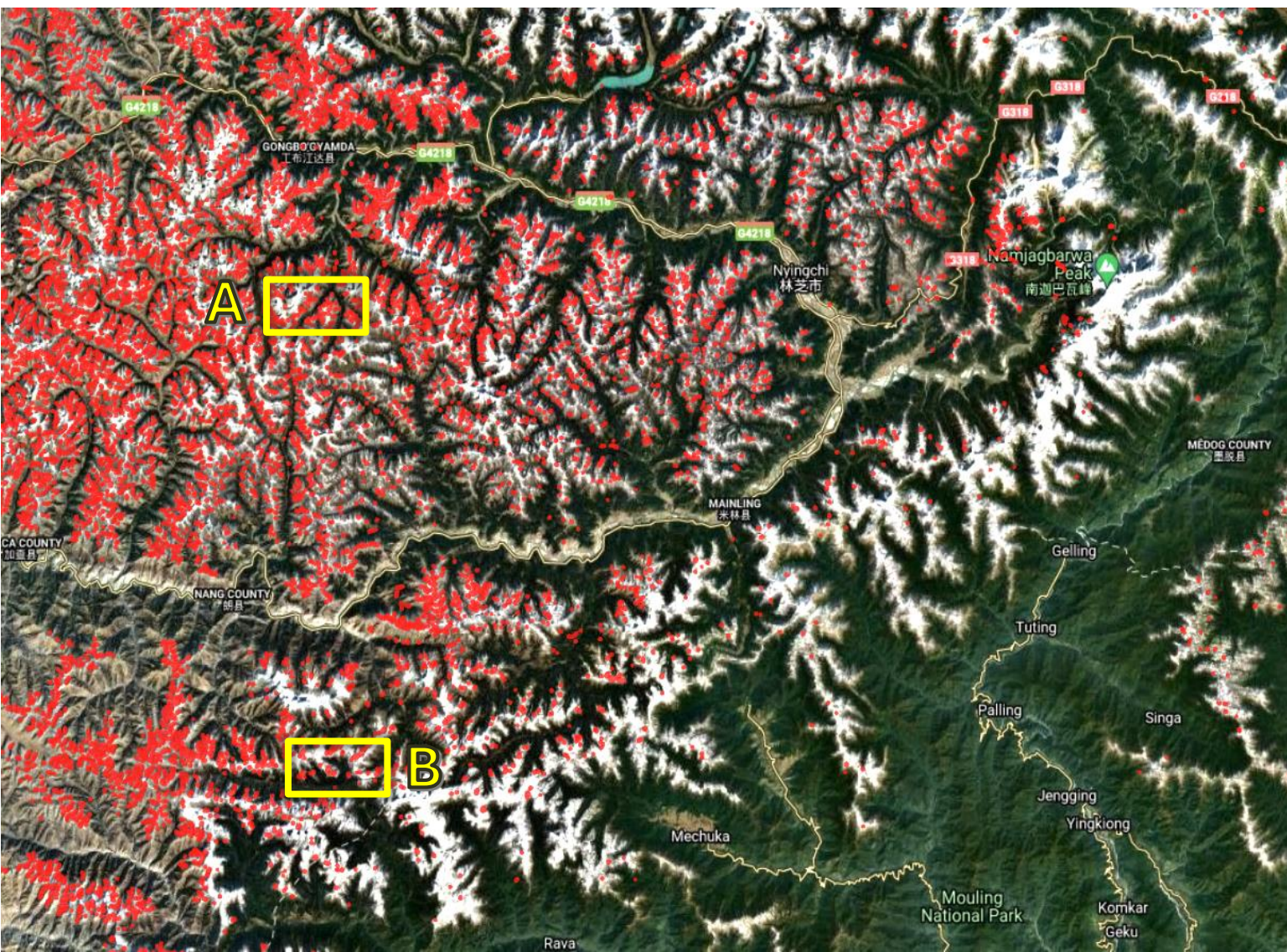
(Xu, Feng* et al., 2020) (Zhang, Feng* et al., 2021 RS; Zhang, Feng* et al., 2023 IJDE)



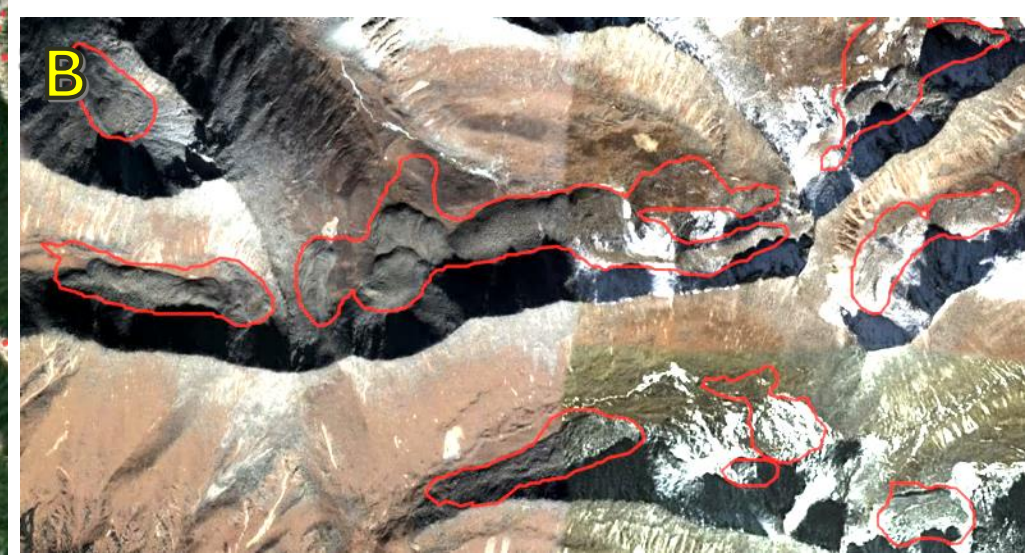
Rock glacier kinematics

Rock glacier inventory

Eastern Himalayas



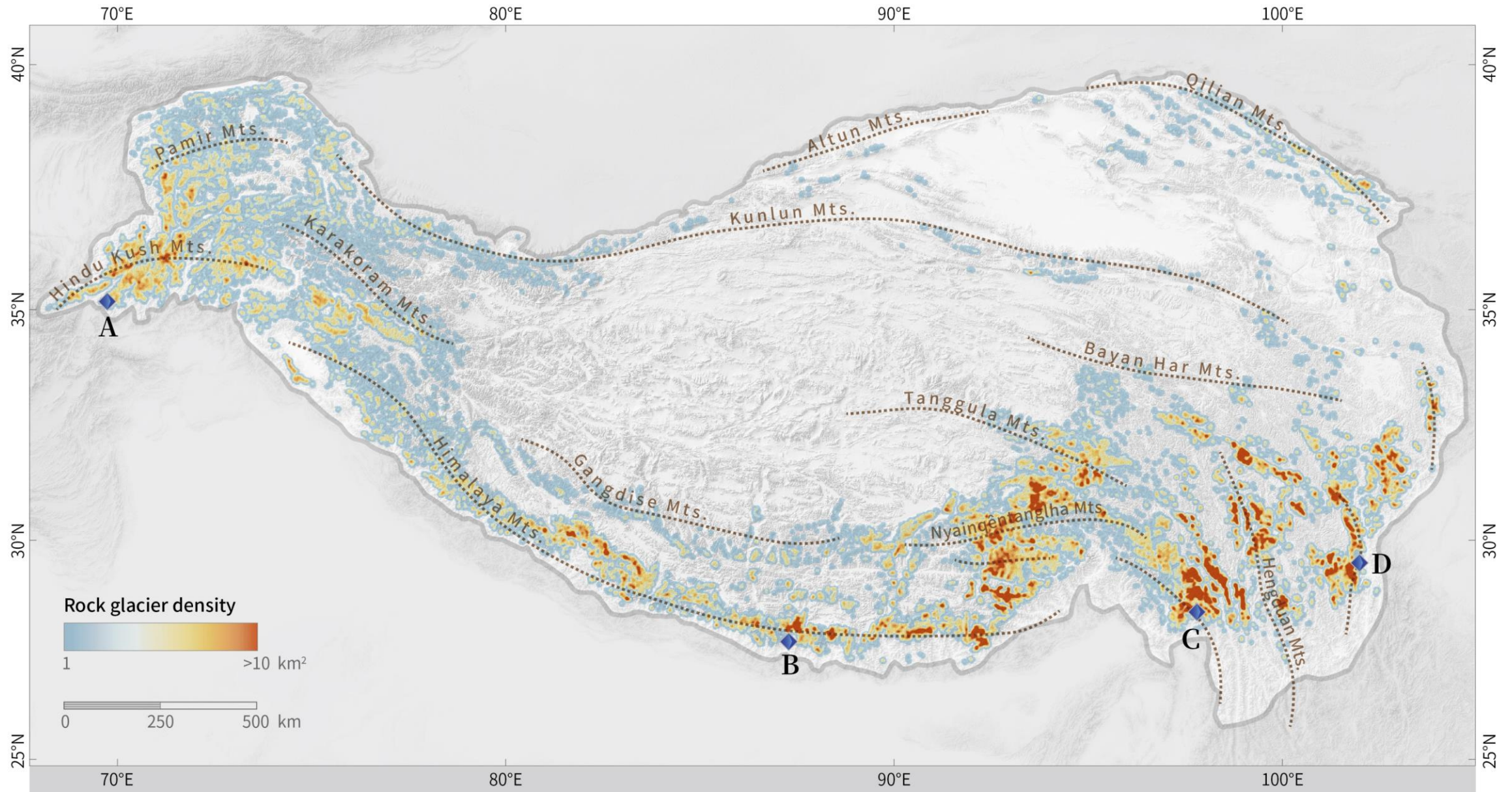
墨脱县



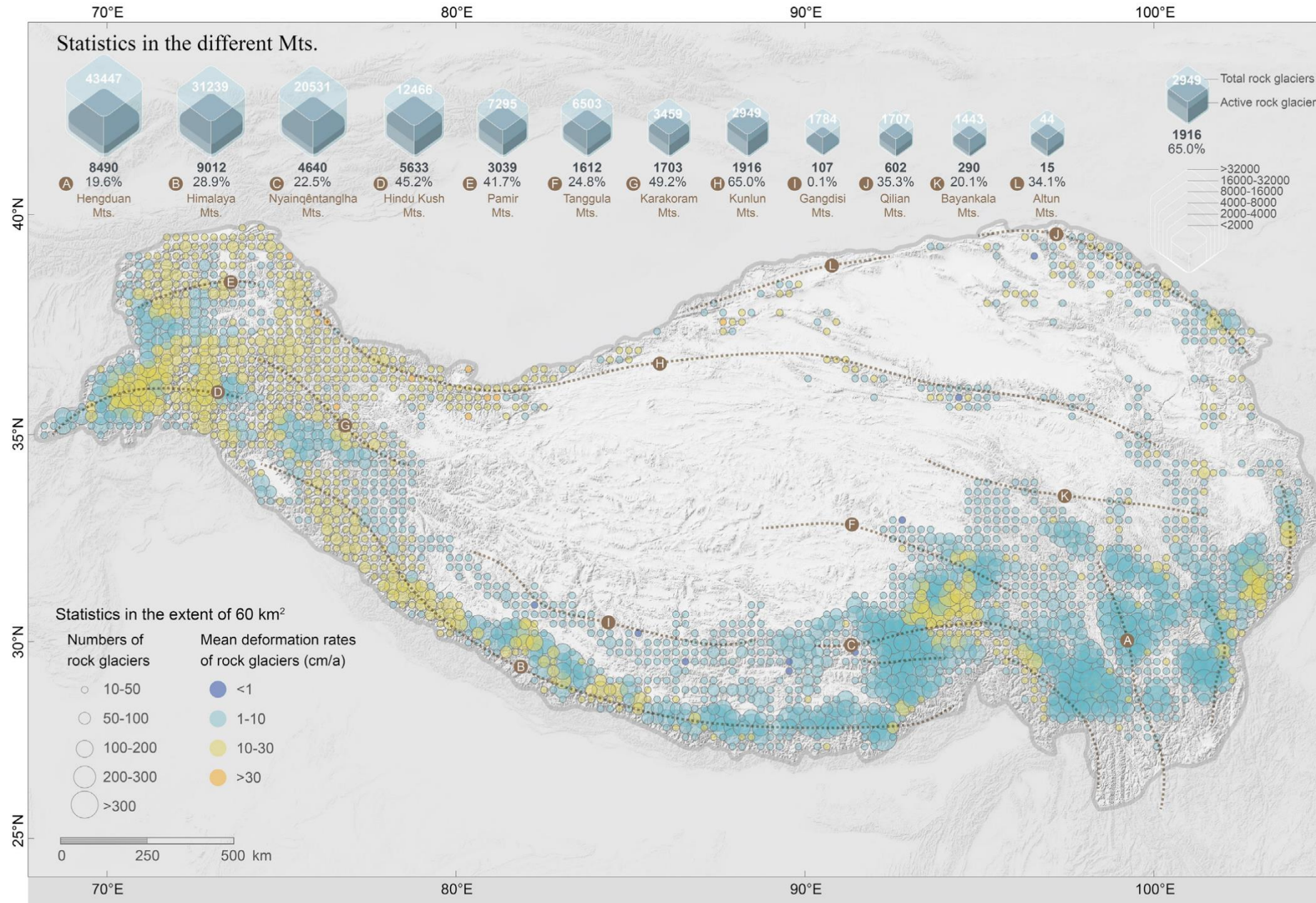
Rock glacier inventory

The first completed inventory rock glaciers for the entire Tibetan Plateau

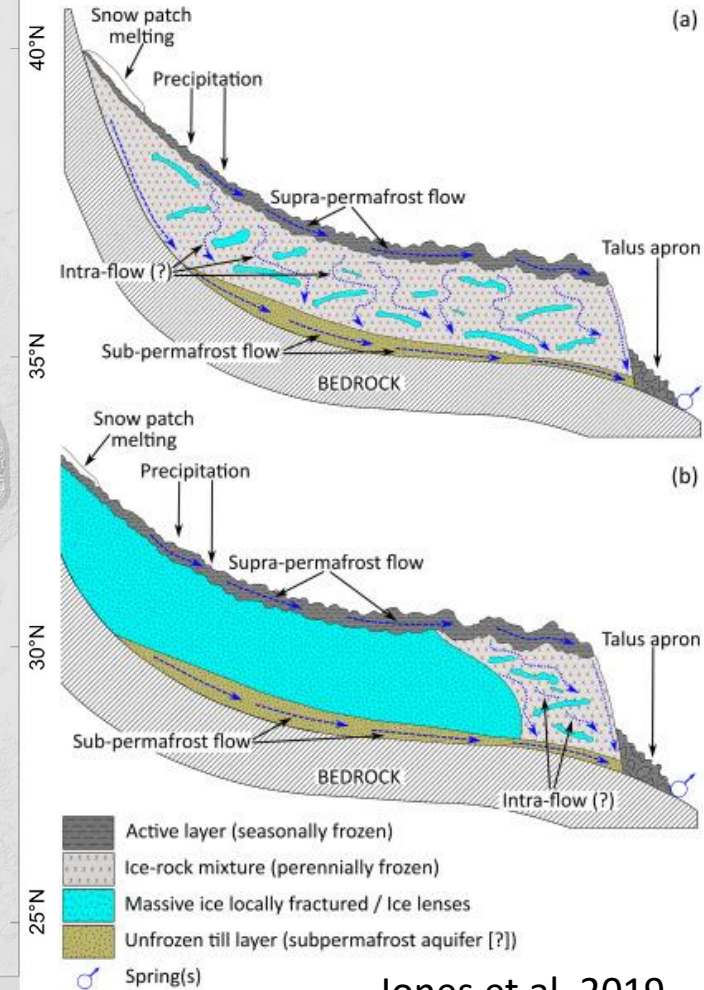
Identified **132,867** rock glaciers



Rock glacier inventory

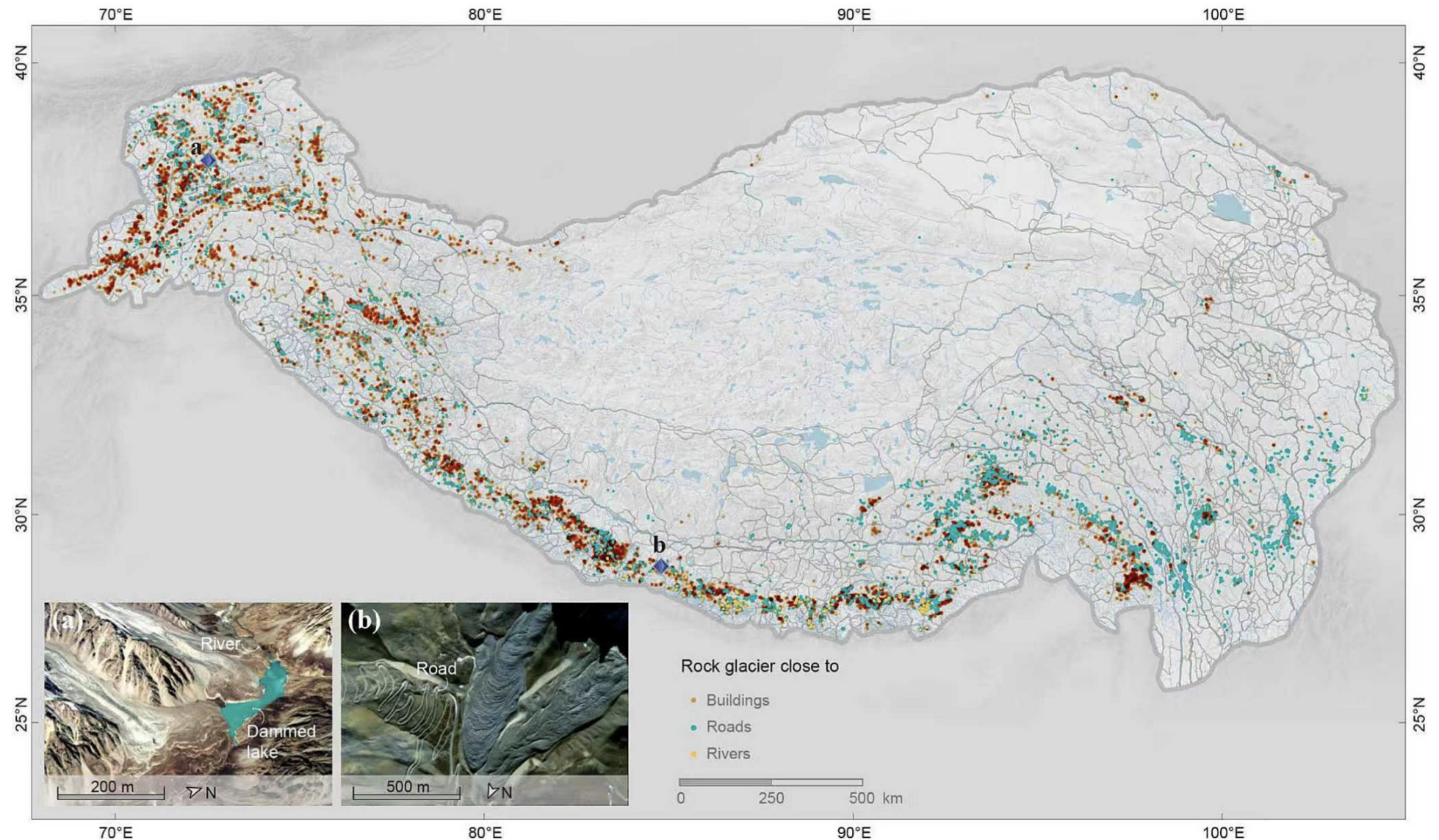


Holds 92 to 186 km³ of freshwater



Rock glacier inventory

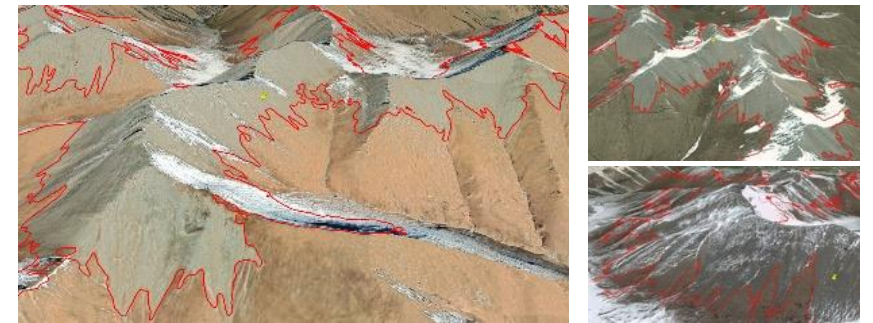
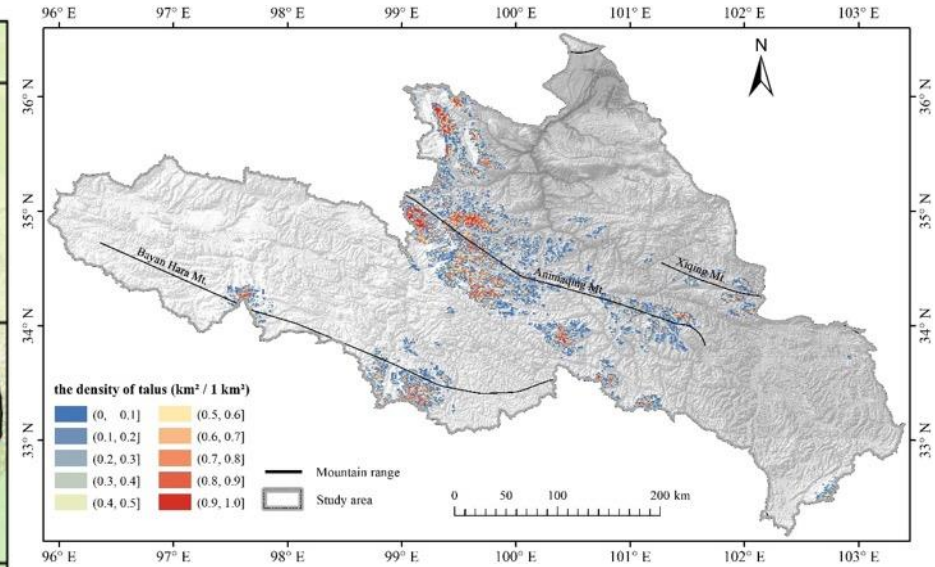
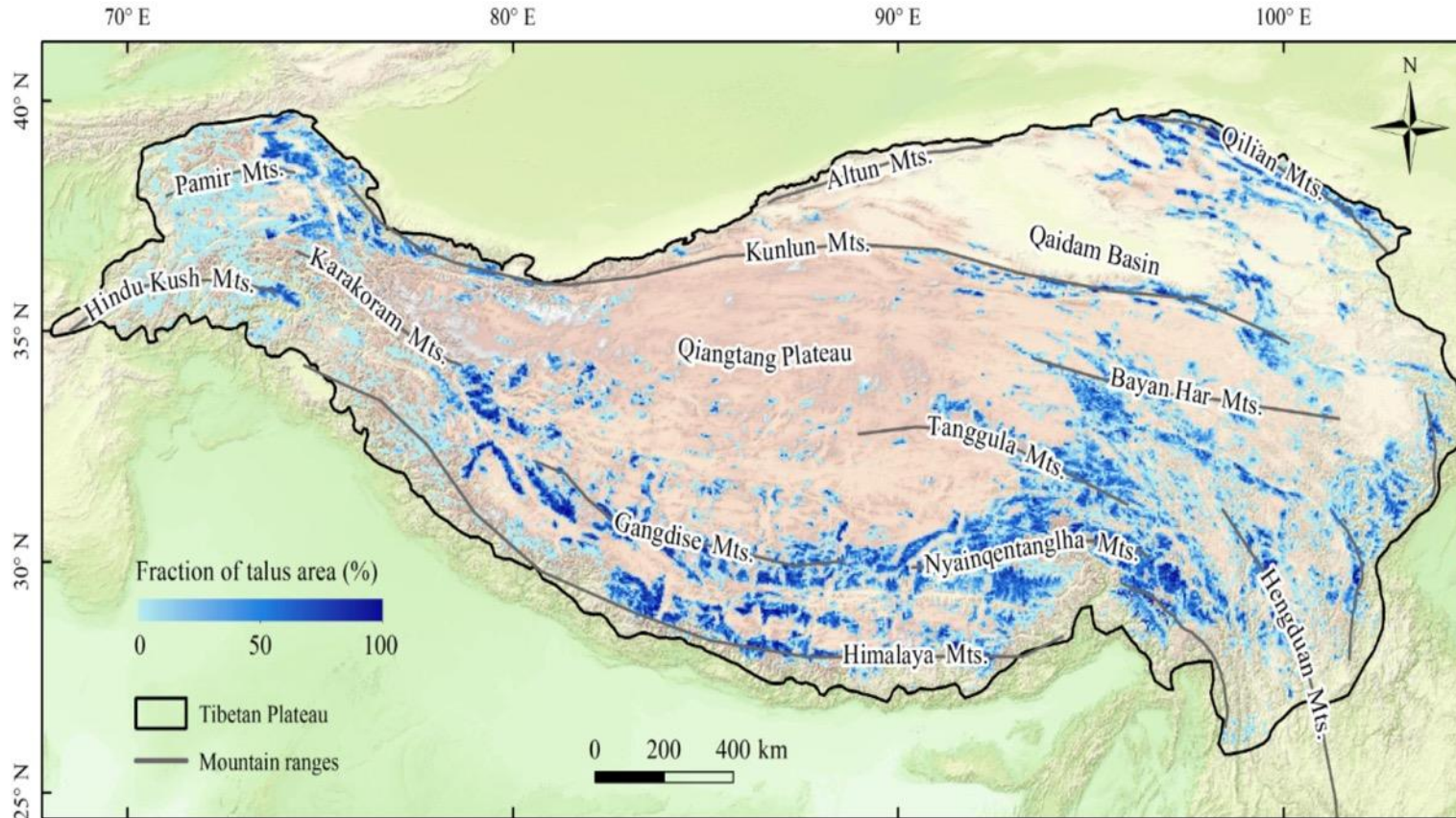
The rock glaciers involve more than 500 km³ material flux, which can lead to hazards



The distribution of rock glaciers located close (within 1 km) to buildings, roads, and rivers

Talus inventory

The first talus inventory for the Tibetan Plateau



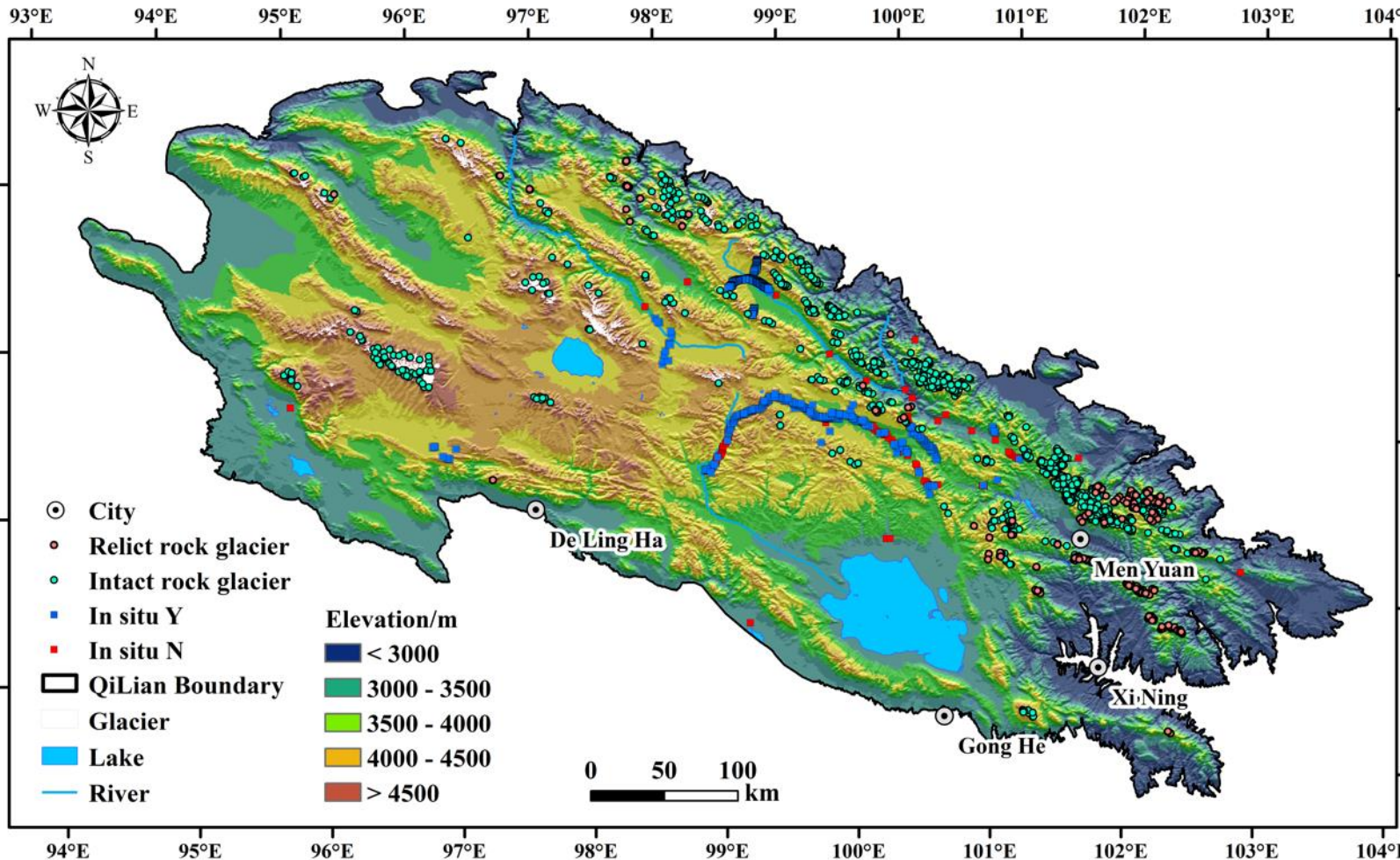
- Identified >65k talus units, with total area > 214k km², about ~6.9% of the plateau.

Examples in the source region of Yellow River

(Jiang, Feng*, *IJDE*, 2025; Jiang, Feng* et al., in prepare)

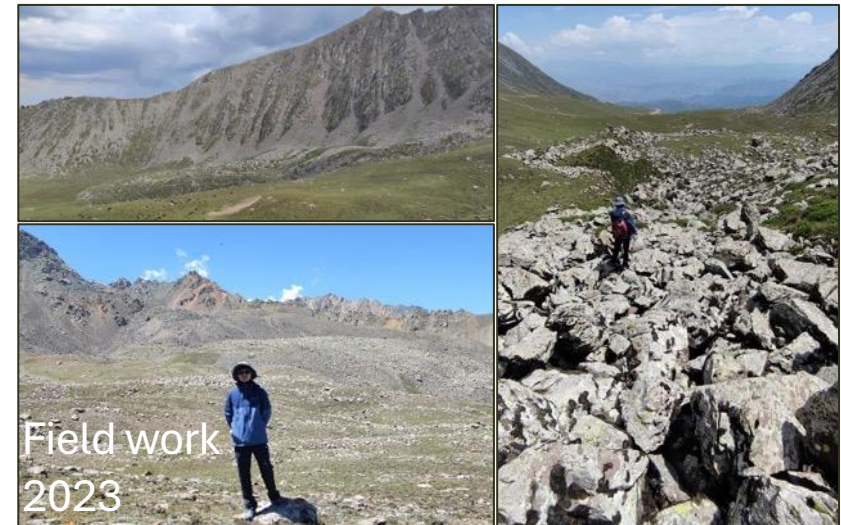
Permafrost mapping with RGI

We combined in-situ and rock glacier records for mapping permafrost in the Qilian Mts.

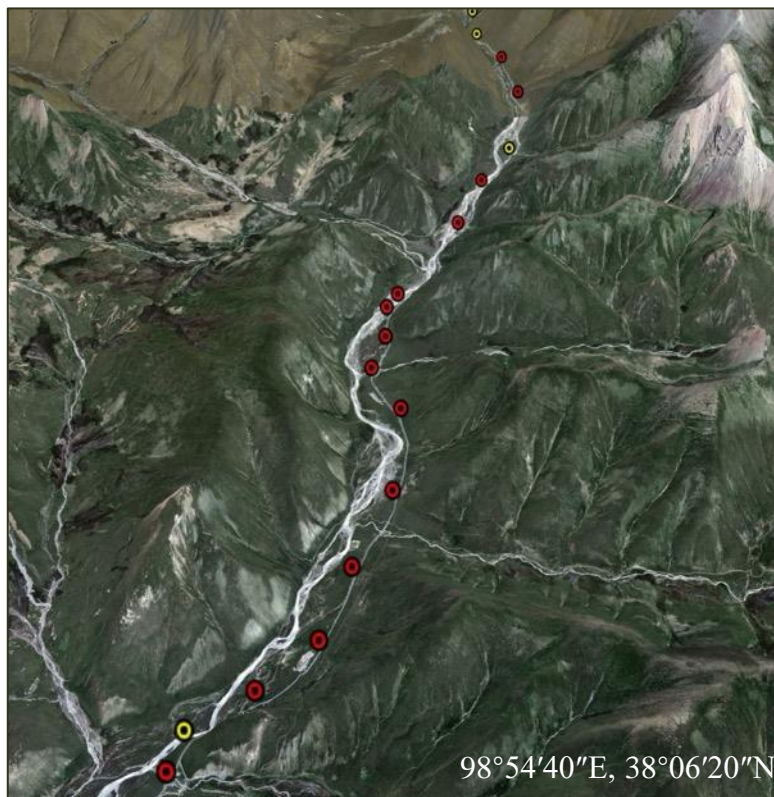


In-situ and rock glacier records

In-situ data (permafrost)	404
In-situ data (non-permafrost)	91
Rock glacier (intact)	1210
Rock glacier (relict)	320



Performance comparison



Borehole

Simulate result

● Permafrost

■ Permafrost

● Non-permafrost

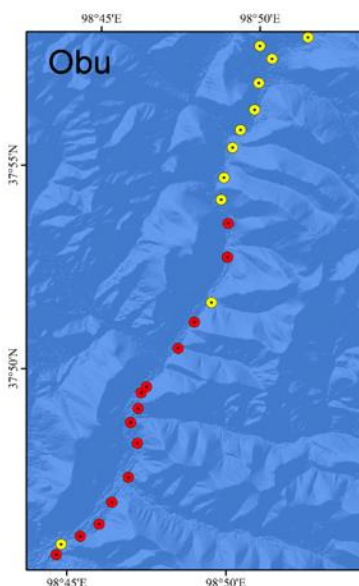
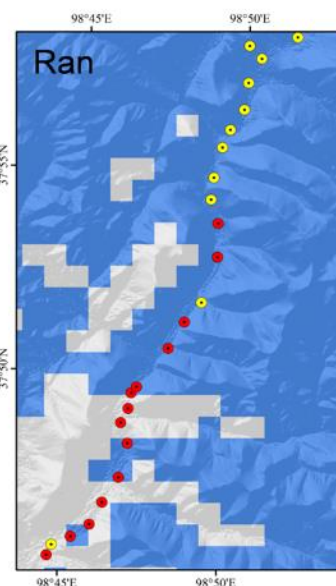
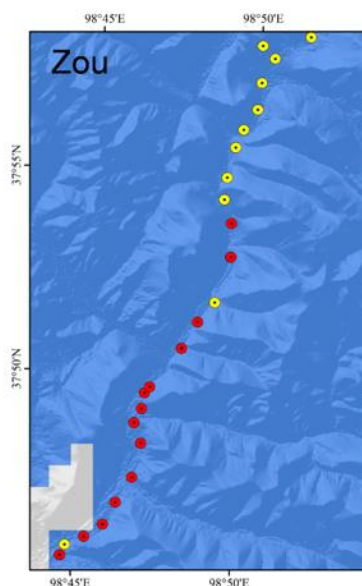
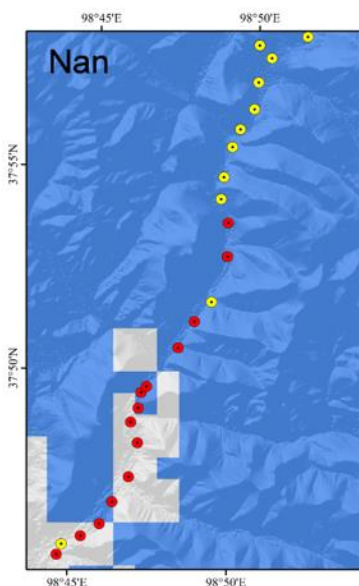
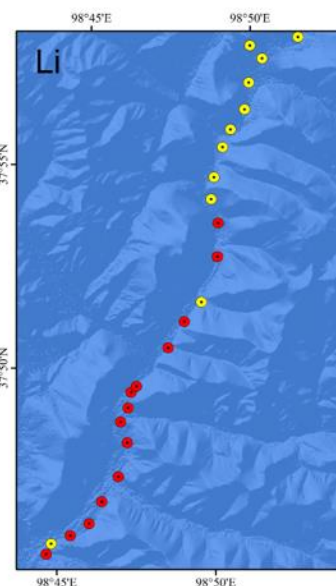
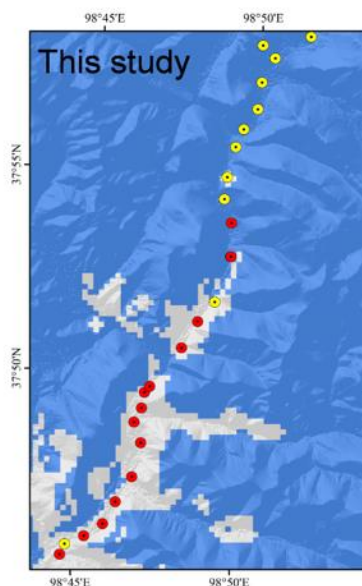
■ Non-permafrost

Li, 1996; Nan et al., 2002 冰川冻土

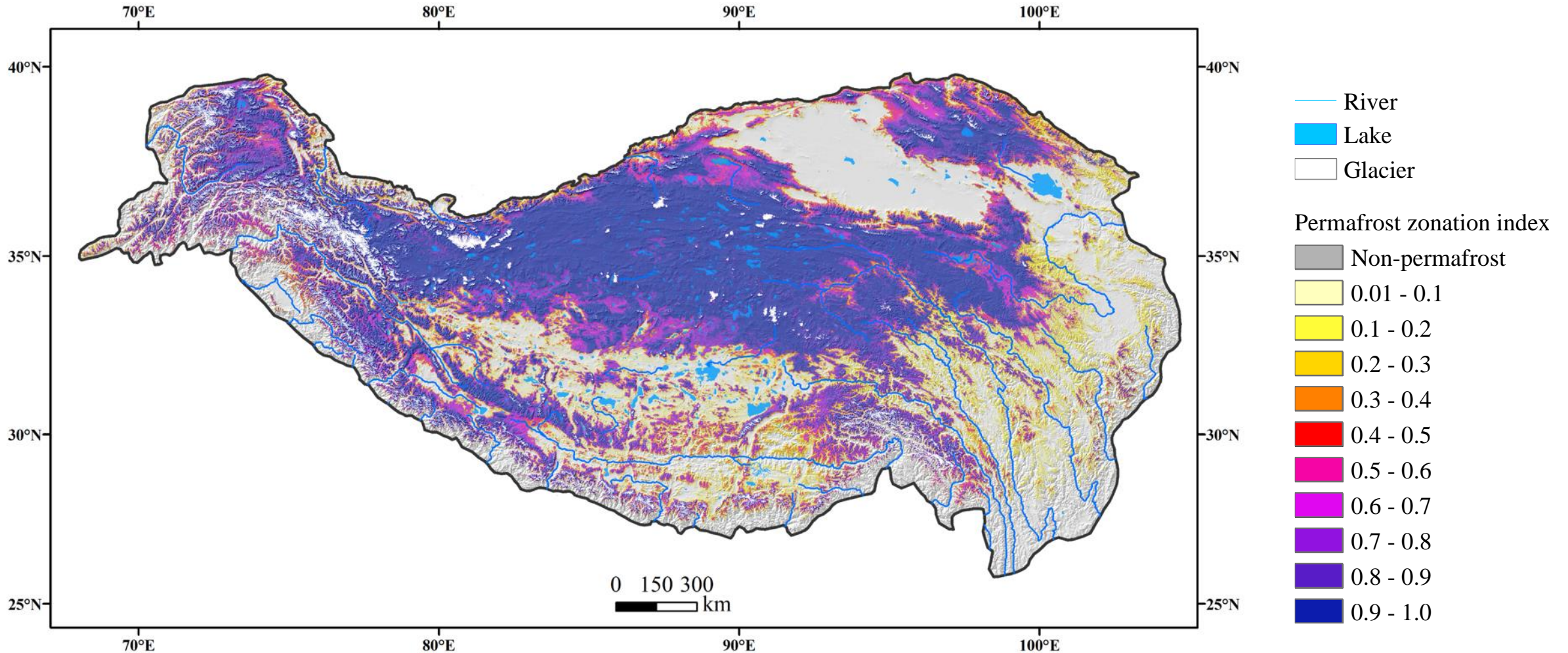
Zou et al., 2017 *TC*

Obu et al., 2019 *ESR*

Ran et al., 2020 *Science China Earth Sciences*



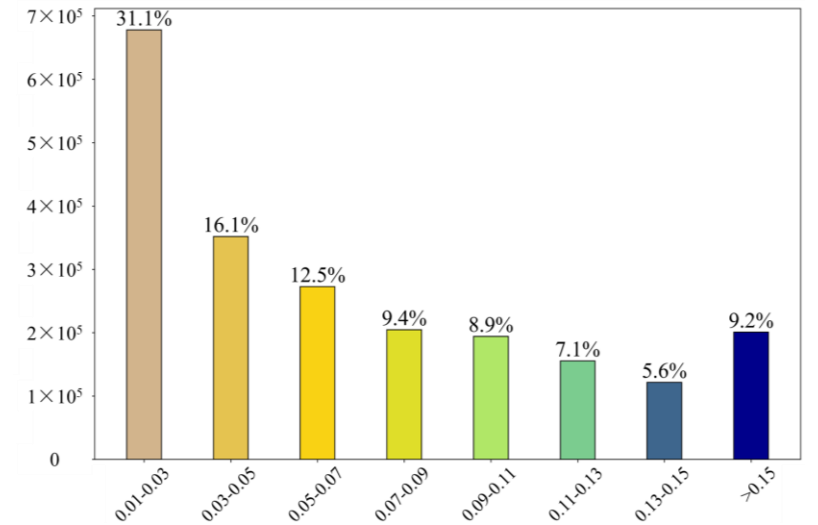
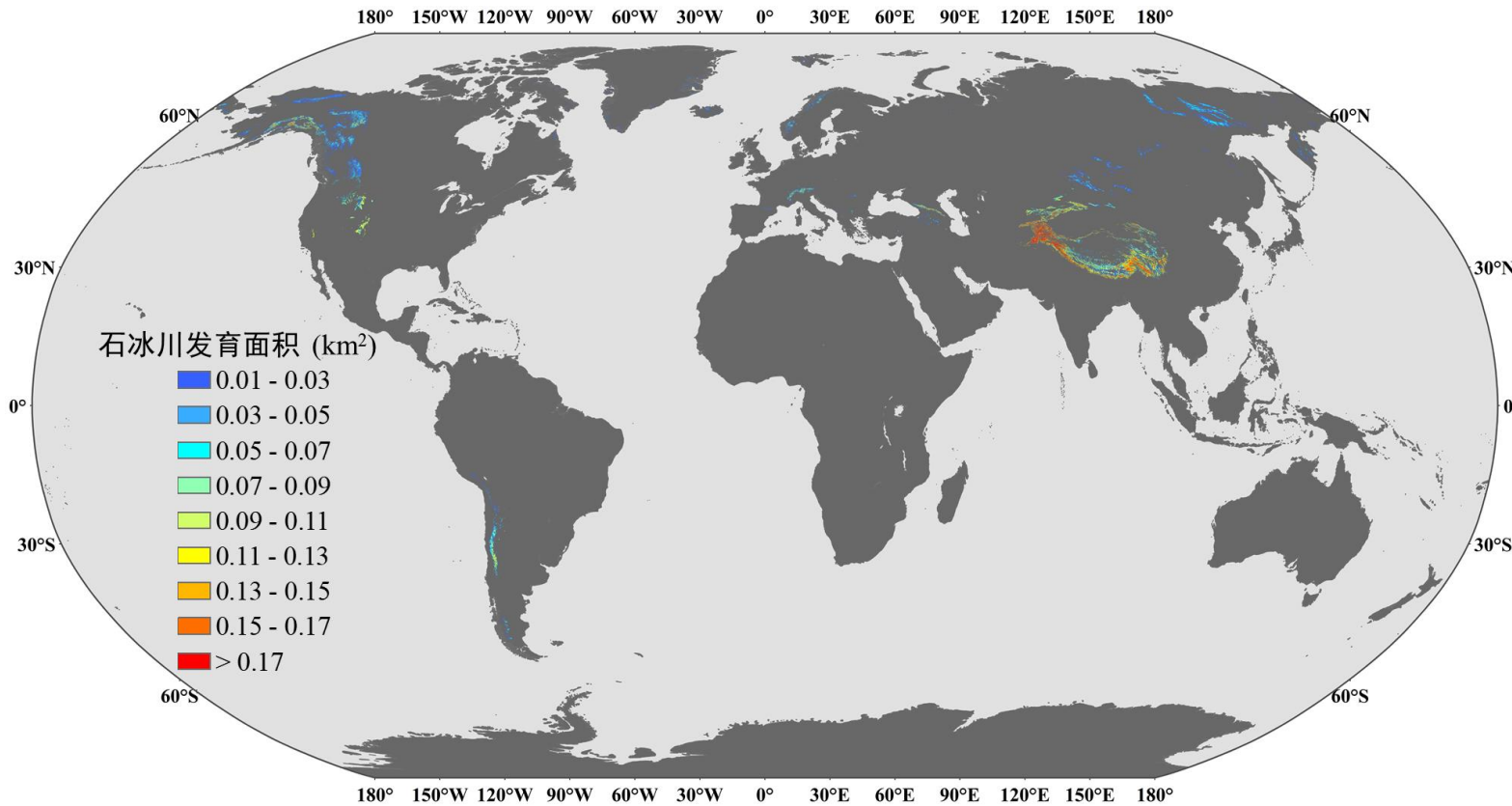
Expanding permafrost mapping to TP



Our preliminary result shows that the total area of permafrost on the Tibetan Plateau is $1.18 \times 10^6 \text{ km}^2$ ($\text{PZI} \geq 0.5$), accounting for 38.1% of the total area.

Global rock glacier inventory

- ❑ Collected >60,000 published rock glacier inventory data entries
- ❑ Estimated the global rock glacier developed area (RDA) to be $141.08 \times 10^3 \text{ km}^2$



Percentage of total cover across various size ranges of RDA

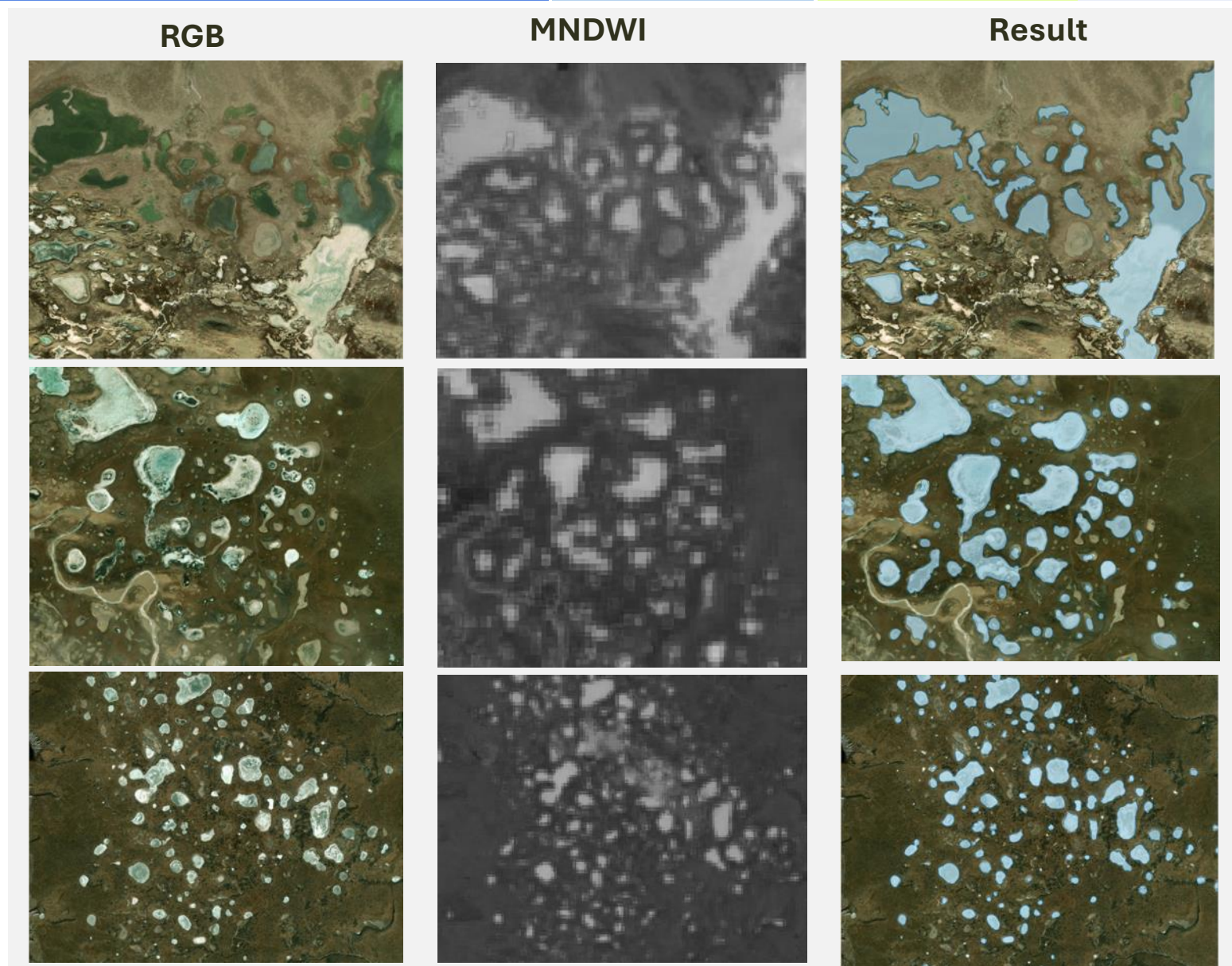
Thermokarst lakes



Source region of the Yellow River

Deep learning and high-resolution satellite data were adopted to identify thermokarst lakes

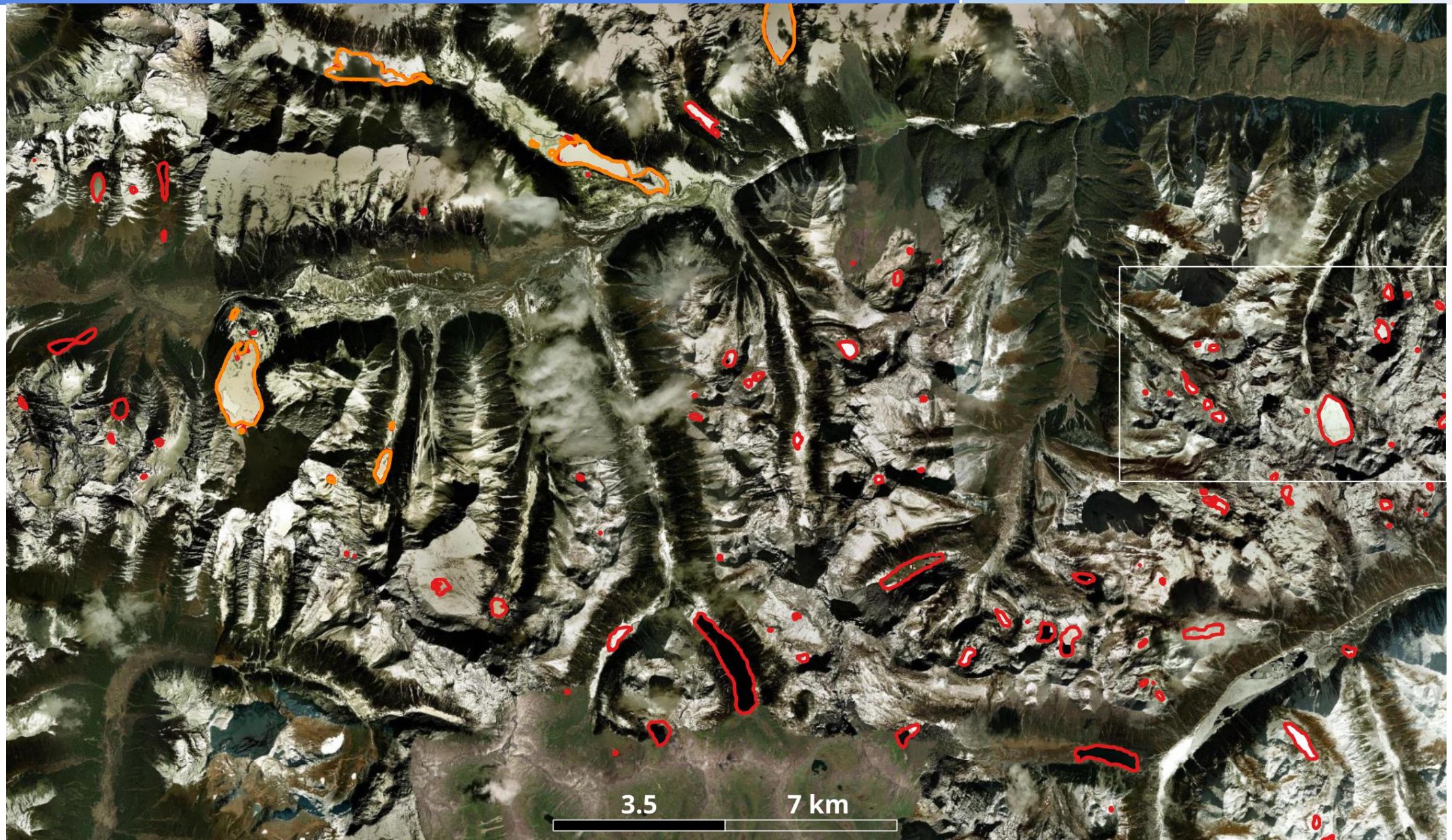
Zhang, Feng*, et al. 2024



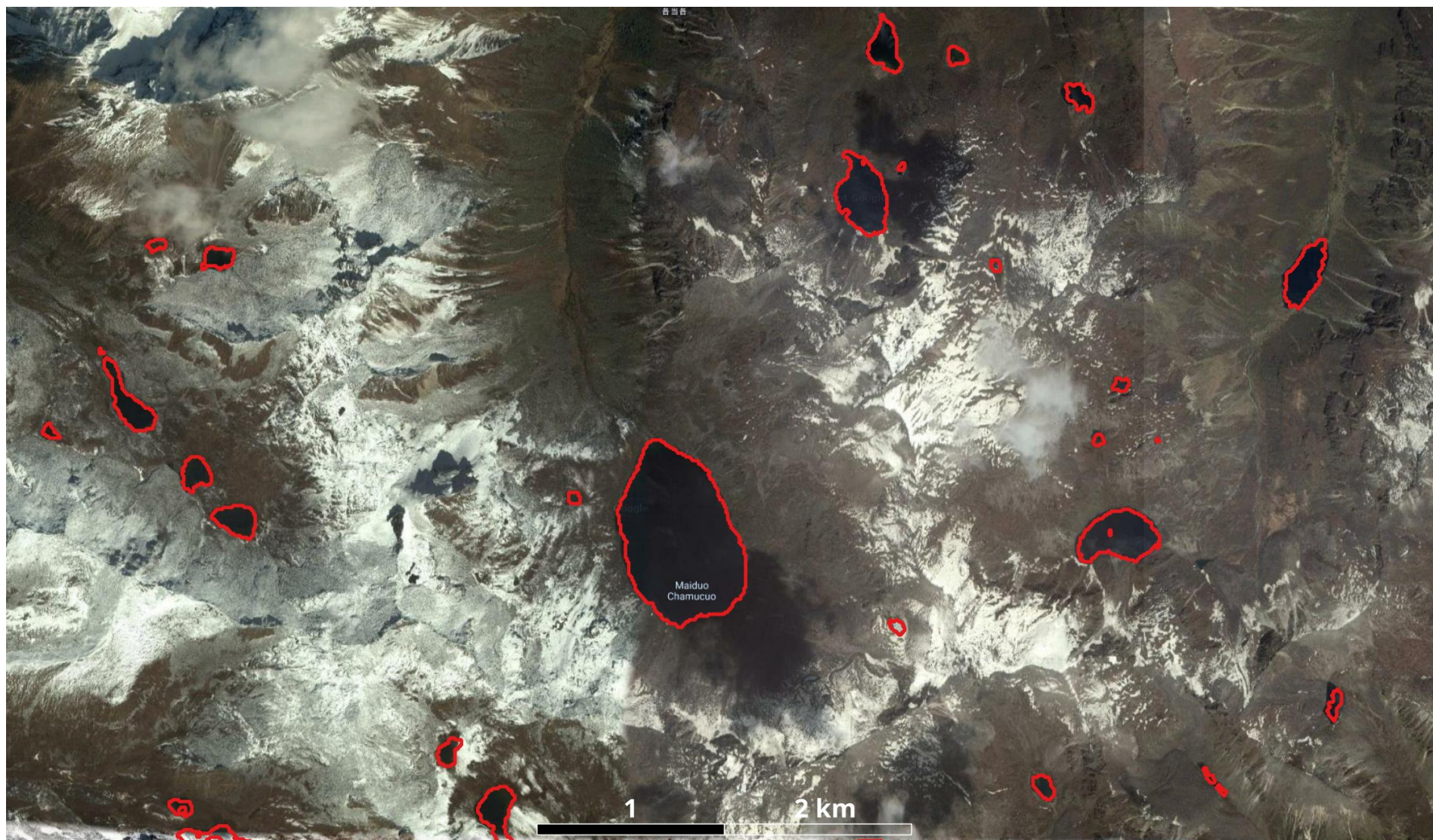
Glacial lakes



Glacial lakes

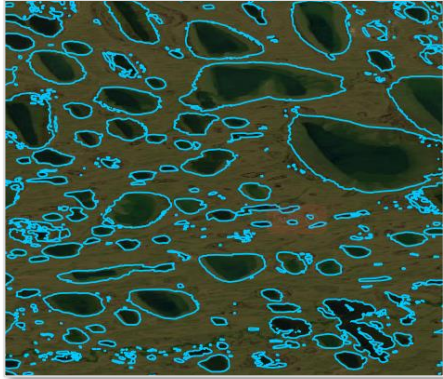


Glacial lakes



(Xu, Feng* et al., 2023; Hu, Feng* et al. 2025; Xu, Feng*, *The Cryosphere*, accepted)

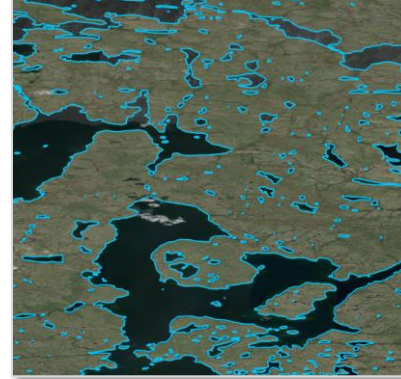
Water bodies in pan-Arctic



70.3158, -155.5385

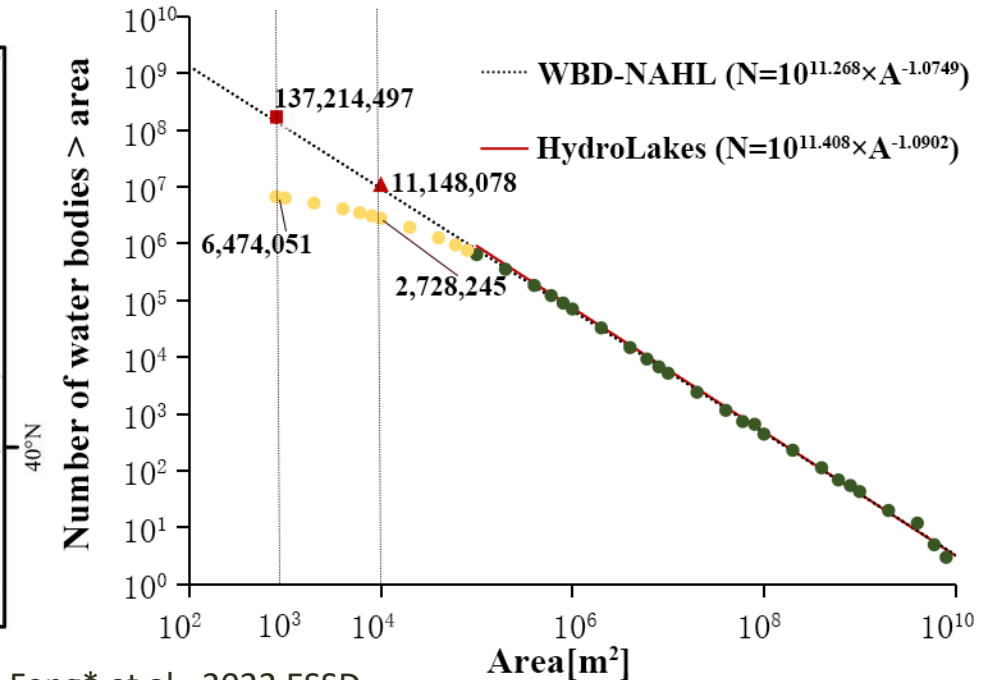
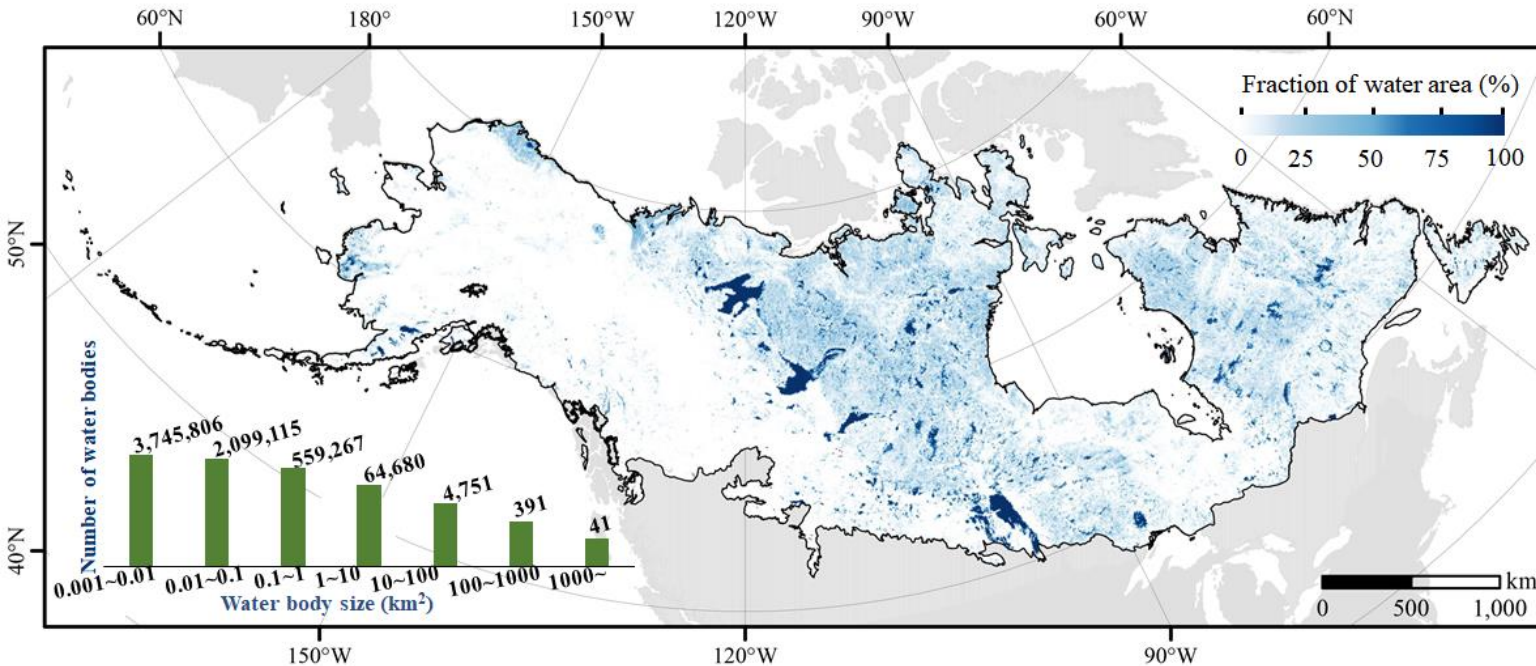


61.5661, -145.9790



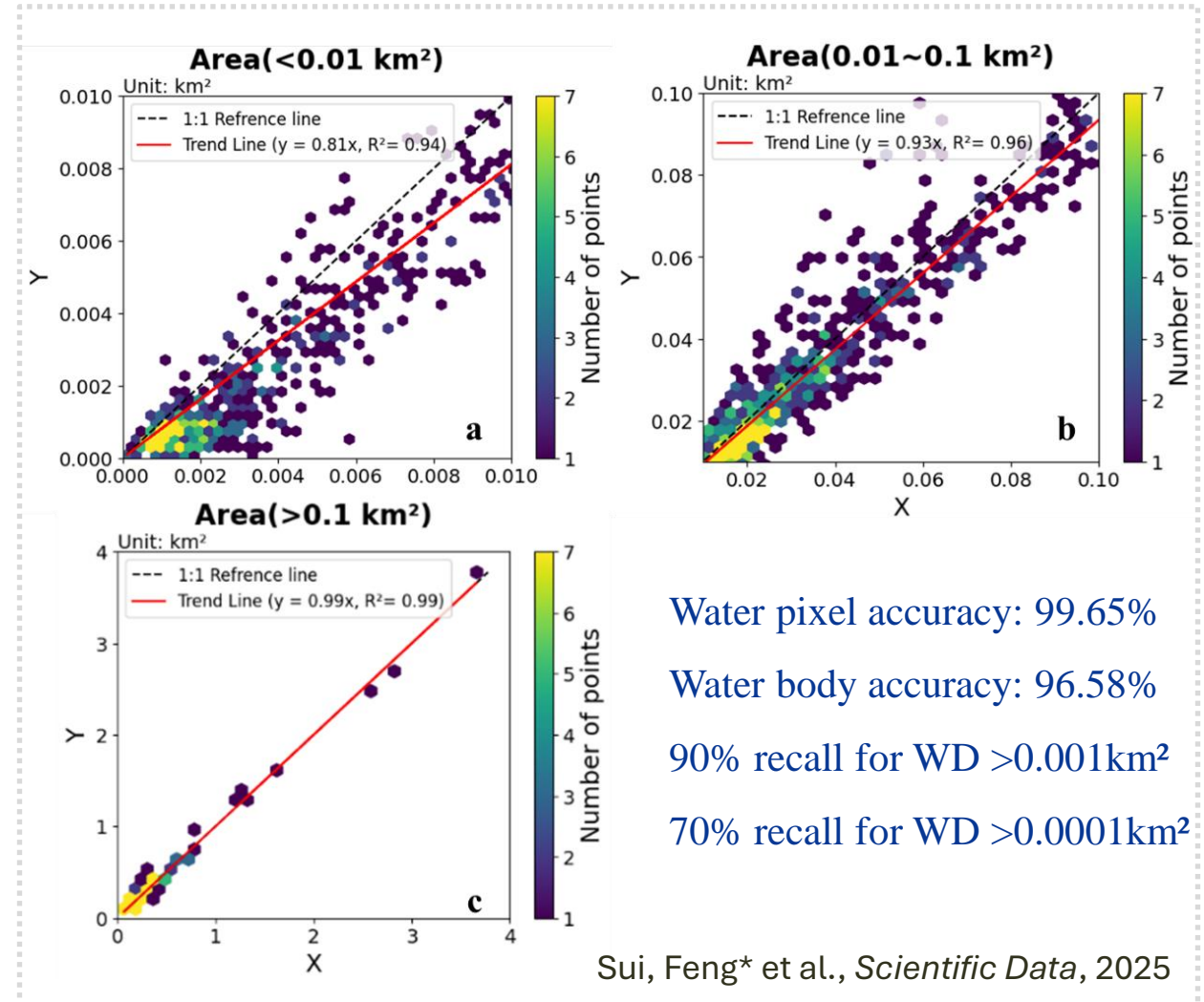
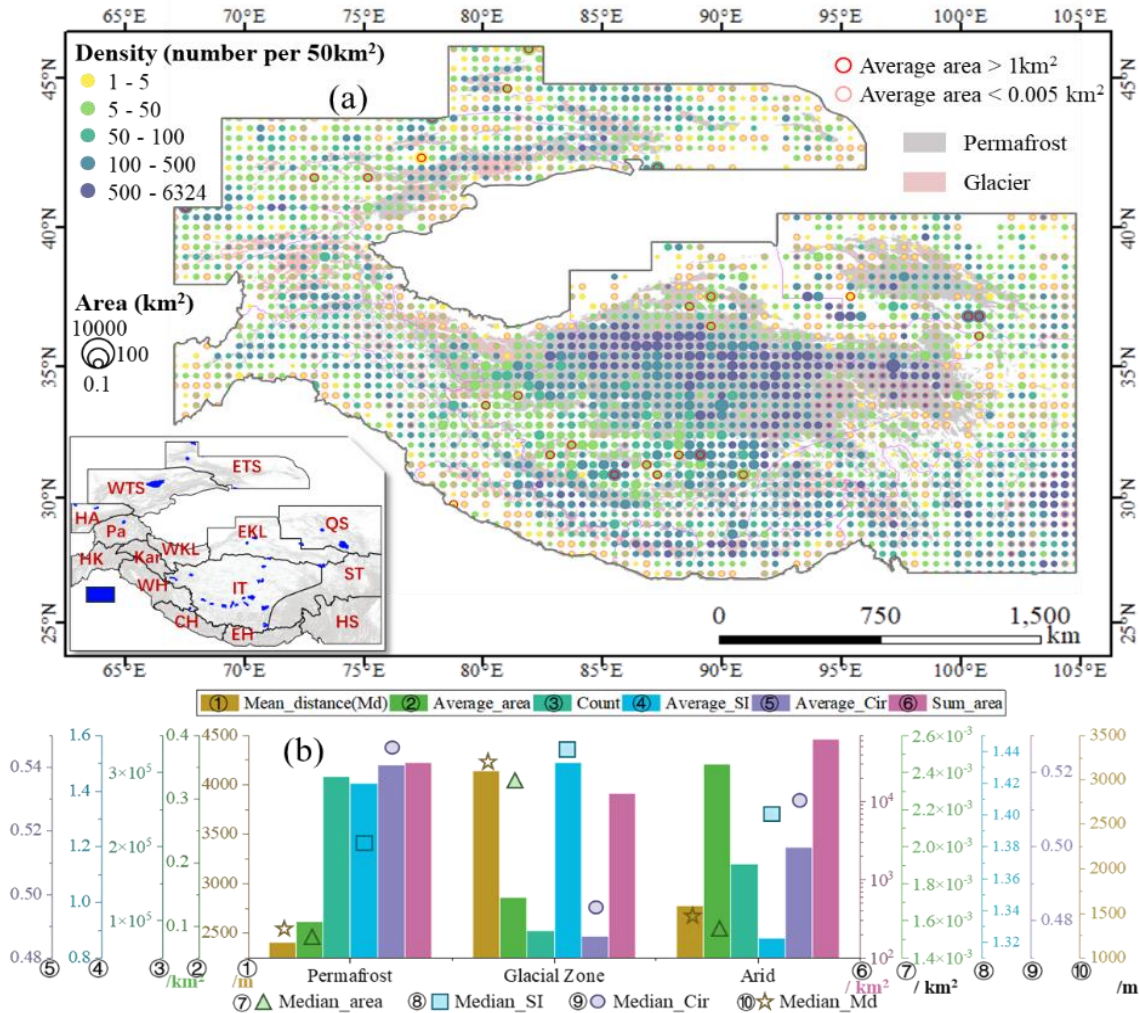
63.9350, -109.2828

- ❑ A more completed inventory of water bodies for pan-Arctic region in North America
- ❑ Identified >650 million water bodies and 90% of them are smaller than 0.1 km²
- ❑ Evidence of overestimation of the area-number relationship



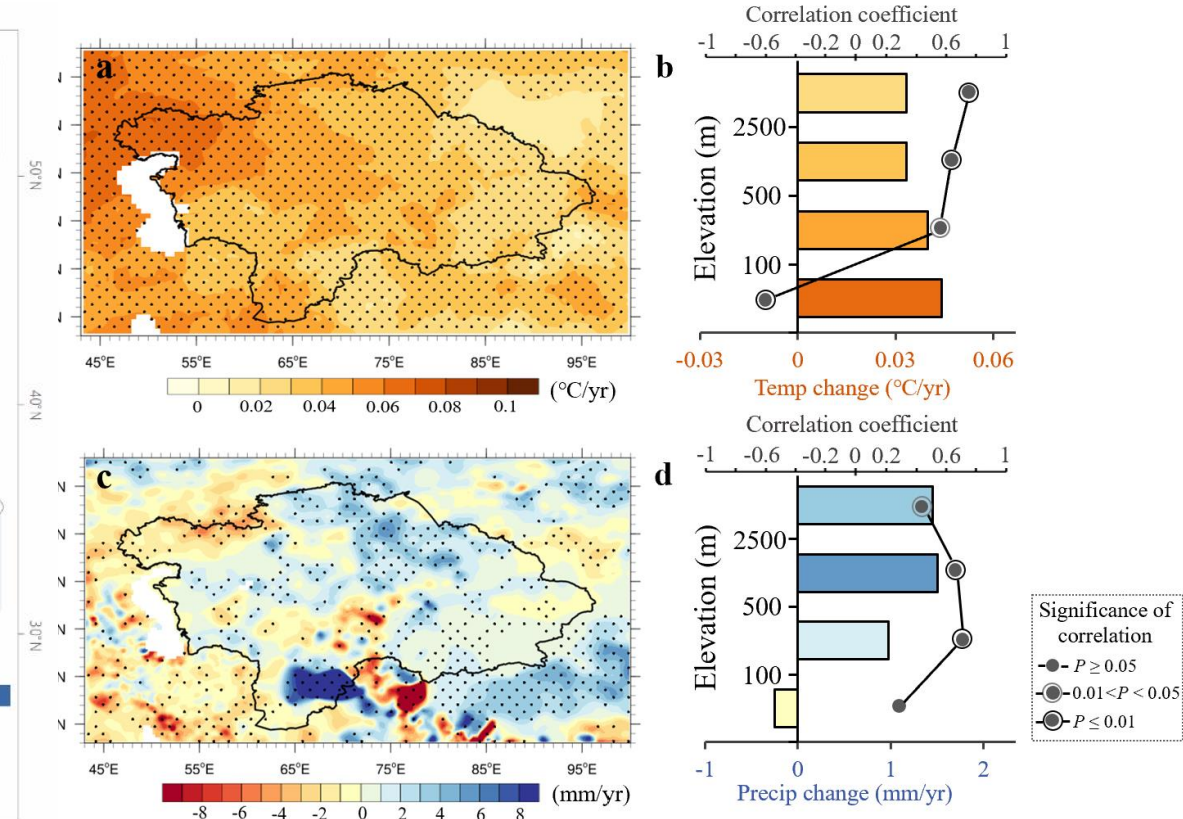
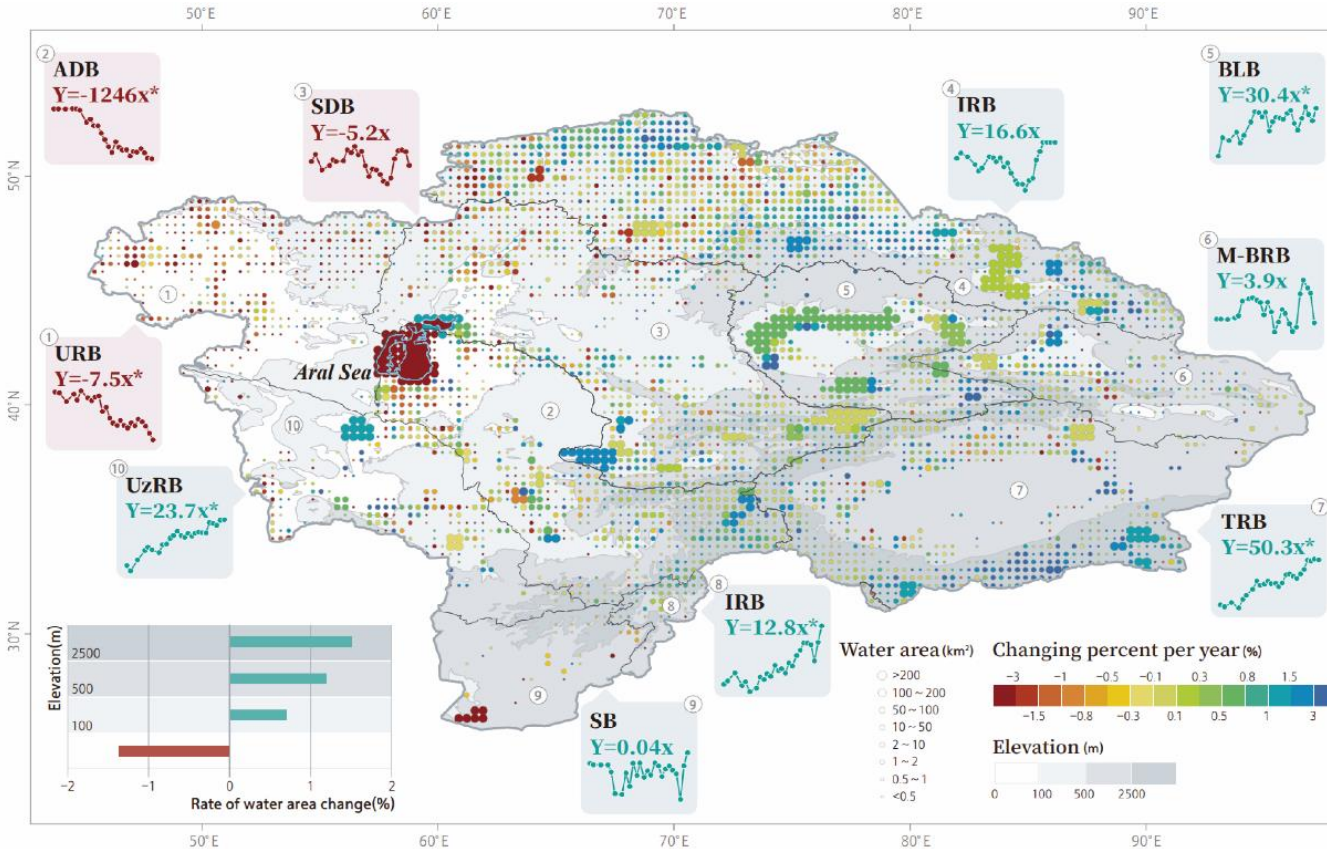
Water body inventory

The water body inventory for high mountain Asia (WBD-HMA), identified >460k water bodies, covering 76,915.9 km²



Water body changes in central Asia

Identified 66,216 water bodies in central Asia with a total area of 98,161.8 km² and 96.5% are smaller than 1 km²

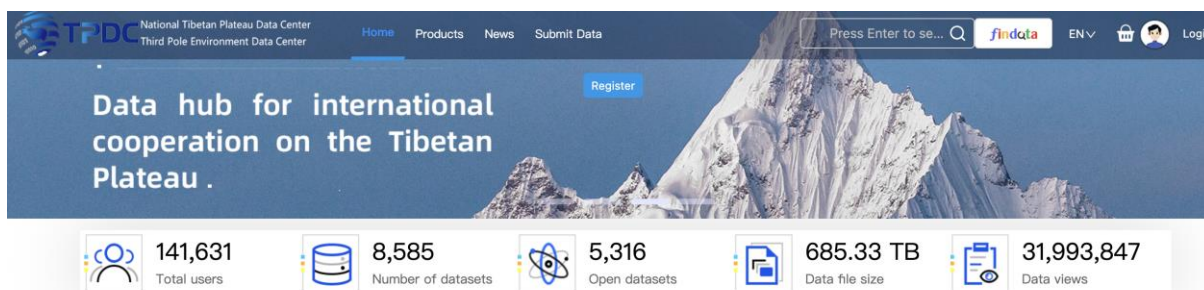


Between 1992 and 2020, the Aral Sea had been shrinking, but other water bodies had been generally expanding and increasing, especially the small water bodies in high altitudes

Evidence for a warm-wet climate in central Asia, critical for correcting the perception of water resources in the region biased by the Aral Sea


Data access

<https://data.tpdc.ac.cn/>




National Tibetan Plateau Data Center
Third Pole Environment Data Center


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Register


Data hub for international cooperation on the Tibetan Plateau .

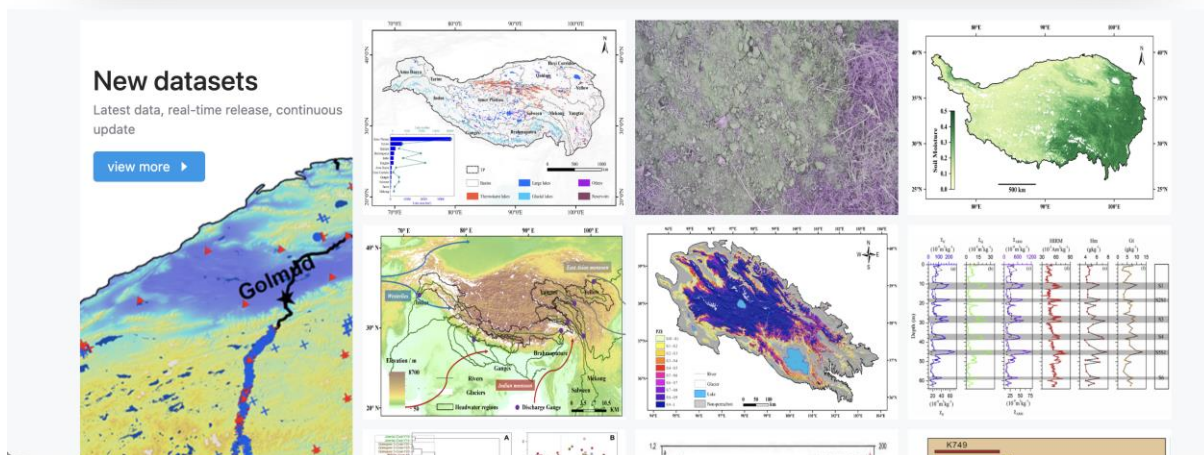
 141,631 Total users

 8,585 Number of datasets

 5,316 Open datasets

 685.33 TB Data file size

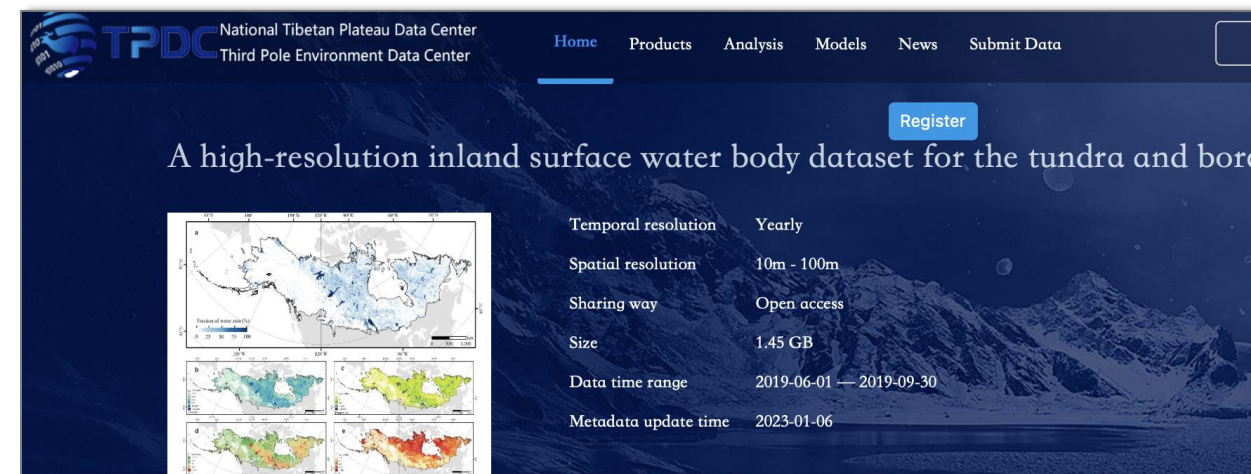
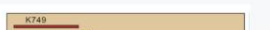
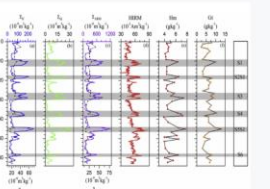
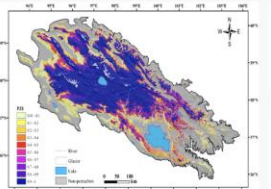
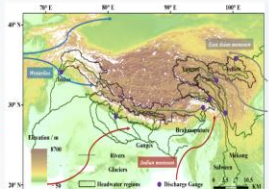
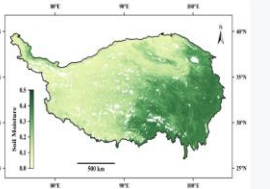

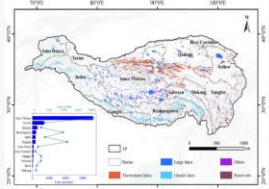
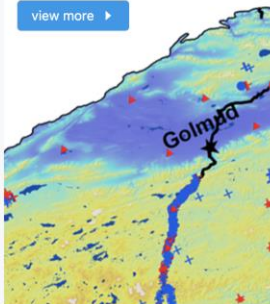
 31,993,847 Data views



New datasets

Latest data, real-time release, continuous update

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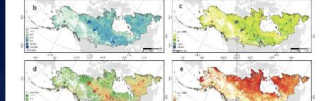
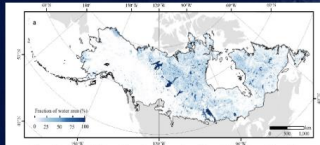


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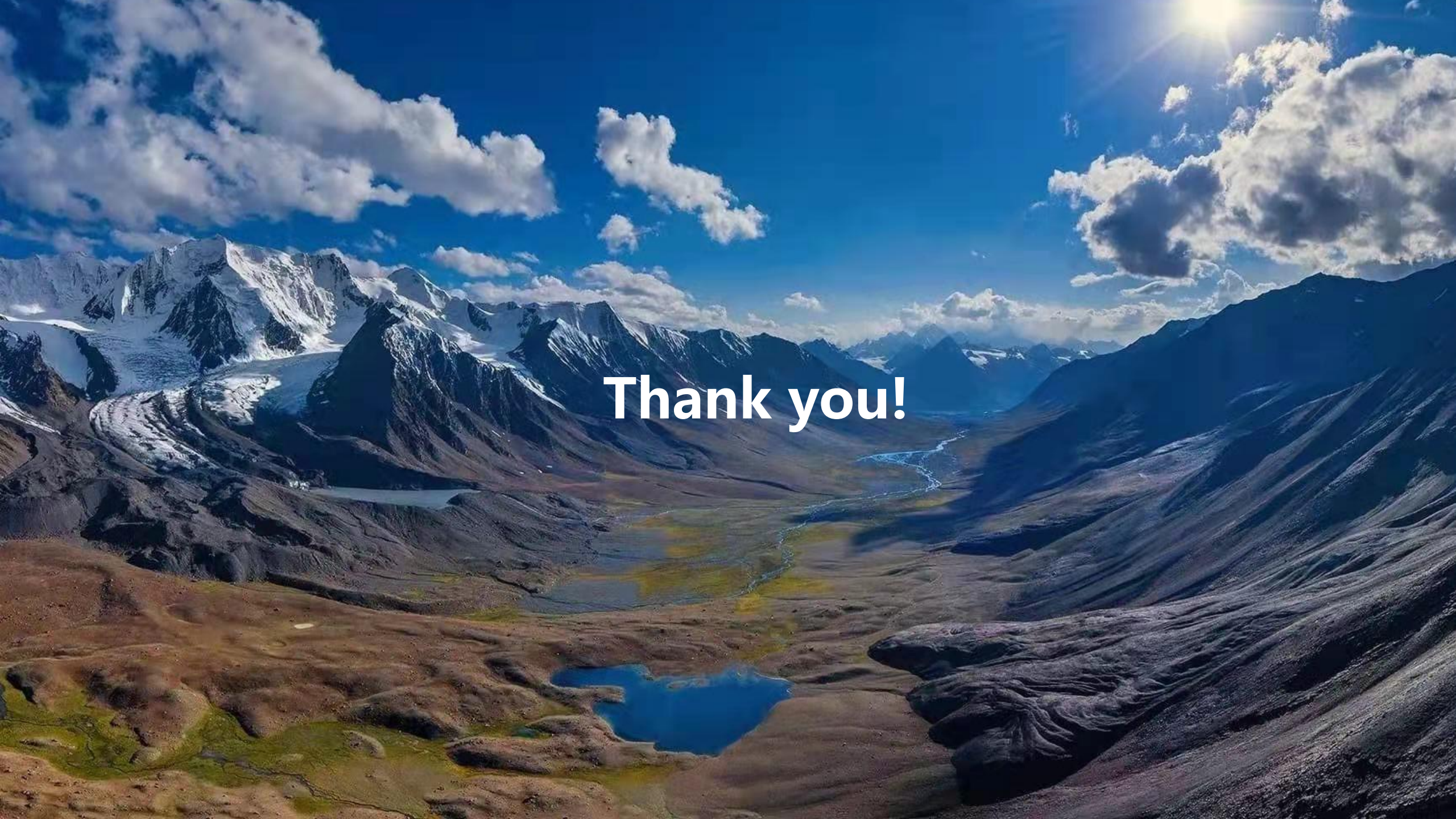
A high-resolution inland surface water body dataset for the tundra and boreal forest regions in North America



Temporal resolution	Yearly
Spatial resolution	10m - 100m
Sharing way	Open access
Size	1.45 GB
Data time range	2019-06-01 — 2019-09-30
Metadata update time	2023-01-06

Datasets Summary

The circumpolar boreal and tundra biomes are the highest concentrations of the global inland water bodies, including lakes, reservoirs, and ephemeral ponds. The majority of these water bodies are small-sized but enormous in number. These small water bodies are essential to global greenhouse gas emissions; however, they are vulnerable to climate change, and little has been known. Thus, it is critical to investigate water bodies in this highly concentrated region, especially the small water bodies. This study presented a comprehensive dataset of water bodies for the tundra and boreal biomes in North America (WBD-NAHL). The 10-m resolution Sentinel-2 and the 30-m resolution JRC water dataset were adopted as the main inputs to enhance the ability on identifying small water bodies (Figure 1). The main contributions of this dataset are as follows: 1) the first investigation of water bodies in the tundra and boreal biomes in North America. Nearly 6.5 million water bodies were identified, about 90% of which were smaller than 0.1 km²; 2) this dataset provides the locations, areas, and morphological attributes for each water body, enabling the analysis of water body distribution, types, and more, which is expected to support studies in the water cycle, carbon emission, and permafrost in high latitudes under global climate change. Figure 1: Distributions of the percent (a), area (b), perimeter (c), and SI (d), and the number (e) of the water bodies in the North American tundra and boreal forest regions (aggregated to 5 km × 5 km grids). This work



Thank you!