ACCELERATED GLACIER MASS LOSS IN THE SOUTHEAST TIBETAN PLATEAU IS DOMINATED BY MONSOON PRECIPITATION PHASE CHANGE

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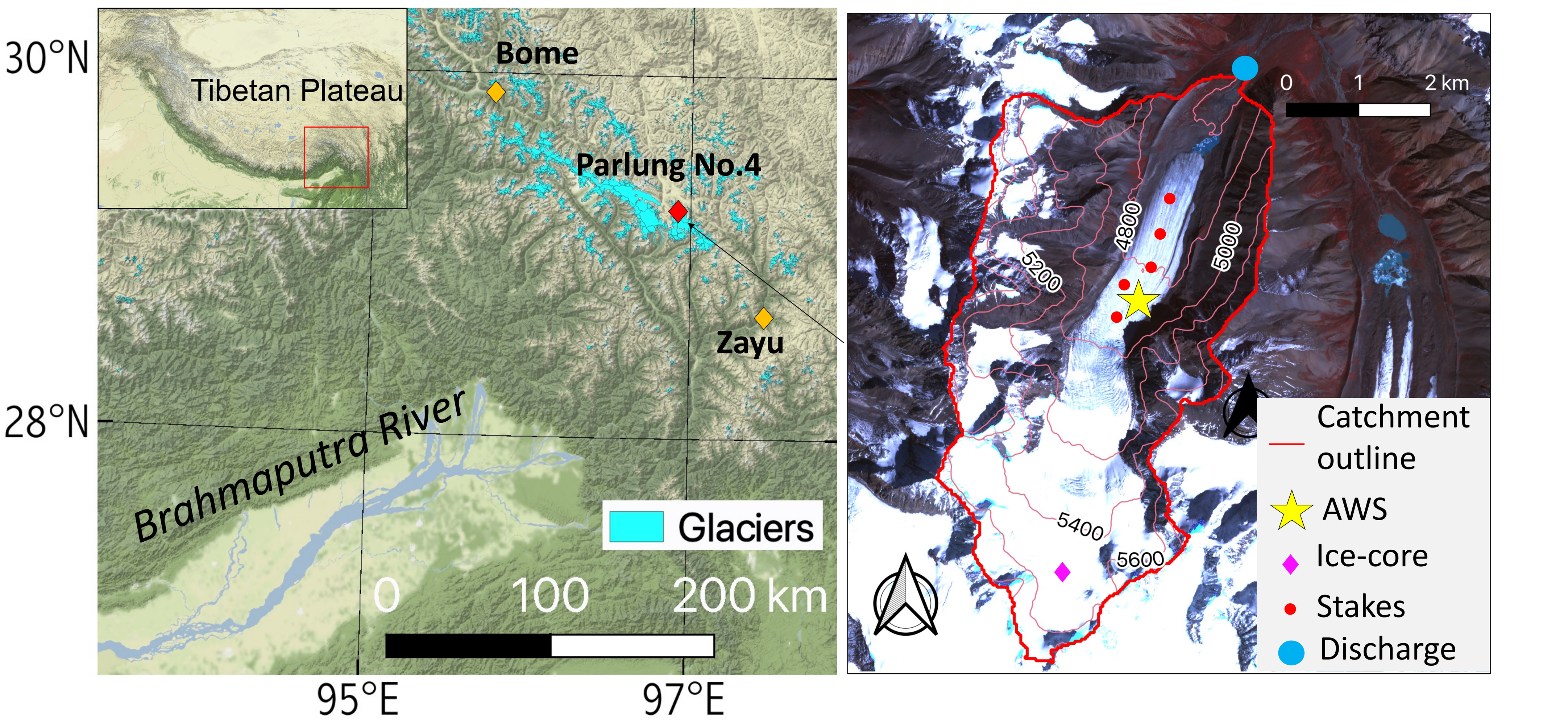

Fig. 1 : Study site. Parlung No.4 glacier is considered as a benchmark glacier in this region, since its meteorology, surface energy fluxes and mass-balance have each been examined in recent years.

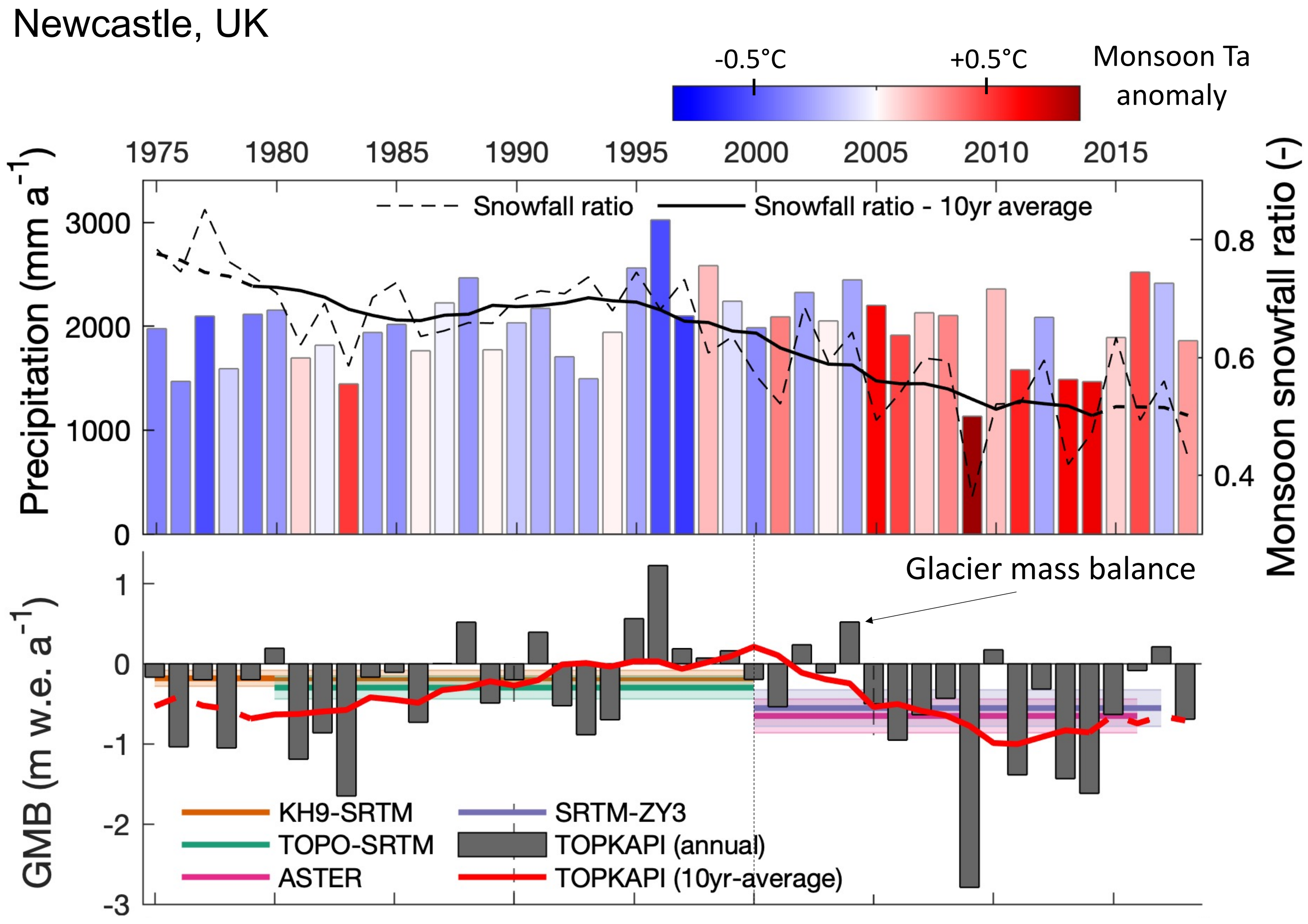

Fig. 2 : Reconstruction of climatic forcing and glacier-mass balance since 1975 at Parlung No.4 catchment

Abstract

Rapid mass loss of glaciers in High Mountain Asia (HMA) have large consequences for downstream water supply and glacier-related hazards. Glaciers in the Southeastern Tibetan Plateau are experiencing the highest mass loss rates within Asia, despite the limited impact of recent warming on their spring accumulation regime. Based on model simulations reconstructing the climate and glacier evolution of the last 45 years, we show that the recent acceleration in observed glacier mass loss was dominated by a warming-induced shift from snowfall to rainfall during the monsoon months, exacerbated by decreasing monsoon precipitation since the 2000s and only partly mitigated by increasing spring precipitation. Our results reveal the processes behind the high sensitivity to climate warming for glaciers in this region.

Introduction

The cryosphere of HMA is highly sensitive to climate change, and its changes will negatively affect more than 800 million people living in the downstream river basins a significant proportion of which depends on snow and glacier melt for their livelihoods or is vulnerable to disasters related to melting glaciers such as glacial lake outburst floods. Glaciers of HMA have experienced contrasting mass changes, with geodetic observations revealing the highest glacier mass loss rates of HMA in the Southeastern Tibetan plateau, where it accelerated over the last decades. This acceleration has been attributed to increased warming, but the mechanisms behind these glaciers' high sensitivity to warming remain unclear. These glaciers are often referred to as maritime, spring-accumulation type glacier experiencing large mass turnover rates.

Objectives

- Reconstruct the climate, glacier mass balance (GMB) and runoff at Parlung No.4 glacier (Fig.1) since 1975.
- Understand the key drivers and processes behind this mass loss that accelerated since the start of the 21st century in the Southeastern Tibetan Plateau.

Methods

- Model : TOPKAPI-ETH, glacio-hydrological, fully distributed, high-resolution (30 m, hourly time step),
- Forcing : Meteorological station data and bias-corrected reanalysis dataset (ERA5-Land, CMFD)
- Study period : 1975 to 2018
- Calibration & validation datasets: on and off-glacier AWSs, ablation stakes, proglacial discharge records, and remote sensing observations of multi-decadal glacier thinning and snow cover from MODIS and Landsat.

Results:

Between 1975-1999 and 2000-2018, the GMB decreased on average from -0.27 to -0.59 m w.e. a^{-1}, concomitant with a warmer average catchment temperature (+0.49°C). This was due to:

- An increase in icemelt (-0.13 m w.e. a^{-1})
- A warming-induced change in monsoon precipitation phase from snowfall to rainfall (-0.15 m w.e. a^{-1})
- A decrease in monsoon precipitation (-0.10 m w.e. a^{-1}).

It was partially compensated by an increase in spring snowfall (+0.10 m w.e. a^{-1}).

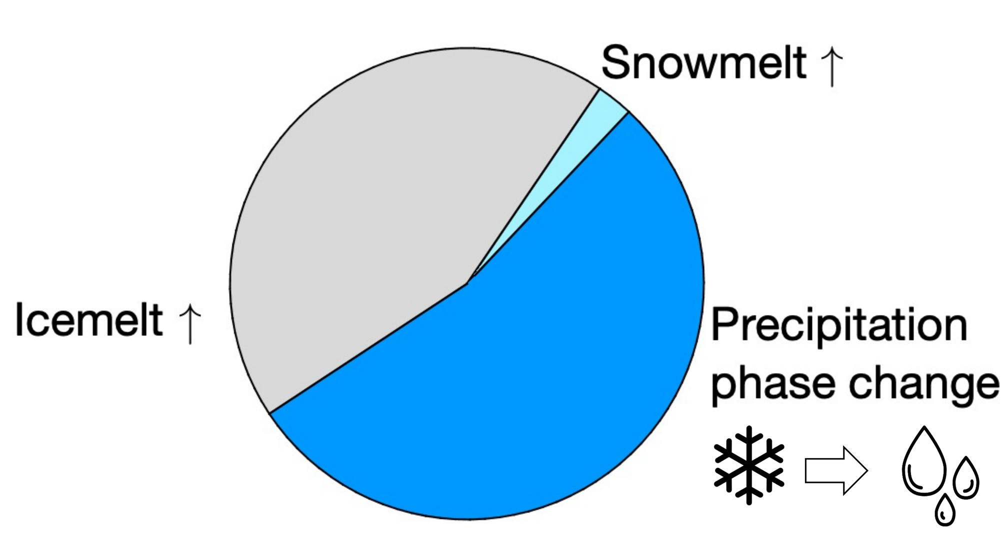

Fig. 4: Relative contribution of each component to the net glacier mass loss between 1975-1999 and 2000-2018

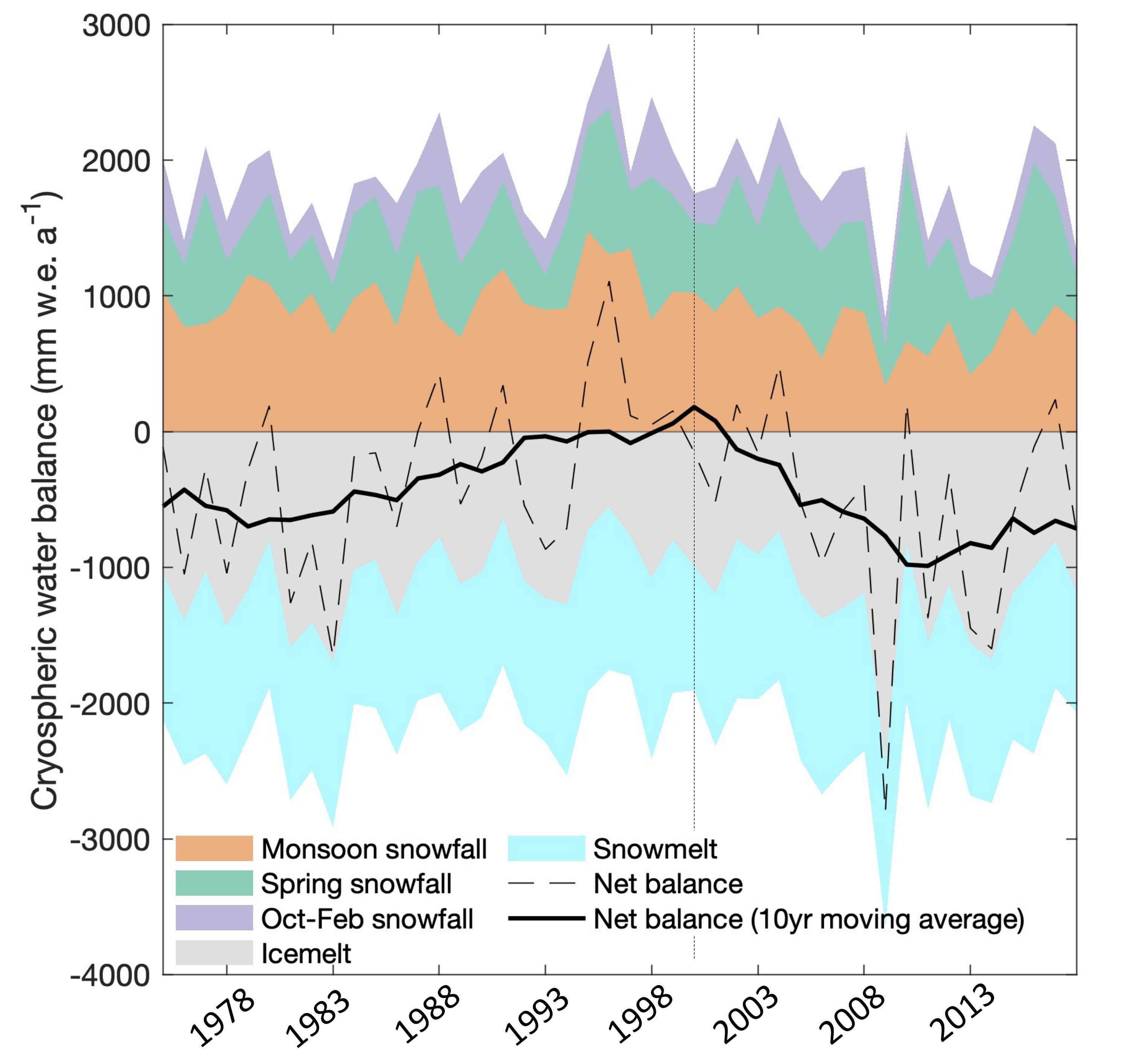

Fig. 3 : Annual solid water balance. The net solid water balance is computed as : Net balance = Snowfall - (Icemelt + Snowmelt)

Discussions

- Spring precipitation phase is still largely unaffected by the warming, thus spring accumulation became increasingly important in providing mass to the glacier.
- The catchment discharge increase due to enhanced ice-melt could raise the risk of glacier lake outburst flood occurrence and decrease the region' water resources in the long-term, both of which must be considered for the future development of hydro-power and water diversion projects.

Conclusions

The role of precipitation phase change in explaining those glaciers' sensitivity to temperature change was suggested in previous studies through sensitivity analyses. Here we attribute the recent mass loss to this change in precipitation phase during the monsoon months (Jun-Sep), and to the concurrent ice-melt intensification.

Major references

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