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Chinese Academy of Sciences

Glacier monitoring and research on the southeastern Tibetan Plateau

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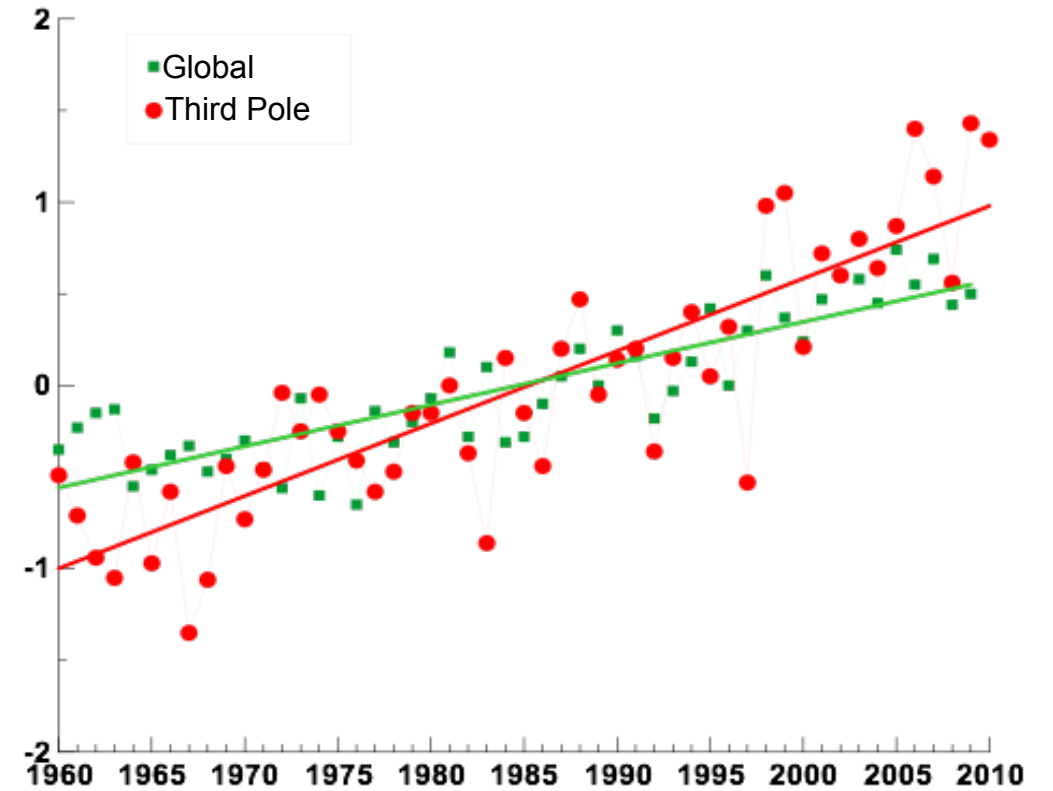
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2025.6.27

Climate warming on the Third Pole



Tibetan Plateau and its surroundings is the highest plateau on the earth, holding the third largest volume of freshwater on the planet and often referred to as “The Third Pole”



Temperature rising rate reach to $\sim 0.4^{\circ}\text{C}/10\text{year}$, which is twice higher than the global average

Sensitive and visible indicator of climate change



1921

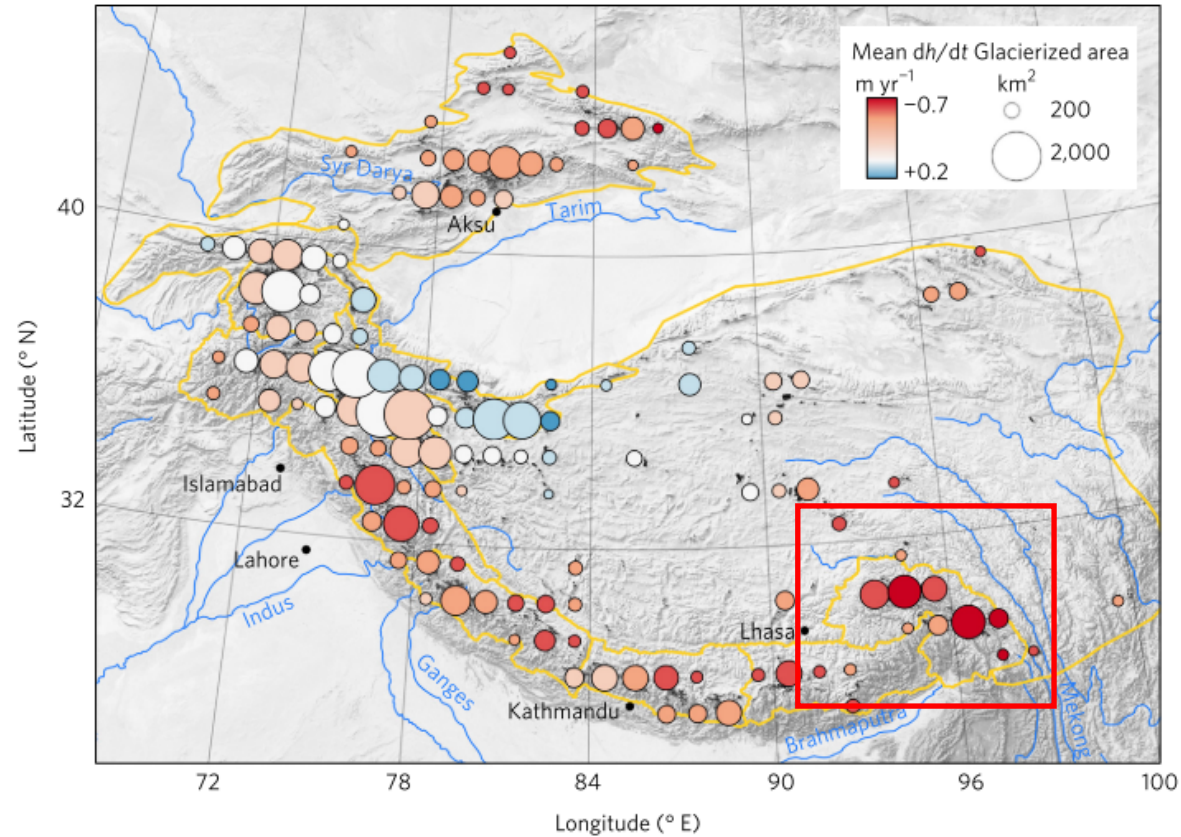
(photo by Major E.O. Wheeler)



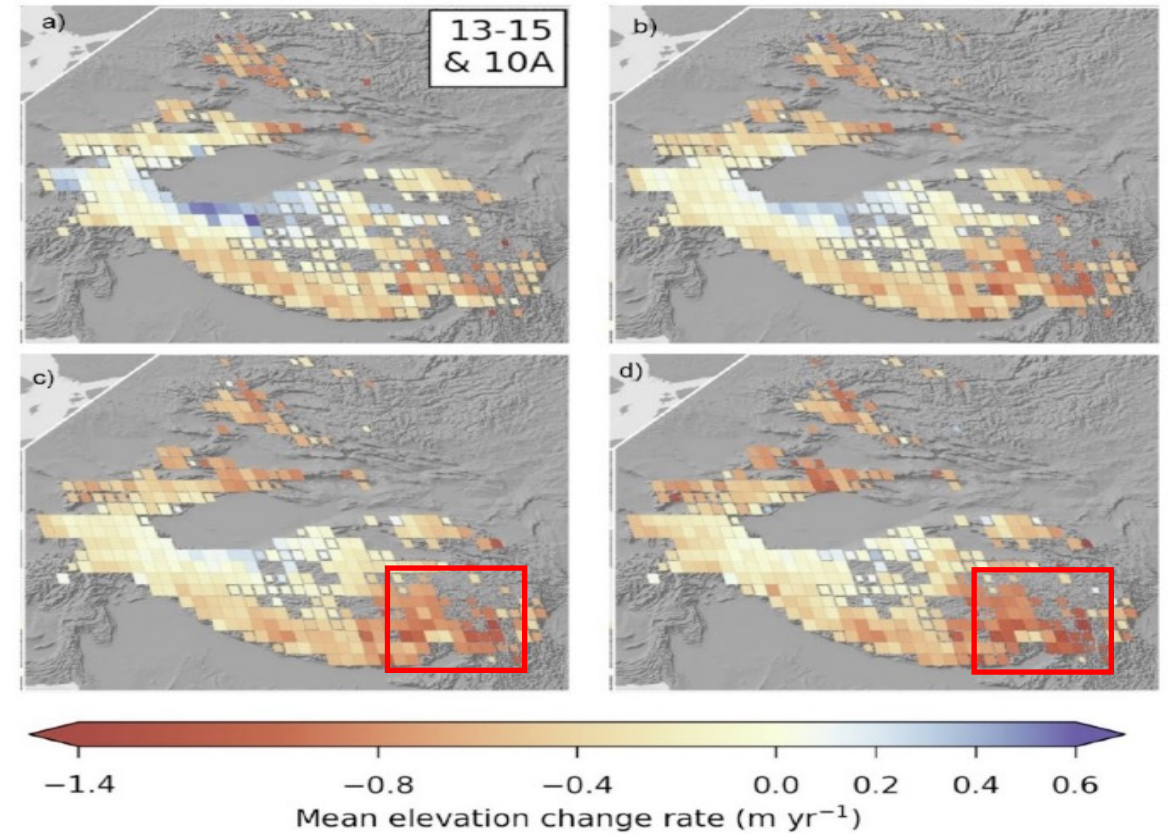
2023

(photo by Wei Yang)

Heterogeneous glacier mass change since 2000



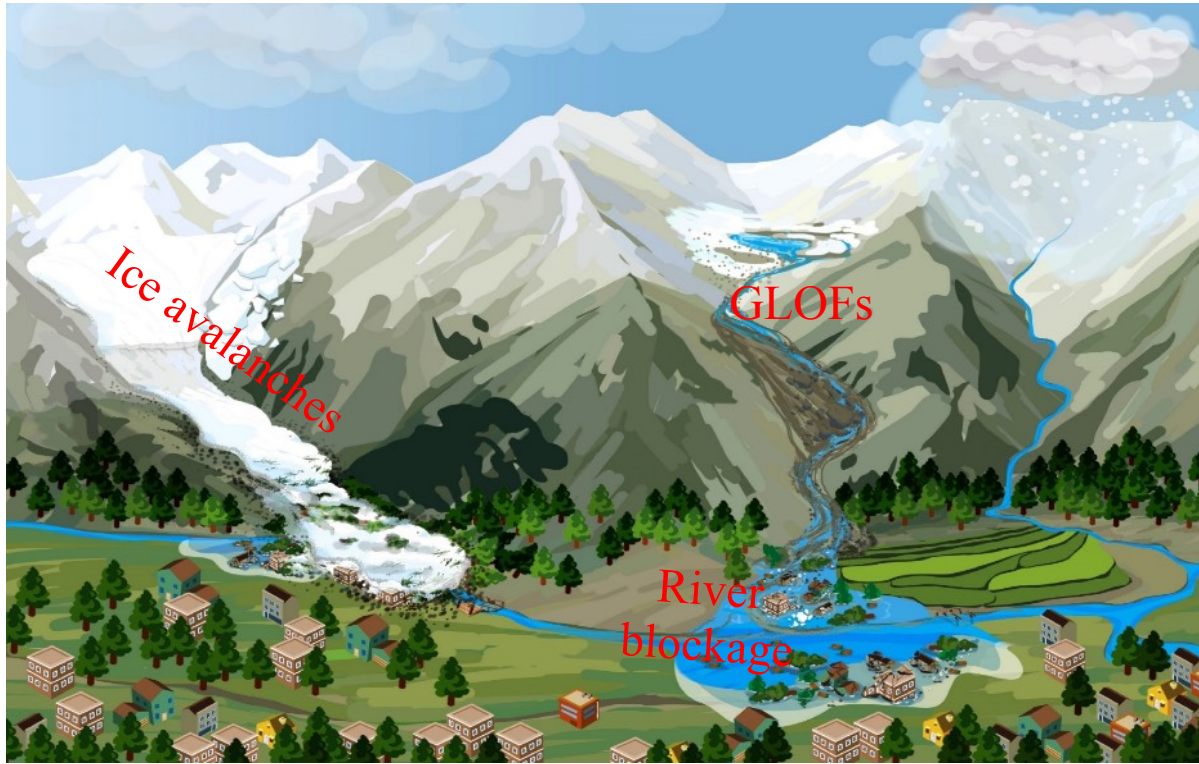
Glacier mass change during 2000-2016 (Brun et al., 2017)



Glacier mass change during 2000-2019 (Hugonnet et al., 2021)

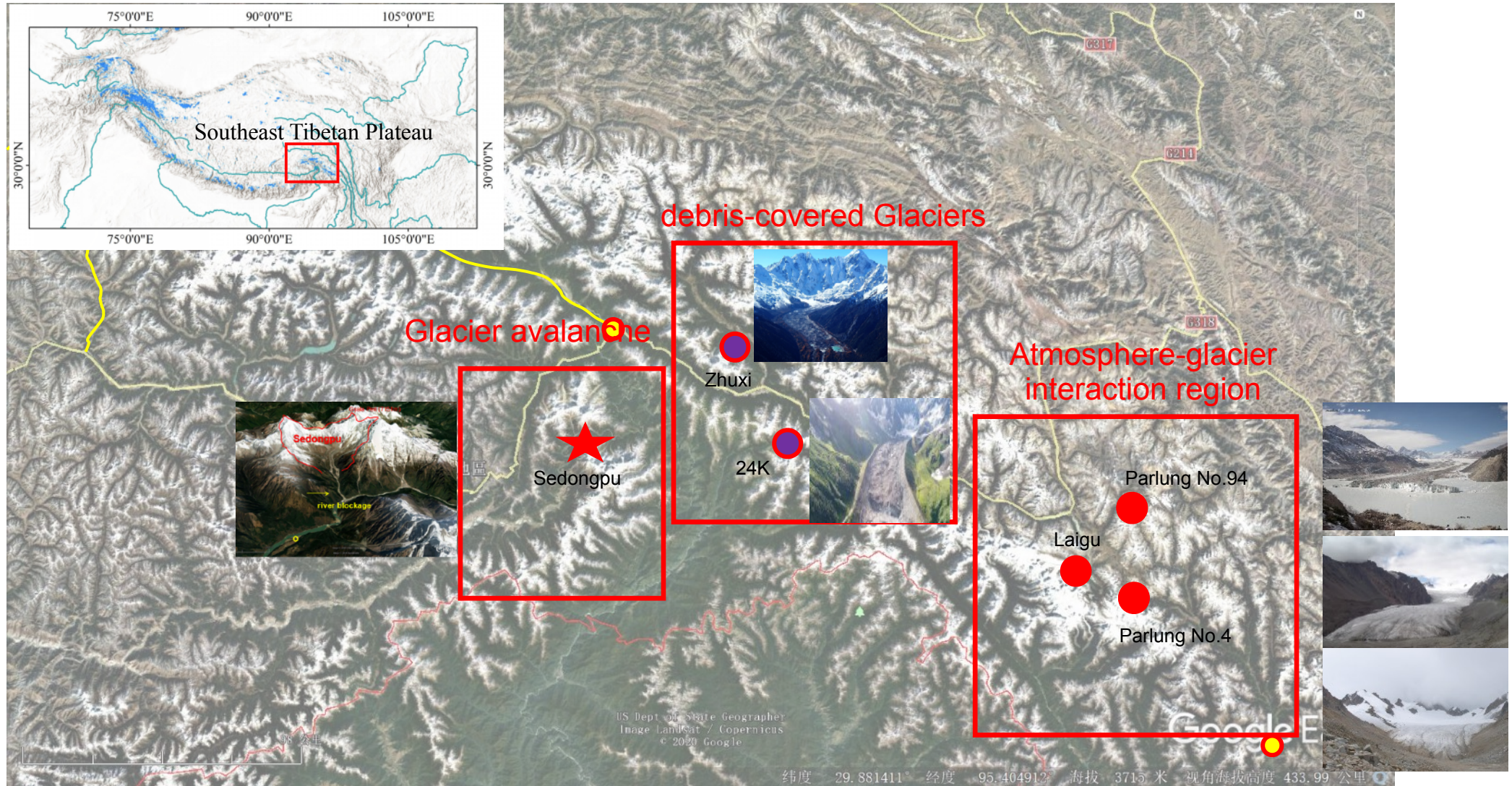
Glaciers in the southeastern Tibetan Plateau are experiencing the most pronounced mass losses in the Third Pole

Glacier-related disasters in the southeastern Tibetan Plateau



It is of great scientific and practical significance to understand the processes and mechanisms of glacier changes and their potential threats to downstream settlements and infrastructures (e.g. *Highways, railway, hydrological power stations*).

Glacier monitoring in the southeastern Tibetan Plateau



Glacier-atmosphere-hydrological observation in glacierized region

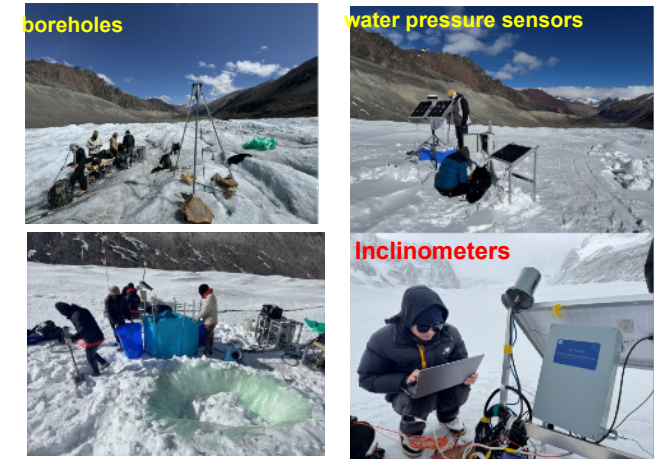
AWS observation (15 AWSs)



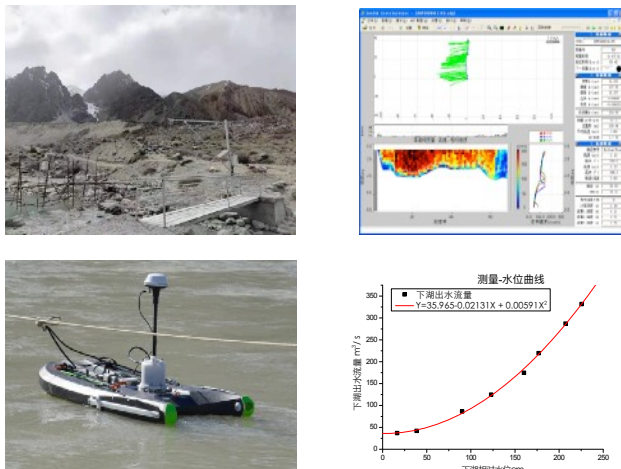
Glacier mass balance and GNSS (4 glaciers)



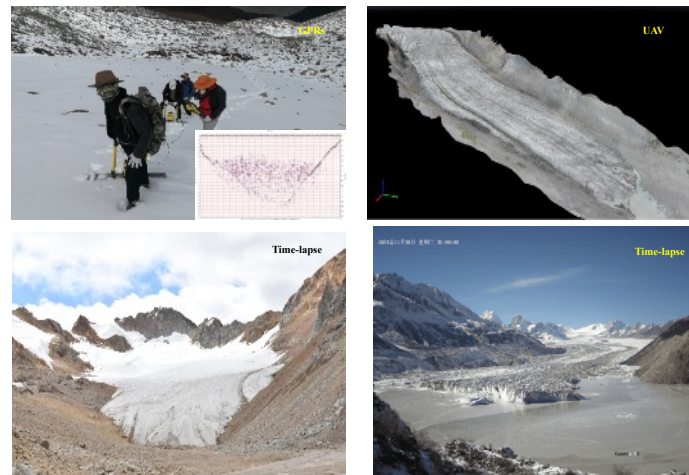
Subglacial -englacial measurements (10 boreholes)



Glacier hydrological stations (4 glaciers)



GPR/UAV measurements and Time-lapse photo



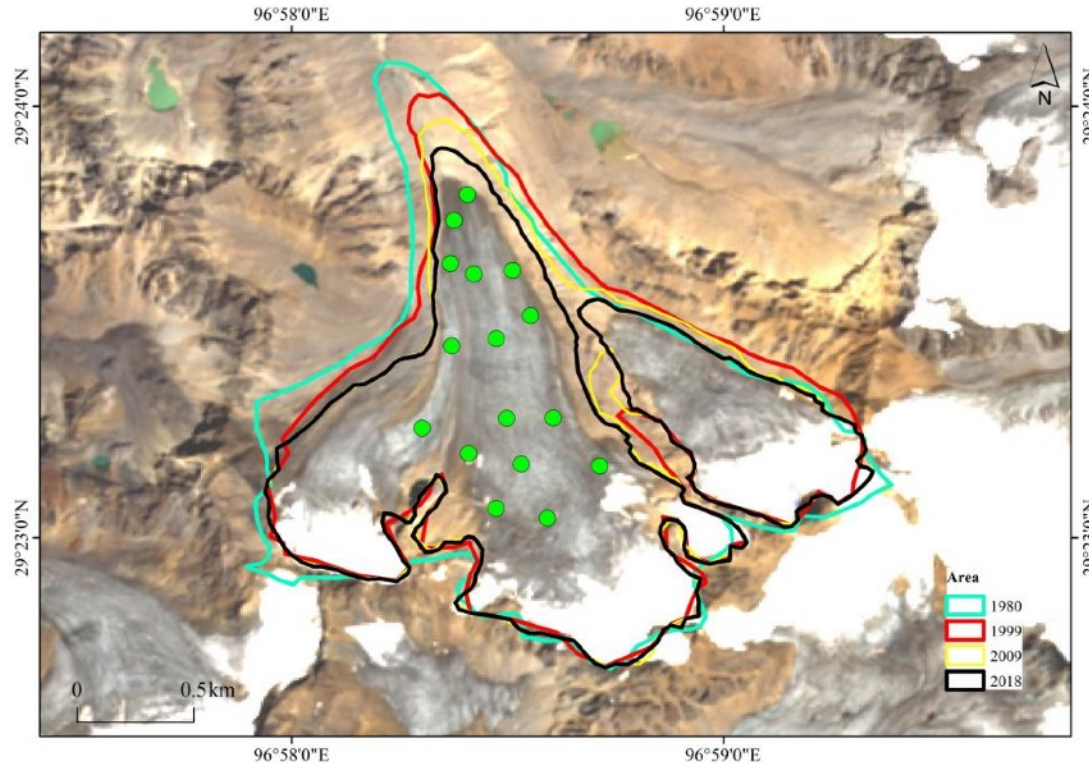
Ice avalanche early warning system



1. Glacier mass balance data in the southeastern Tibetan Plateau

Parlung No. 4 Glacier (29.303°N, 96.90179°E)

Glacier area change and ablation stakes



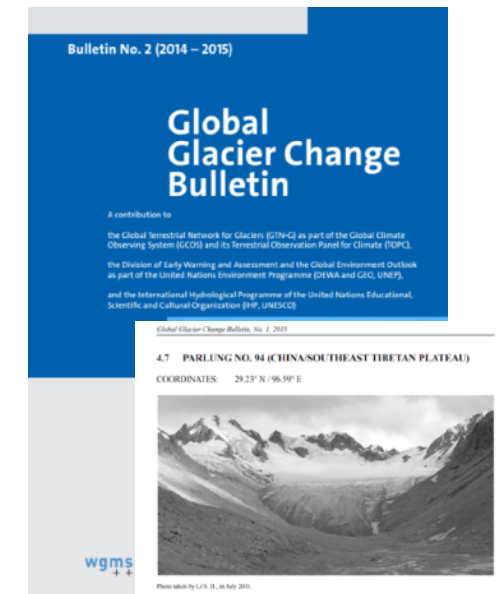
- Glacier area reduced from 2.7 km² in 1980 to ~2.0 km², with about 26% reduction during the past 43 years.
- The retreat rate increased from -9.8 ± 0.8 m a⁻¹ during 1980-2000 to -12.2 ± 0.8 m a⁻¹ during 2000-2023

Data submitted to WGMS

world glacier monitoring service

under the auspices of: ISC (WDS), IUGG (IACS), UN environment, UNESCO, WMO

China			
Urumqi Glacier No.1	-780	-682	-711
- East Branch	-939	-773	-817
- West Branch	-498	-520	-521
Parlung (Glacier No. 94)	-1086	-959	-1469
Colombia			
Conejeras	-5545	-4265	-3411
Ritacuba Blanco	-514	+339	+656
Ecuador			
Antizana 15 Alpha	-257	-379	-258



4.7 PARLUNG NO. 94 (CHINA SOUTHEAST TIBETAN PLATEAU)

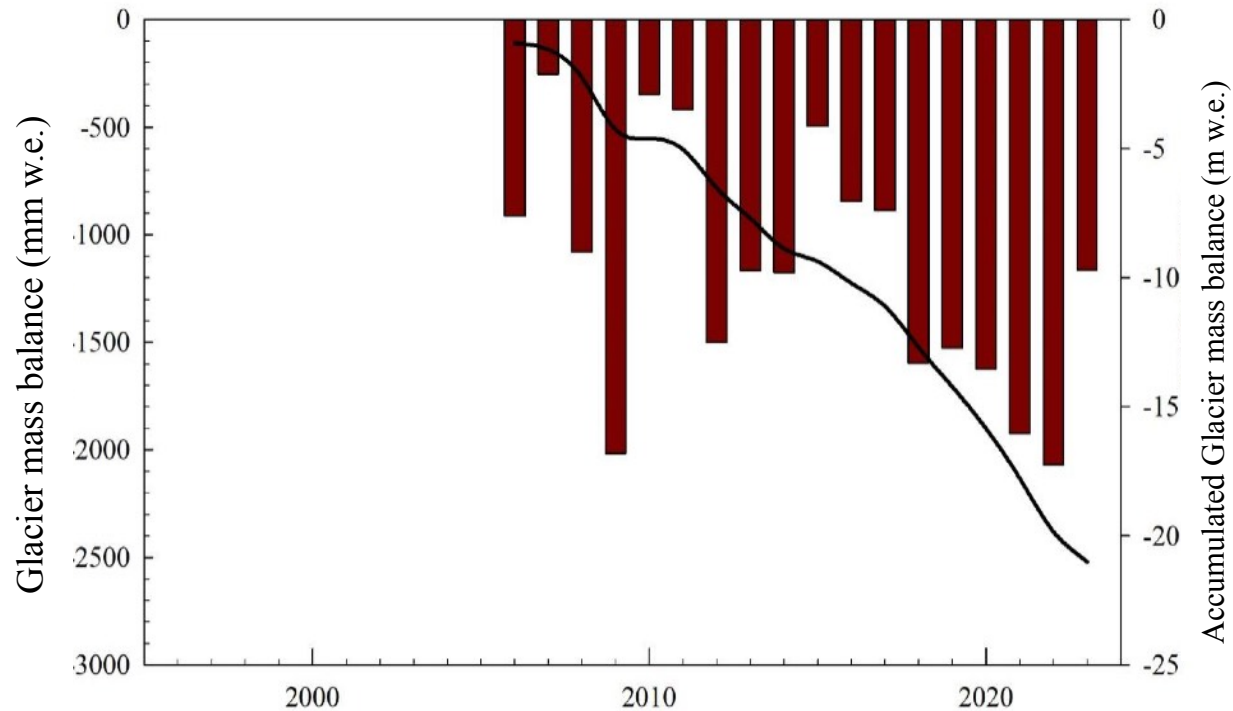
COORDINATES: 29°23' N / 96°59' E



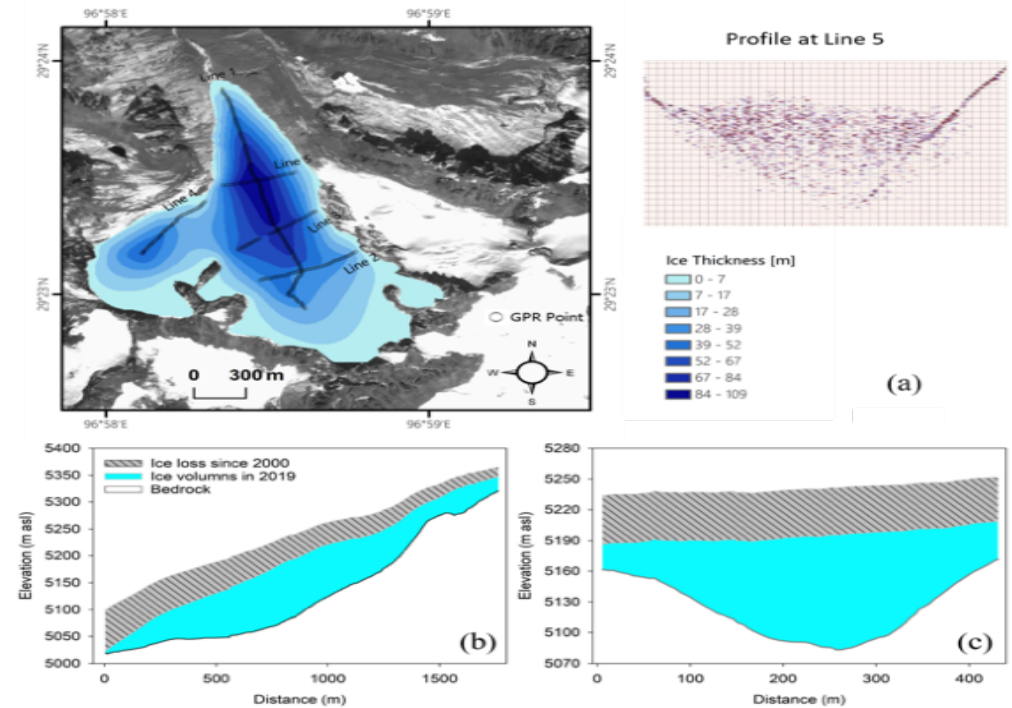
Photo taken by J. L. Li, 18. July 2011.

Parlung No. 94 Glacier is located within the headwaters of the Parlung Zangbo River, a tributary of the Brahmaputra River in southeastern Tibetan Plateau. It is a typical valley glacier with an area of 2.4 km² and an axis length of nearly 2.5 km. It flows northward from an elevation of 5615 to 5015 m a.s.l. at its front position. Mean annual air temperature is about -2 to -4 °C, and annual precipitation is generally 160 to 381 mm based on the past four years AWS (Automatic Weather Stations) and rainfall observation. The AWS is 5.6 km away from the center of the glacier at an altitude of 4900 m a.s.l. Glaciers in this region have the largest glacier mass loss over the Tibetan Plateau. According to the latest research, the maritime glaciers here were more vulnerable to ongoing climate warming than to potential changes in the amount of precipitation and the recent glacier shrinkage in this region was related to the increasing air temperature. Both the mass balance observations and simulations reveal that these glaciers are the "spring accumulation" type.

Glacier mass balance data in the southeastern Tibetan Plateau



The annual and accumulated glacier mass loss during 2006-2023



The maximum ice thickness of ~110 m, which was measured by GPR in 2018

- Between 2006 and 2023, the cumulative ice loss reached about 21 m w.e., and the average annual glacier mass balance was -1200 mm w.e.
- The most negative year for mass balance occurred in 2022, followed by 2009
- Since 2015, there has been a trend of accelerating ice loss

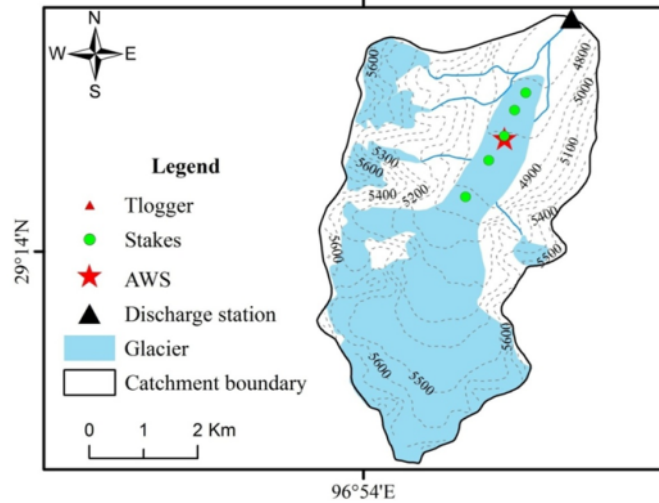
Glacier shrinkage of Parlung No.94 Glacier during 2007-2023



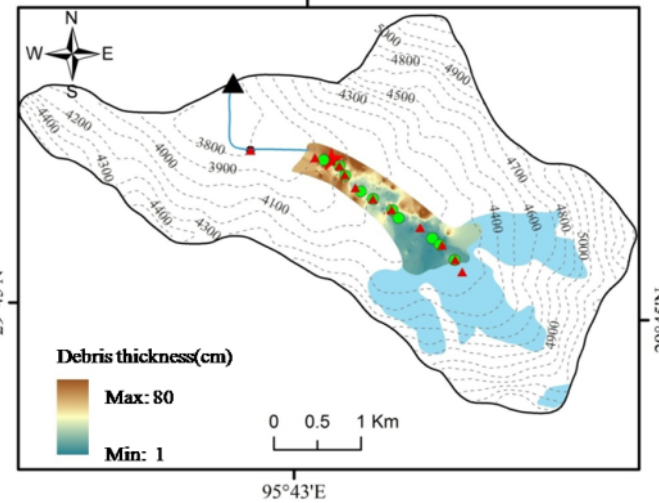
2007
VS
2023

Field photos taken in 2007 show that the glacier is a small valley glacier consisting of three glaciers. Since 2015, the right glacier has completely separated from the main glacier to form an independent small glacier

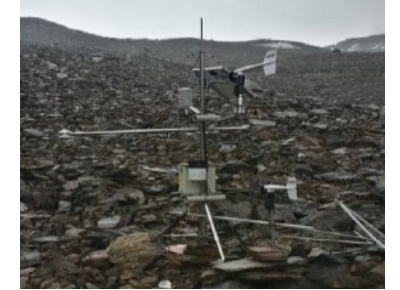
2. Contrasting glacier and hydrological changes between debris-free and debris-covered glacier in the southeastern TP



Debris-free Parlung No.4 Glacier

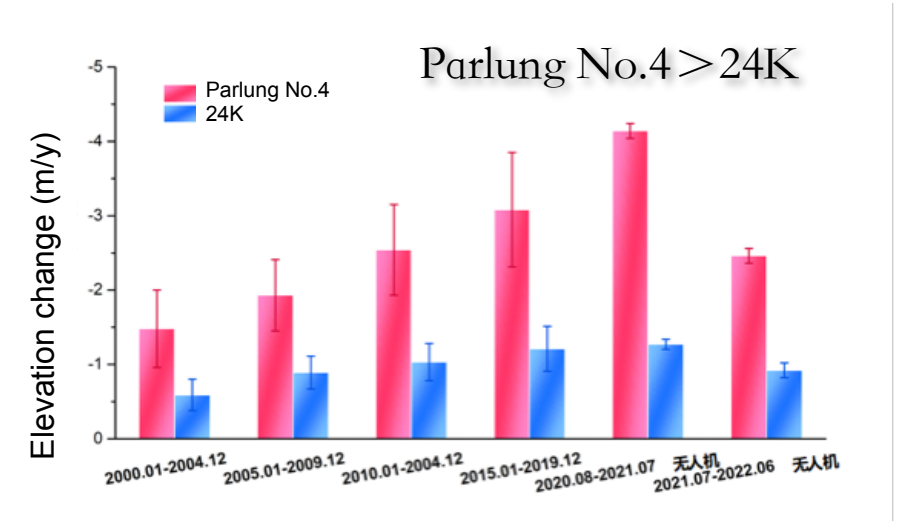
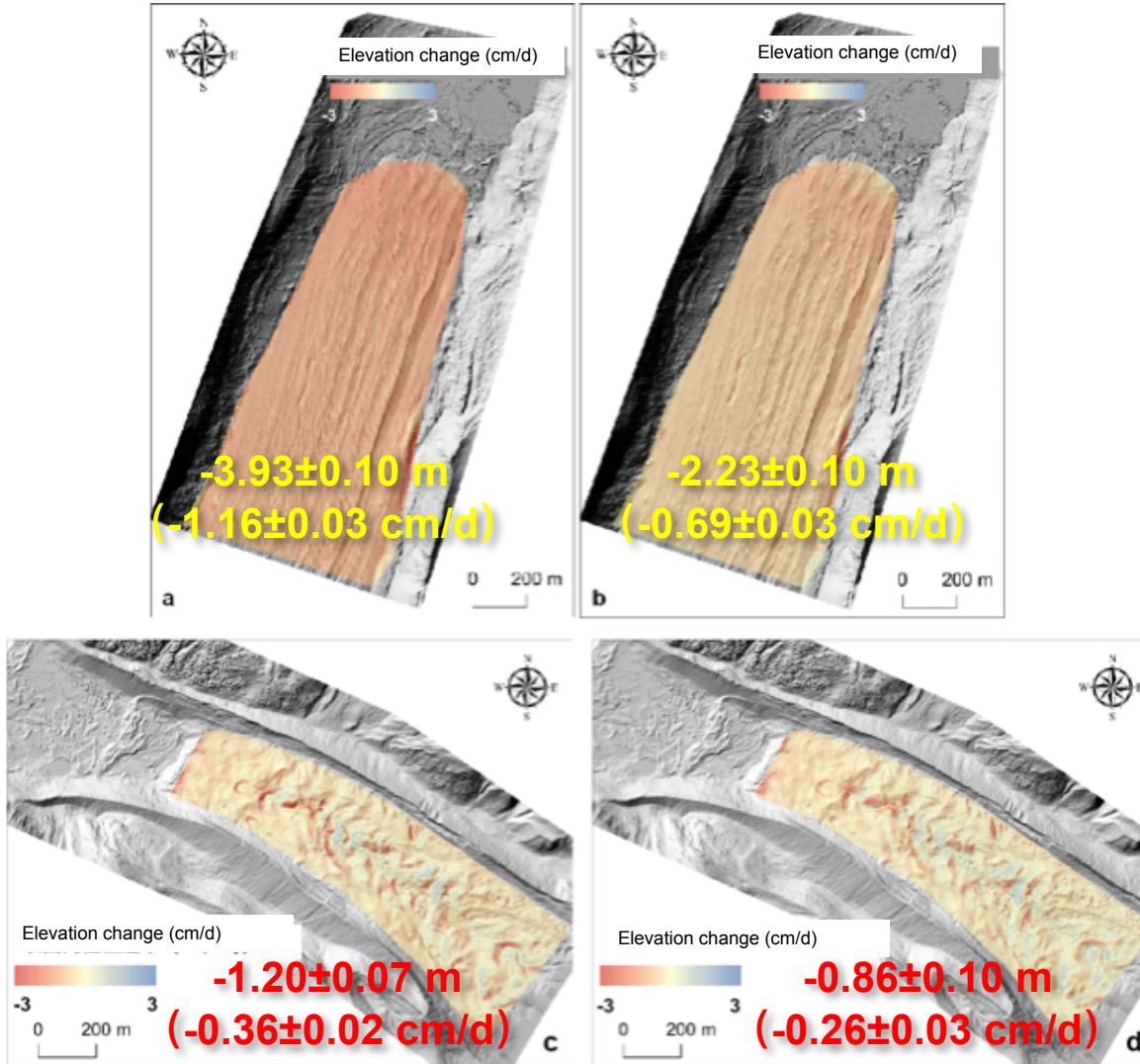


Debris-covered 24K Glacier



Glaciological-meteorological-hydrological comparing experiments

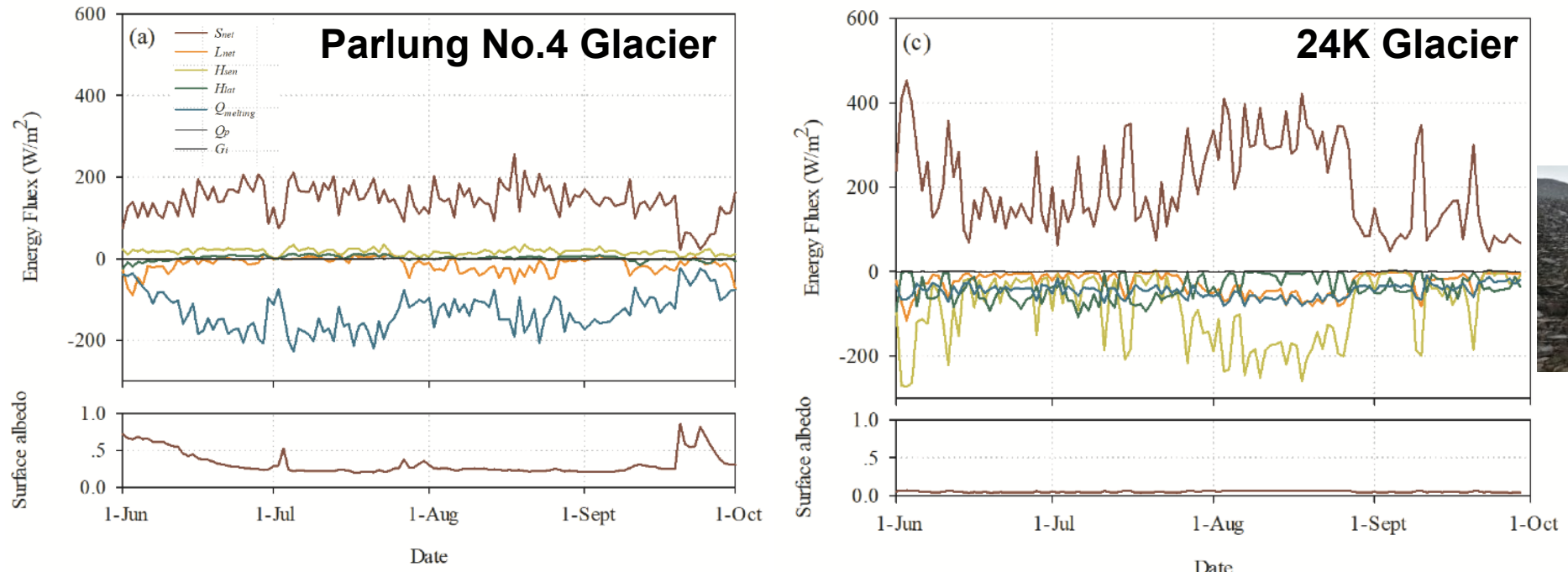
Difference of mass balance between debris-free and debris-covered glacier



The magnitude of glacier mass loss for debris-free glacier is significantly higher than that of debris-covered glaciers.

Zhaot et al., 2023

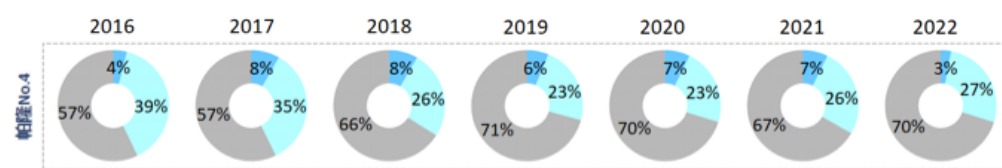
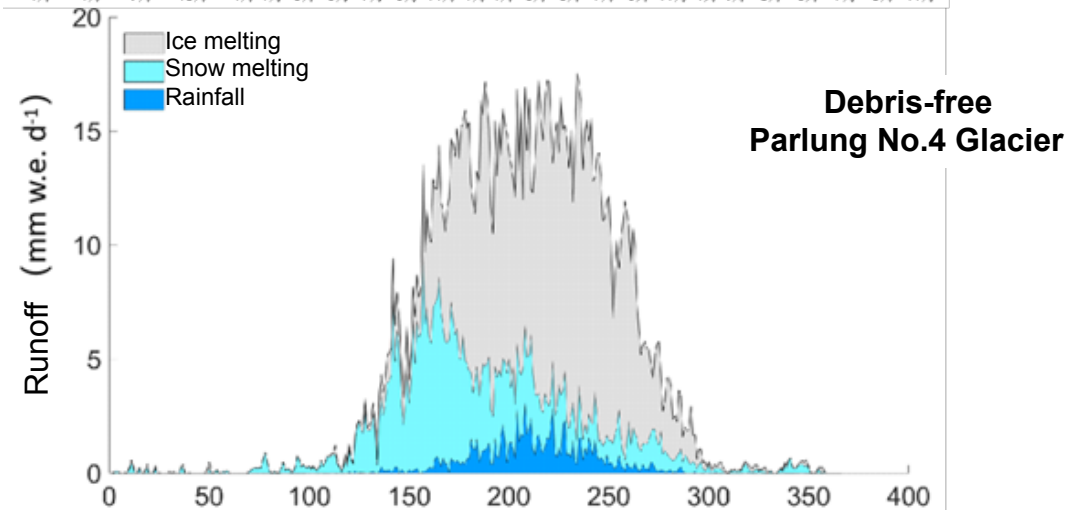
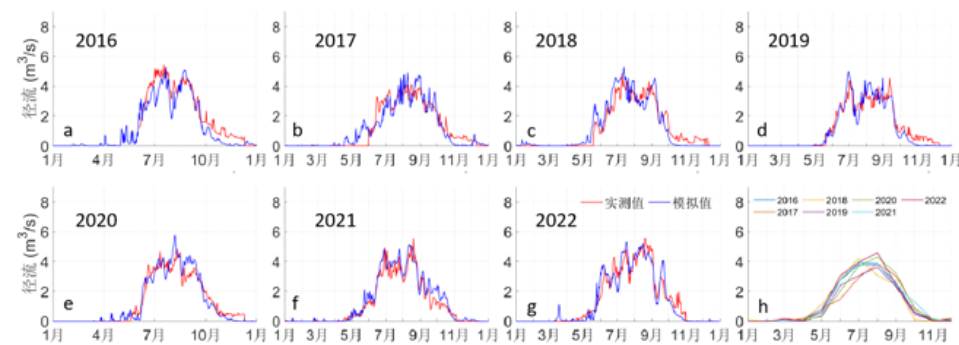
Difference of surface energy balance between debris-free and debris-covered glacier



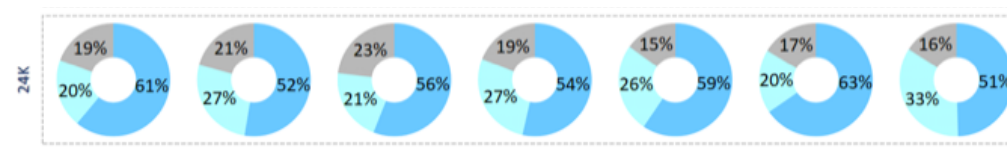
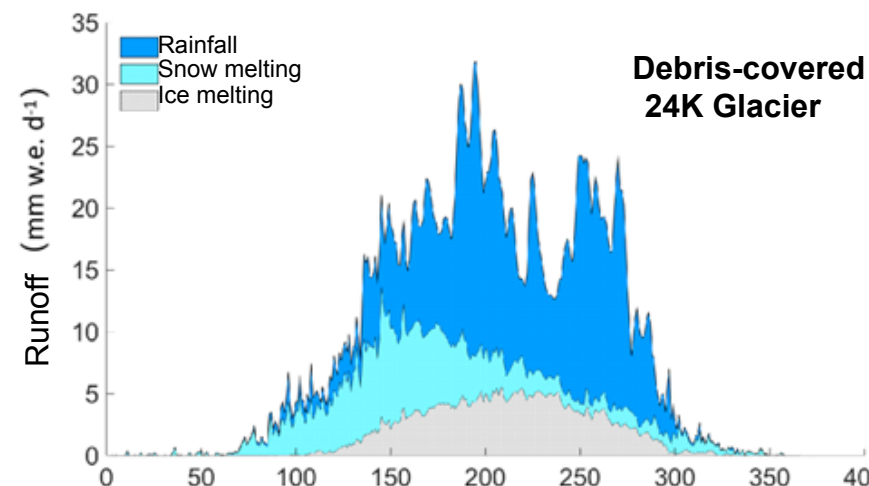
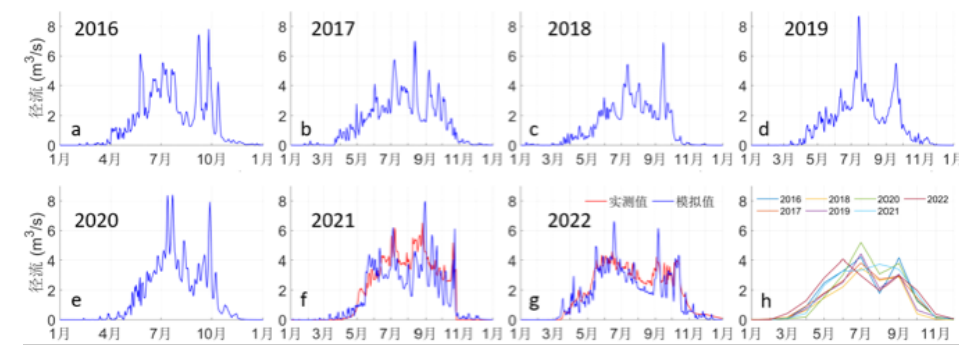
Glacier	Net Shortwave Radiation (S_{net})	Net Longwave Radiation (L_{net})	Sensible heat flux (H_{se})	Latent heat flux (H_{la})	Melting Energy ($Q_{melting}$)
Debris-free Parlung No.4 Glacier	142.5	-13.0	17.1	1.5	-145.9
Debris-covered 24K Glacier	201	-25.2	-87.1	-25.0	-63.8

Debris greatly influences surface energy by changing shortwave radiation and sensible heat flux

Difference of hydrologys and future change between debris-free and debris-covered glacier



Glacier melt accounts for 57%-71% of the total runoff, snow melt accounts for about 23%-39%, and rainfall accounts for only 3%-8%.

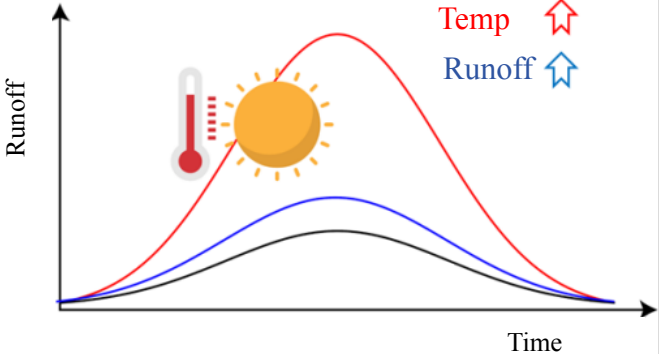
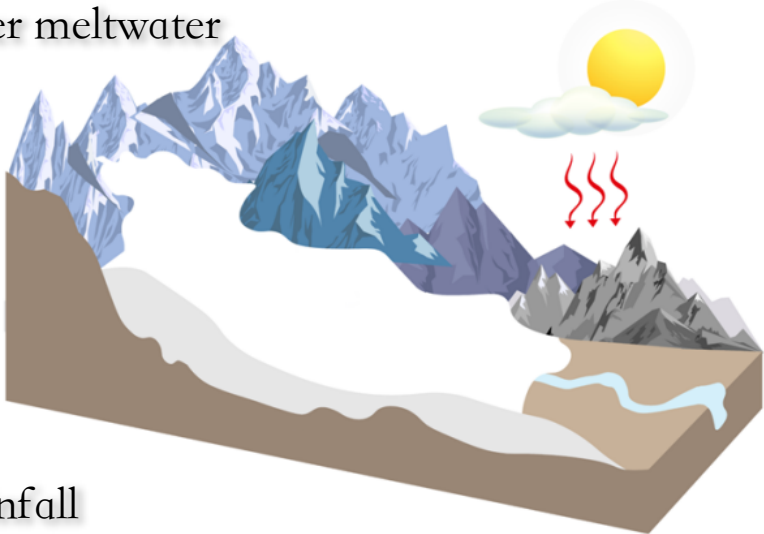


Glacier melt accounts for 15%-23% of the total runoff, snow melt accounts for about 20%-33%, and rainfall accounts for only 51%-63%

Difference of hydrologys and future change between debris-free and debris-covered glacier

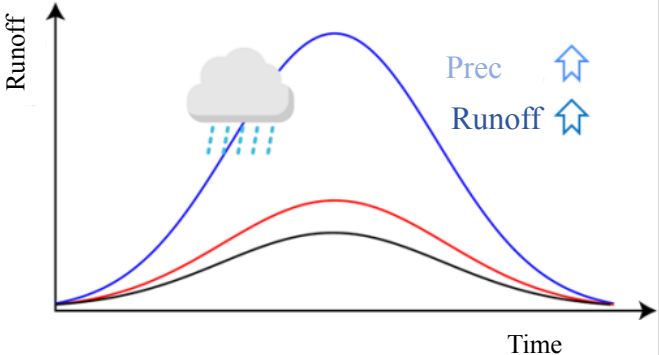
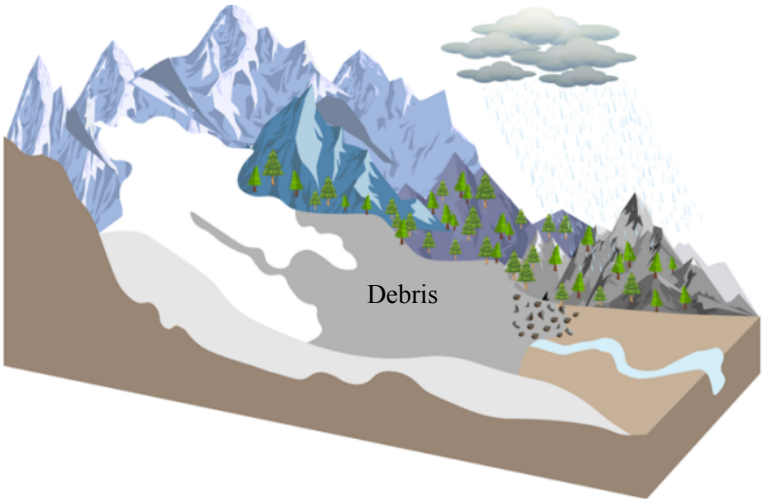
"Glacier meltwater
dominative patterns"
Parlung No.4 Glacier

Glacier meltwater

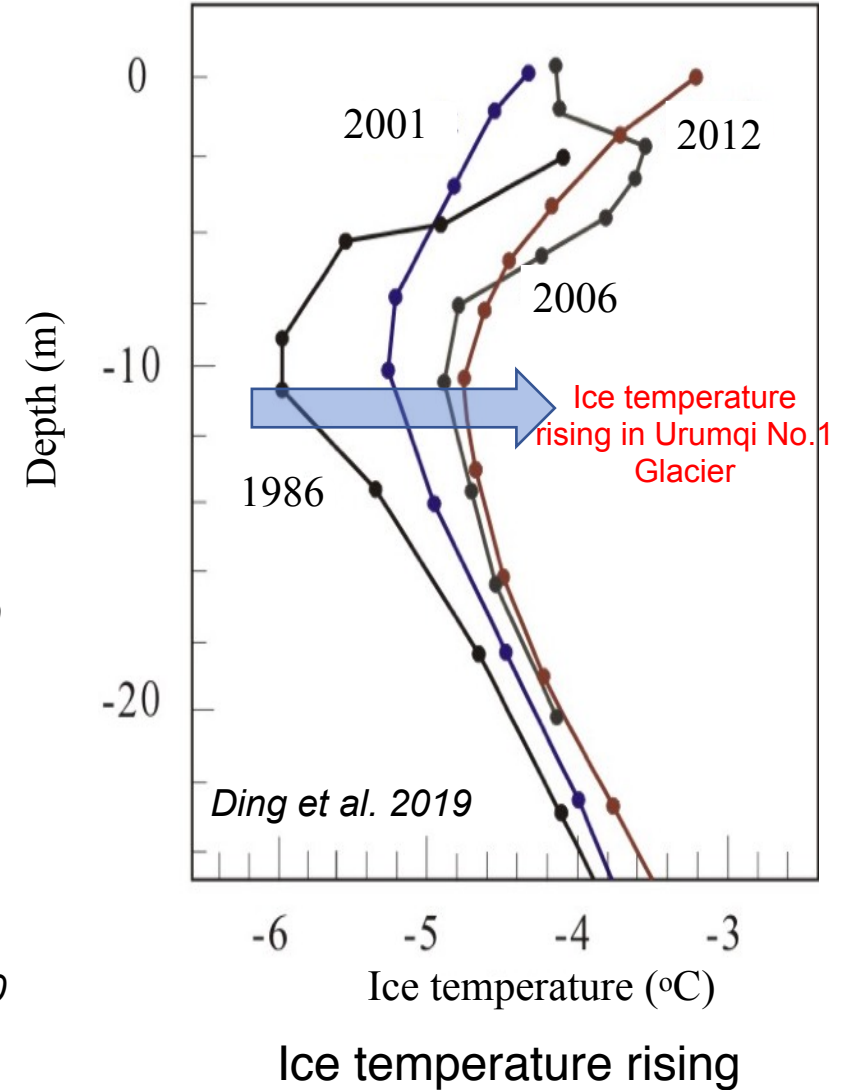
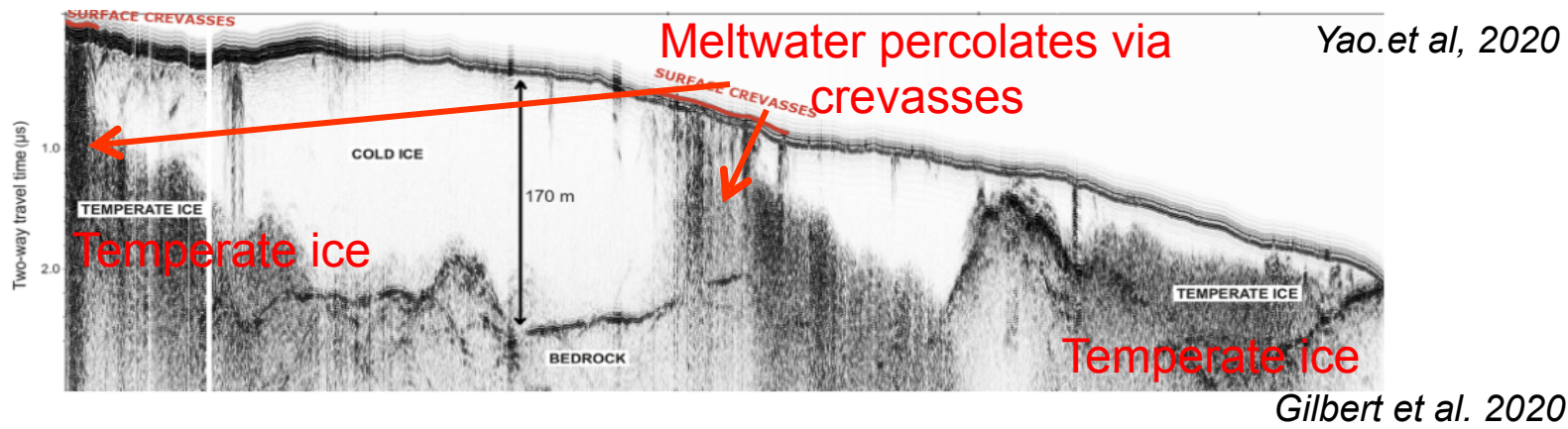
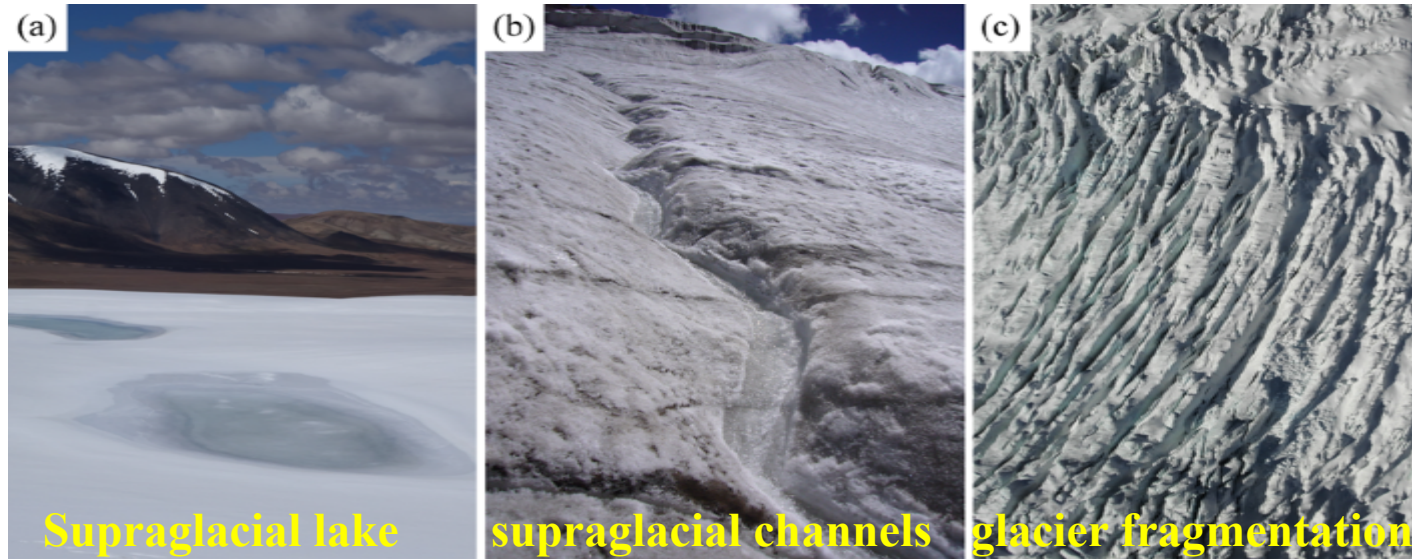


"Rainfall dominative
patterns" 24K Glacier

Rainfall

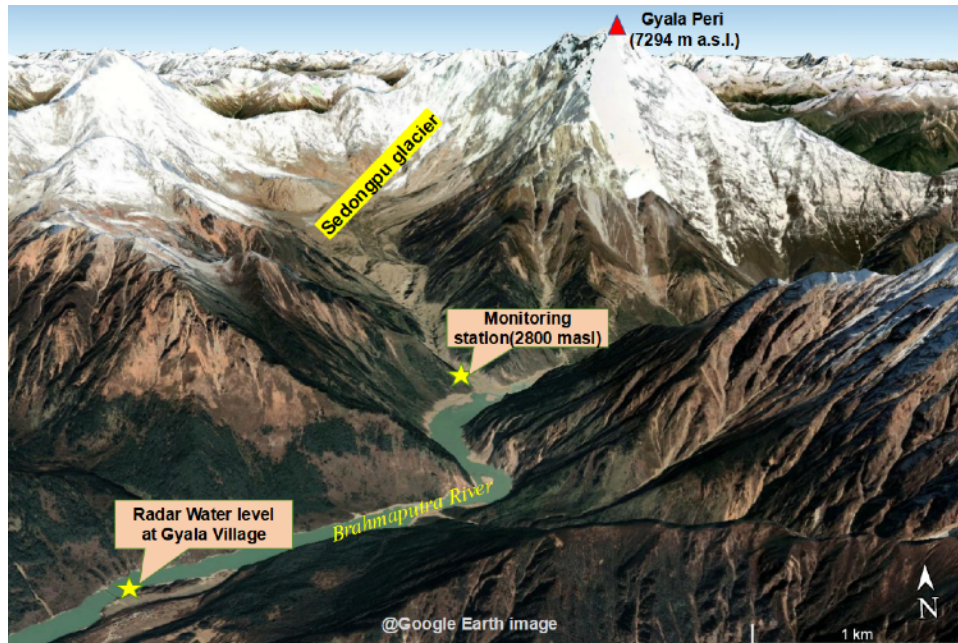


3. Glacier instability under anthropogenic warming

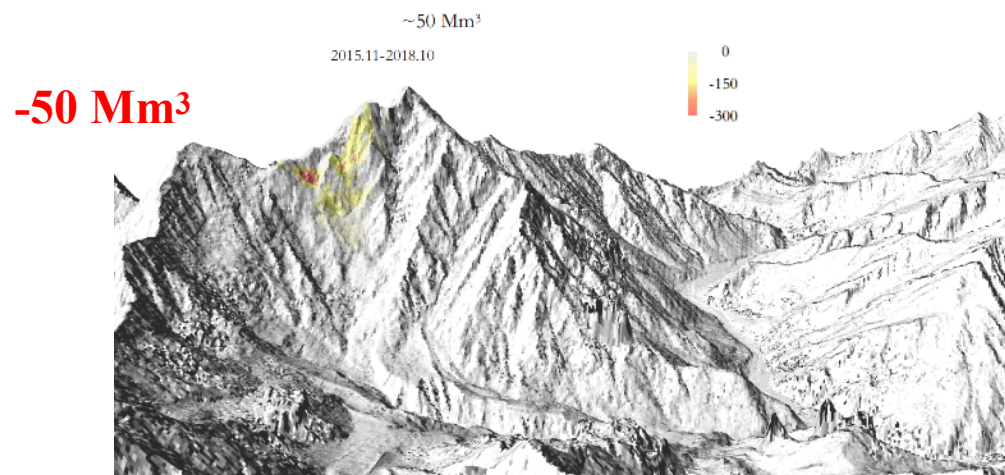


The formation of glacial lakes and supraglacial channels and thermal structure change

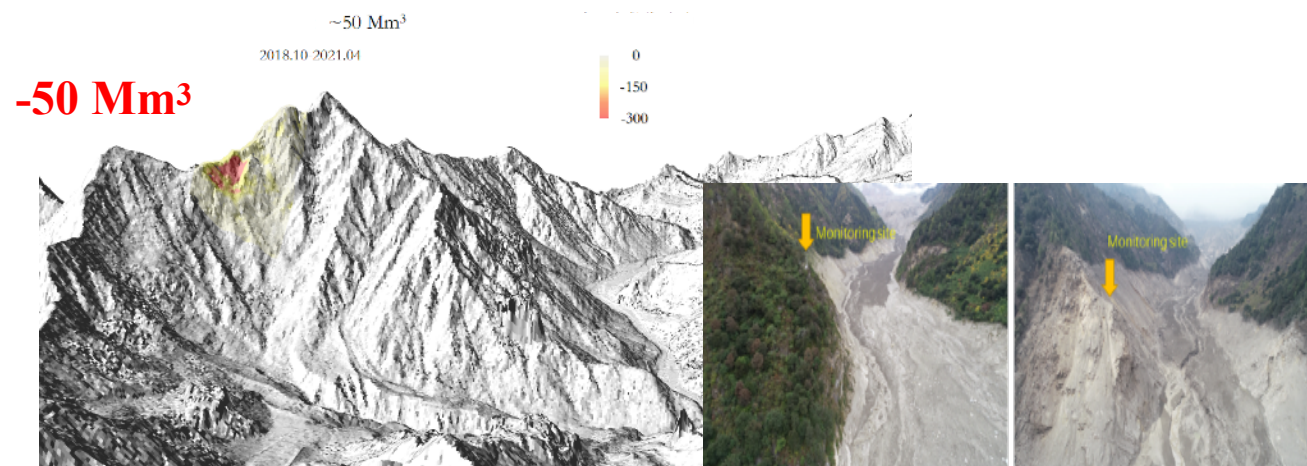
Massive ice avalanches and river blockages in the Sedongpu valley



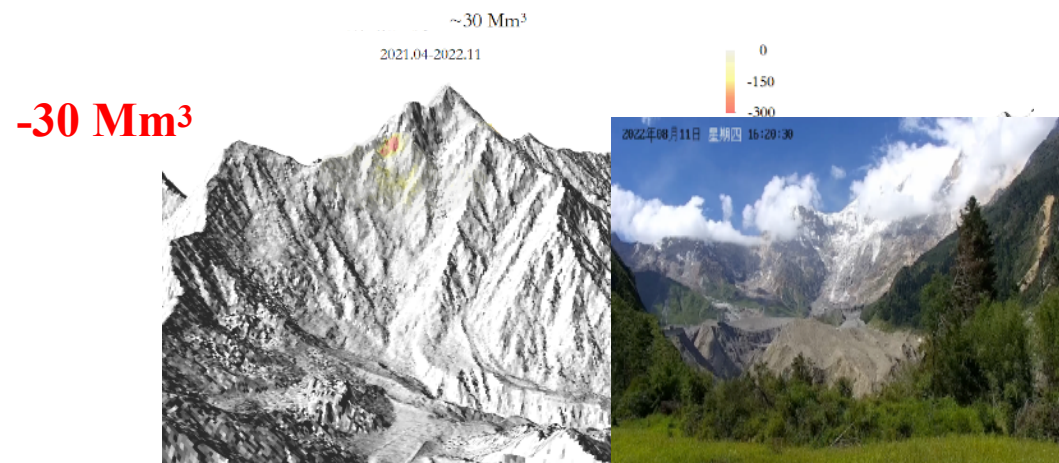
Repeated ice-rock avalanches in the Sedongpu valley



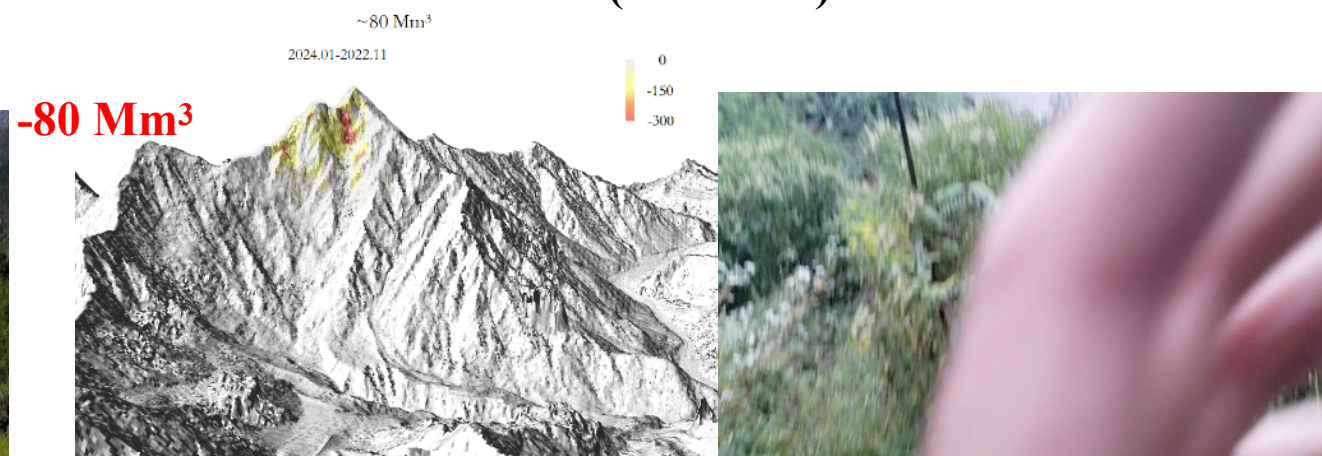
2015-2018



2018-2021 (2021.3.21)

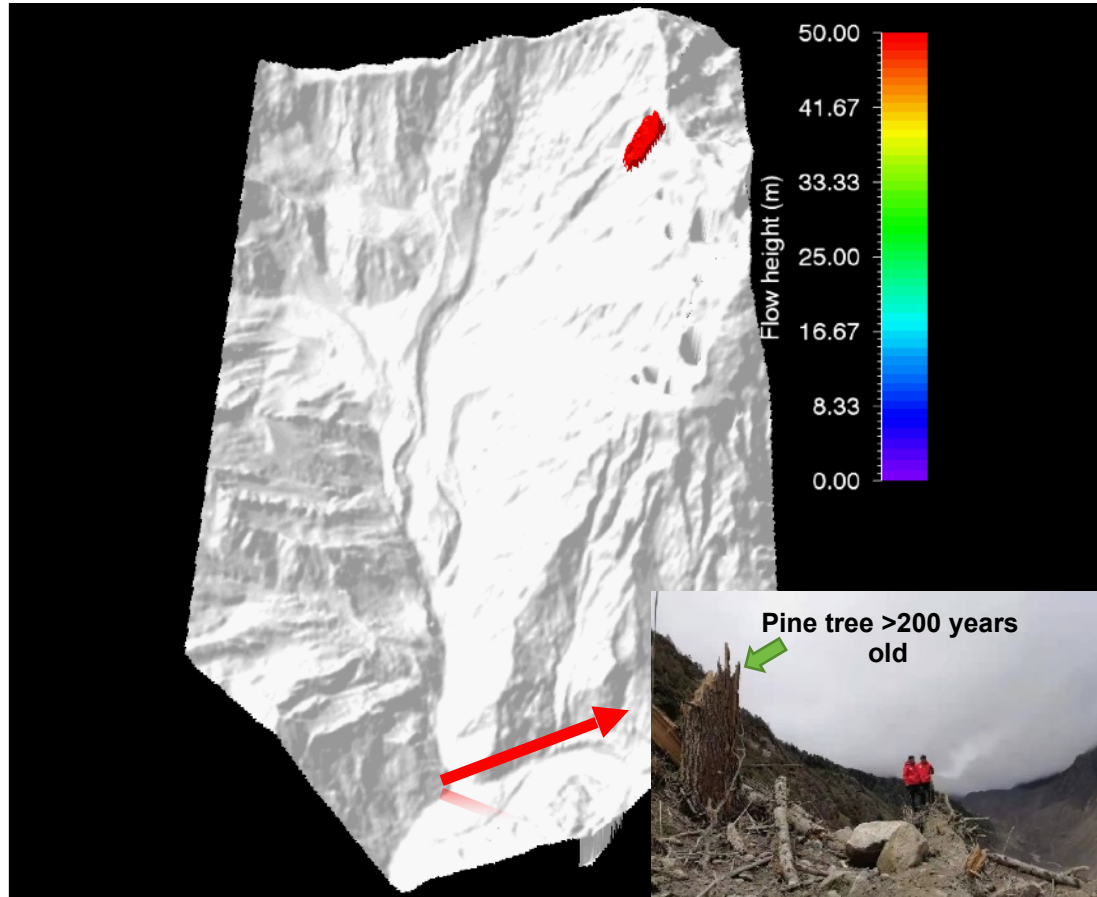


2021-2022

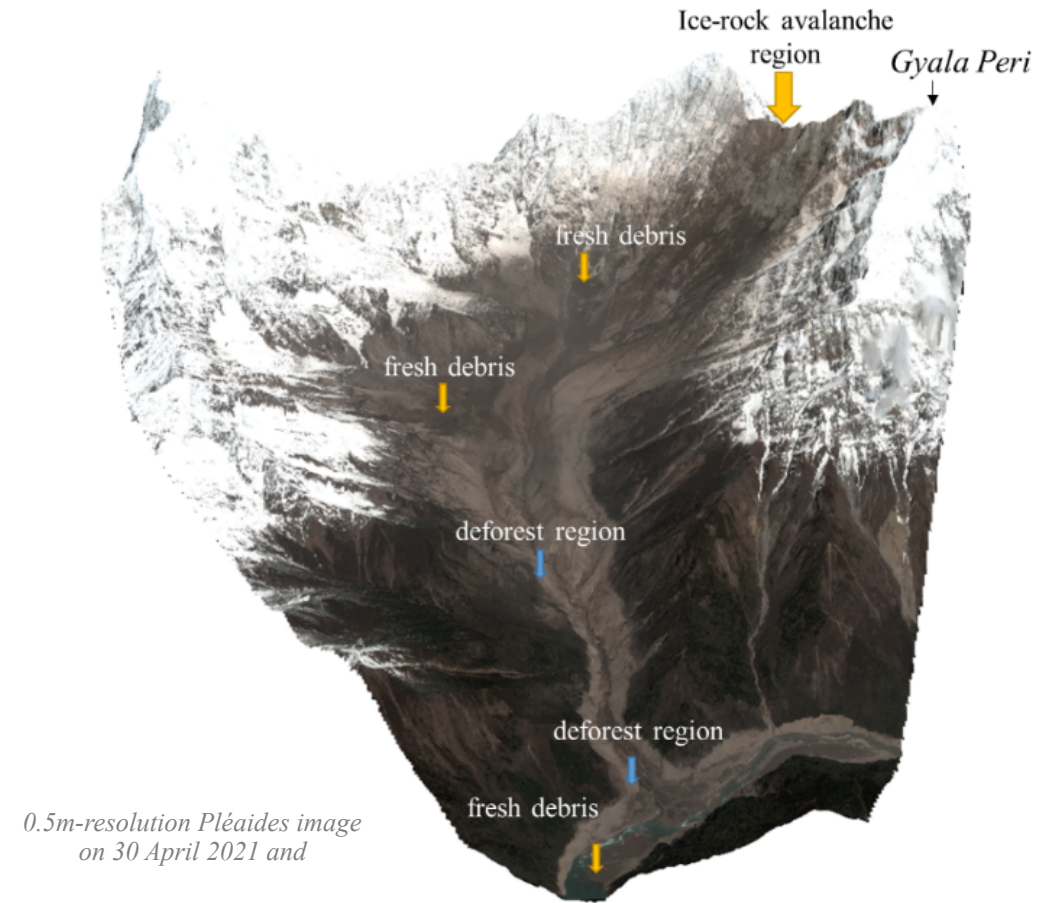


2022-2024 (2023.9.28)

River blockage and vegetation damage



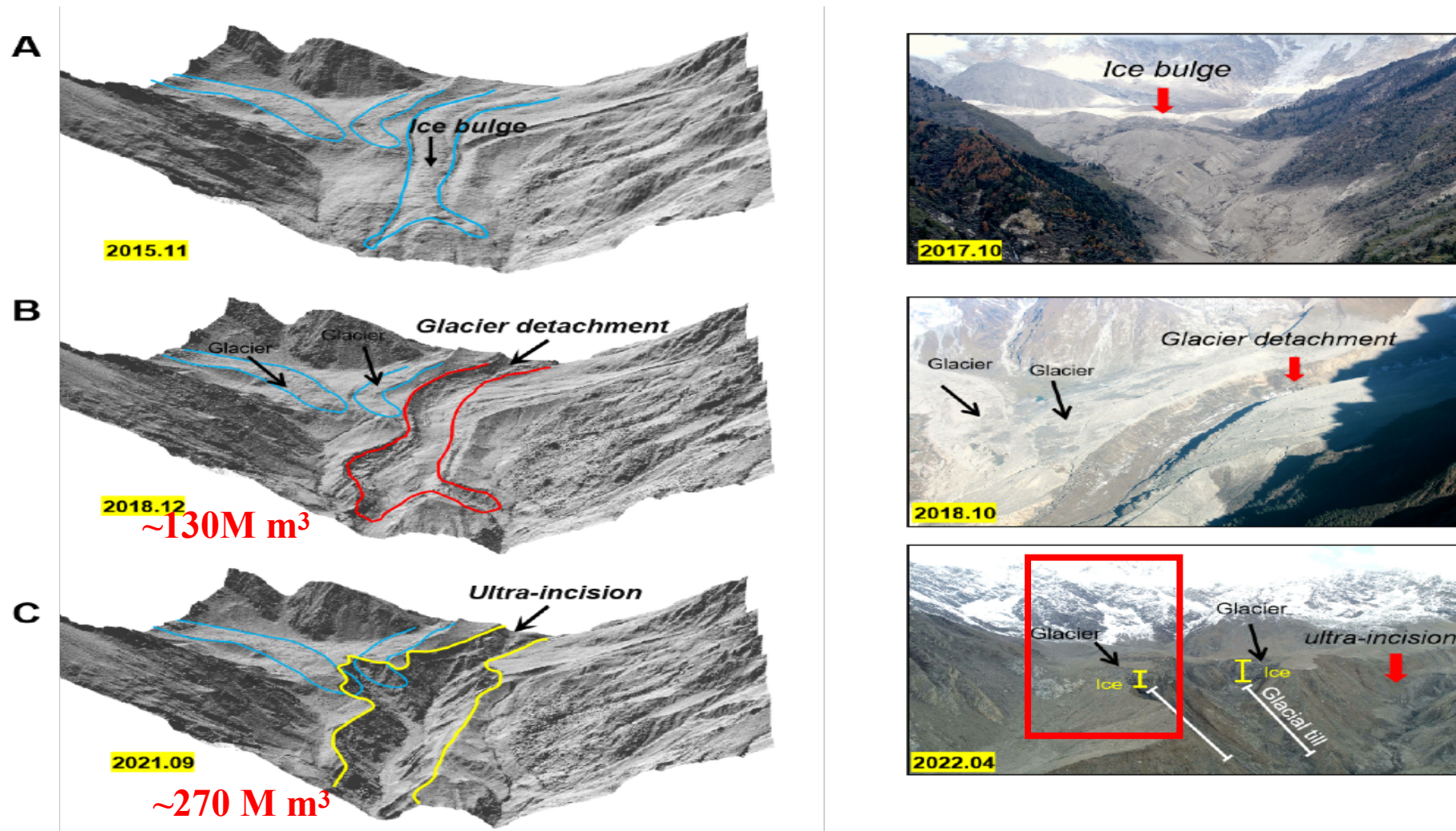
Modelling process of 2021 ice-rock avalanche by
RAMMS model



Valley bottom was covered by fresh, water-rich debris

The mass flowed across the 200m-high forest-covered mountain are well reproduced at 150 Second

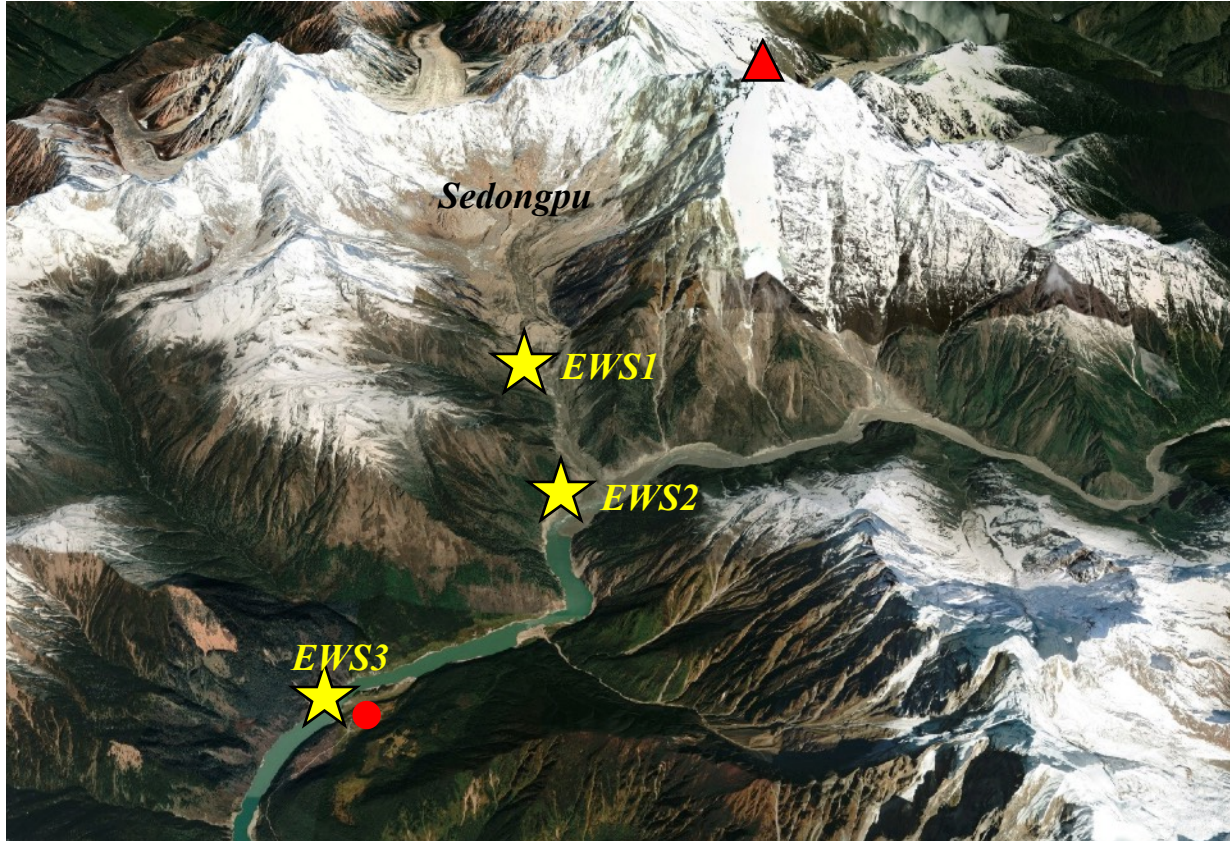
The highest glaciofluvial erosion in the world



Daily erosion of 0.8m/d (~2 M m³/day) during April-September 2021

Ice-avalanche related disasters around the Namcha Barwa-Gyala Peri massif contributed greatly to the sediment load of the Brahmaputra River

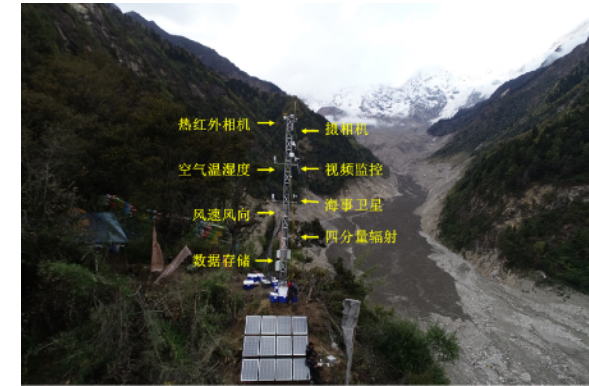
Early warning systems of ice-rock avalanche in Sedongpu Valley



The distribution of EWSs



EWS1



EWS2



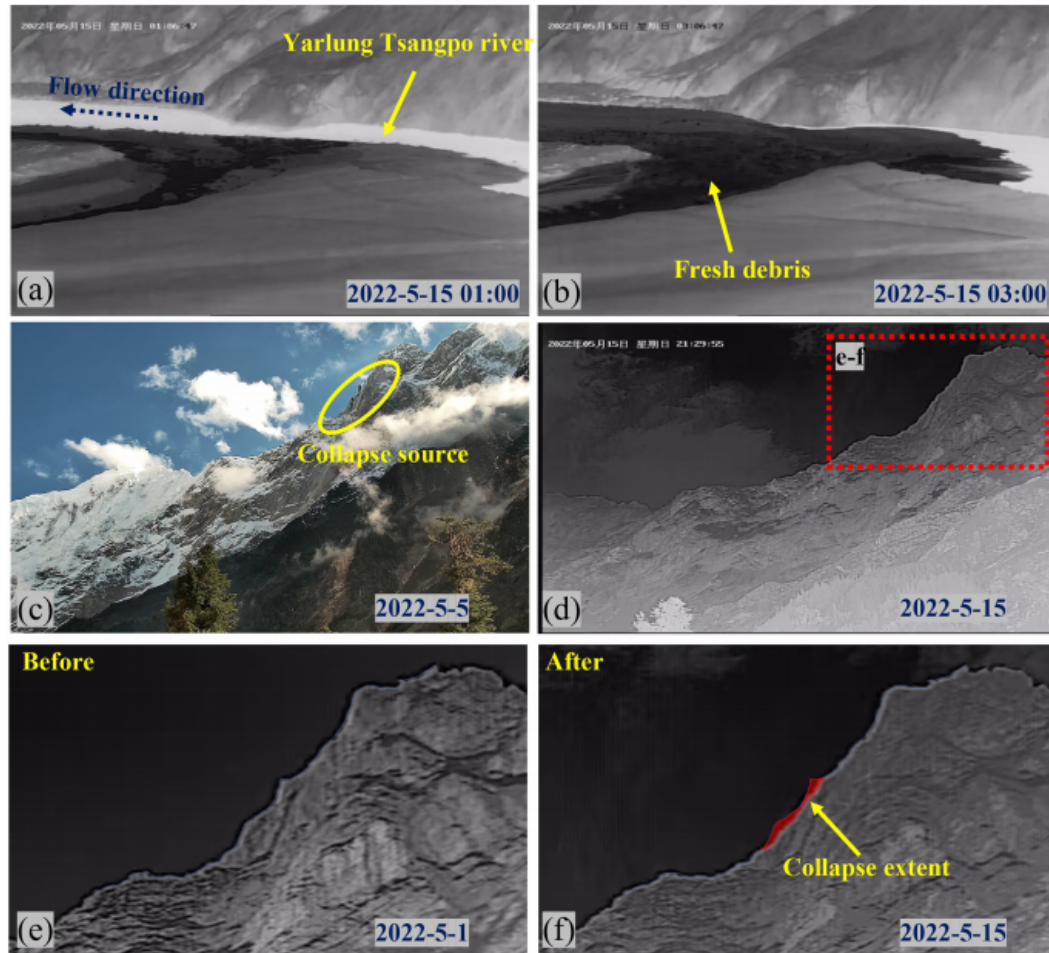
EWS3



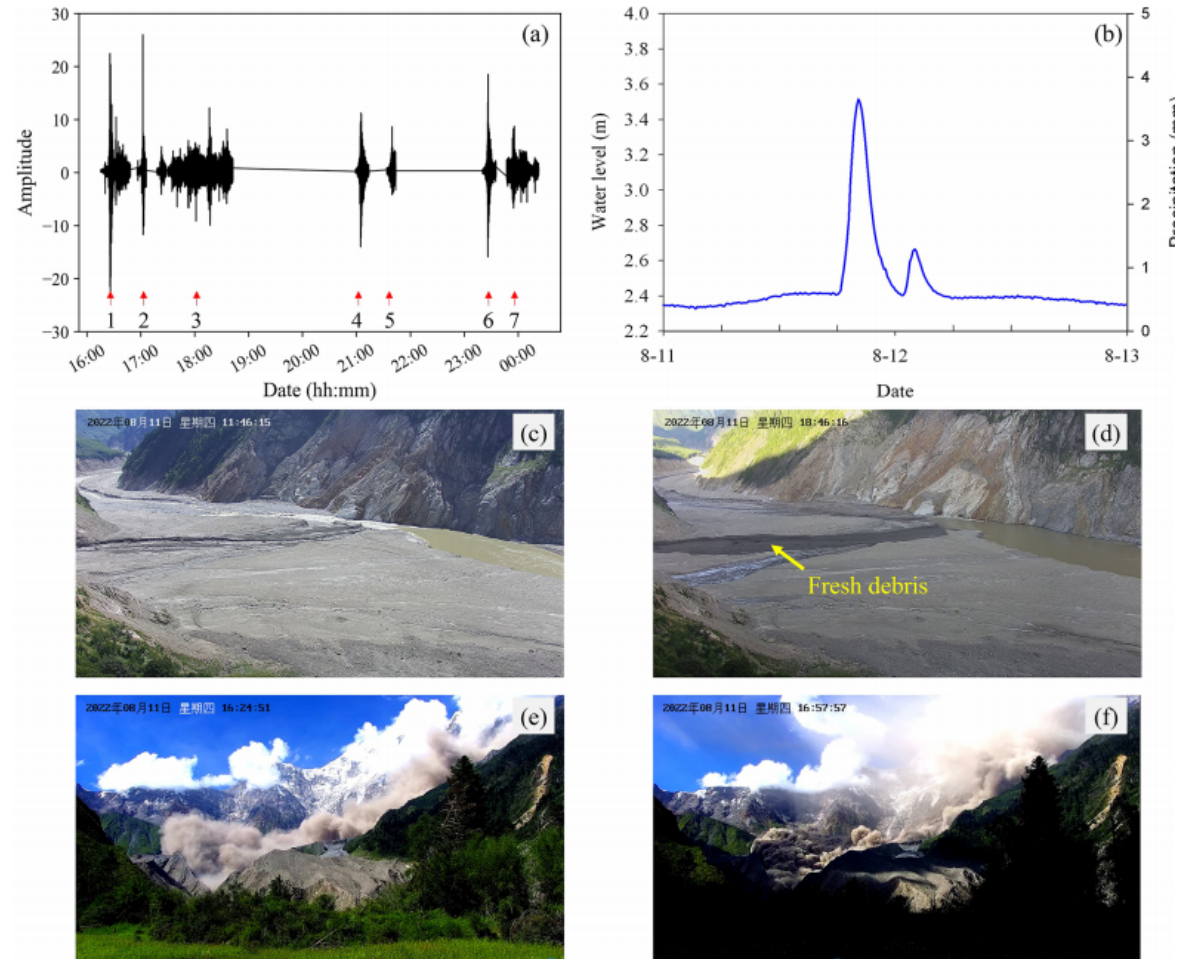
EWS3

The EWS collected datasets of optical/thermal videos/photos, geophone waveforms, water levels, and meteorological variables in this sparsely populated zone

The system successfully detected four chain disasters involving ice-rock collapse, debris flow and river blockage

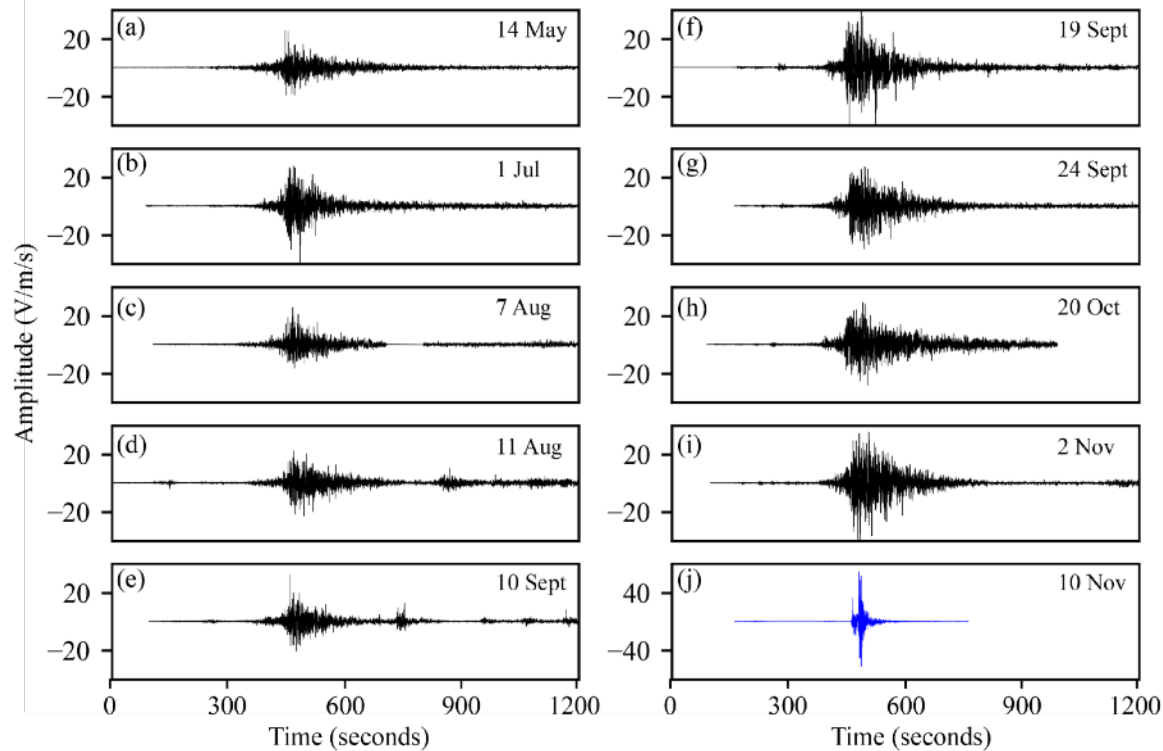


The ice-rock collapses on 14 May 2022 and debris-induced blockage of the Yarlung Tsangpo River

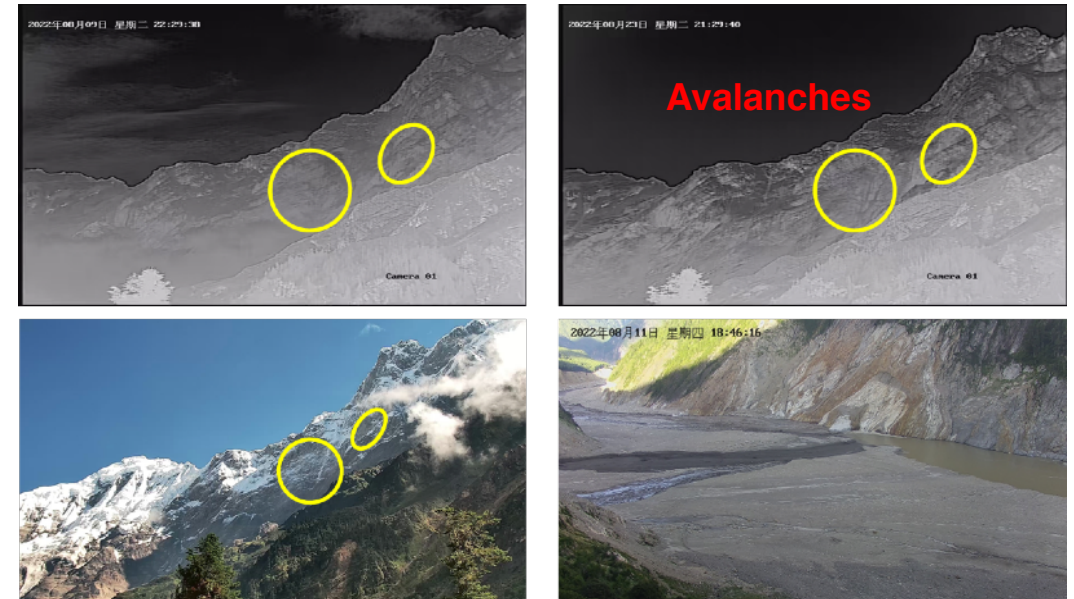
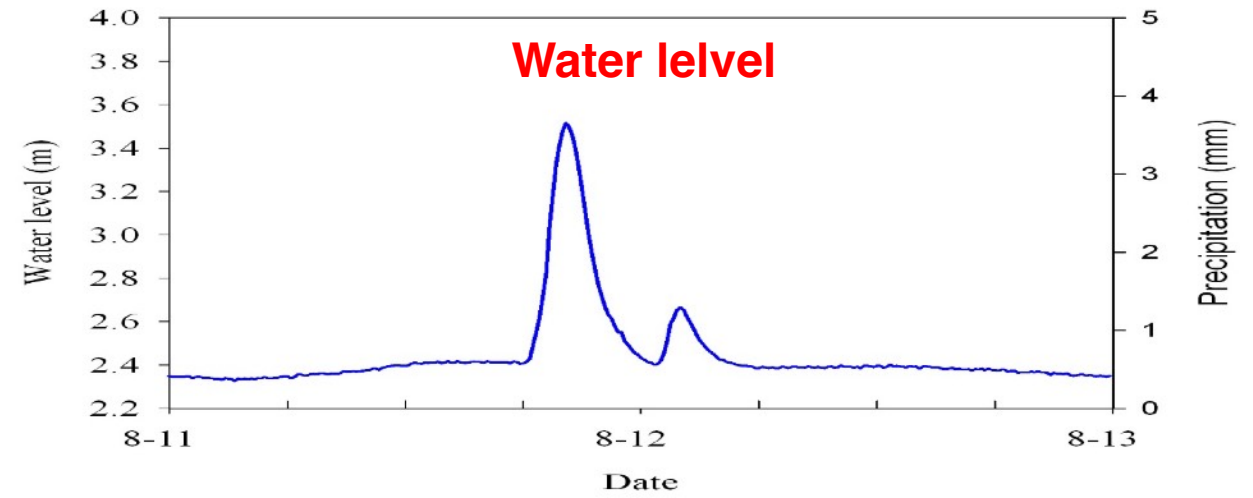


The repeated ice-rock collapses on 11 August 2022

A combination of in-situ geophone waveforms, water levels and photographs can be used effectively to provide warnings about the occurrence and magnitude of ice-rock collapses.



Comparison of the waveforms generated by ice-rock collapses (a–i) and by the earthquake on 10 November 2022 (j).



Synthesis: glacier monitoring in the southeastern Tibetan Plateau

Mass balance



Glacier types



Disasters



- Observation of glacier mass balance evidenced an accelerating trend of ice loss in the southeastern Tibetan Plateau.
- The contrast between meteorological and surface conditions (debris-free and debris-covered) had a significant impact on glacier dynamics and the hydrological response to climate change.
- Glacier instability and the related disaster chains caused by anthropogenic warming pose a threat to the downstream region, but this mechanism needs to be investigated further.



Thanks for your attention!