Session: P.3.1

2023 Dragon 5 Symposium 11-15 September 2023 | Hohhot, Inner Mongolia, China

Spatiotemporal variability of glacier albedo over the Third Pole from 2001 to 2020

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INTRODUCTION and METHOD

Glacier albedo is an expression of glacier interactions with climate and light-absorbing particles, and albedo reductions has been known to enhance glacier mass loss in the Third Pole (Fig. 1a), but its changes and drivers are still poorly quantified. Here, we leverage MODIS surface reflectance data (2001–2020) with an improved retrieval method (Ren et al., 2021) to explore the variability of glacier albedo across the Third Pole, including the interannual, seasonal, and altitudinal changes.

RESULTS

1. Interannual variability

Glacier albedo shows a declined trend at the rate of -0.009±0.008 dec^{-1} across the entire Third Pole. The most rapid decrease occurs in the Inner Tibetan Plateau (-0.024±0.013 dec^{-1}) which is the transition area of the westerly- to monsoon-dominated regions (Figs.1a and 1c). In the Karakoram, we find a lower mean albedo in 2010–2020 than before, providing further evidence for a recent reduction of the "Karakoram Anomaly".

In addition to the complex spatial patterns of change, the observed glacier albedo trends remain weak relative to the interannual variability for most regions, as indicated by the trends' significance, which have been ignored in previous trend-based analyses.

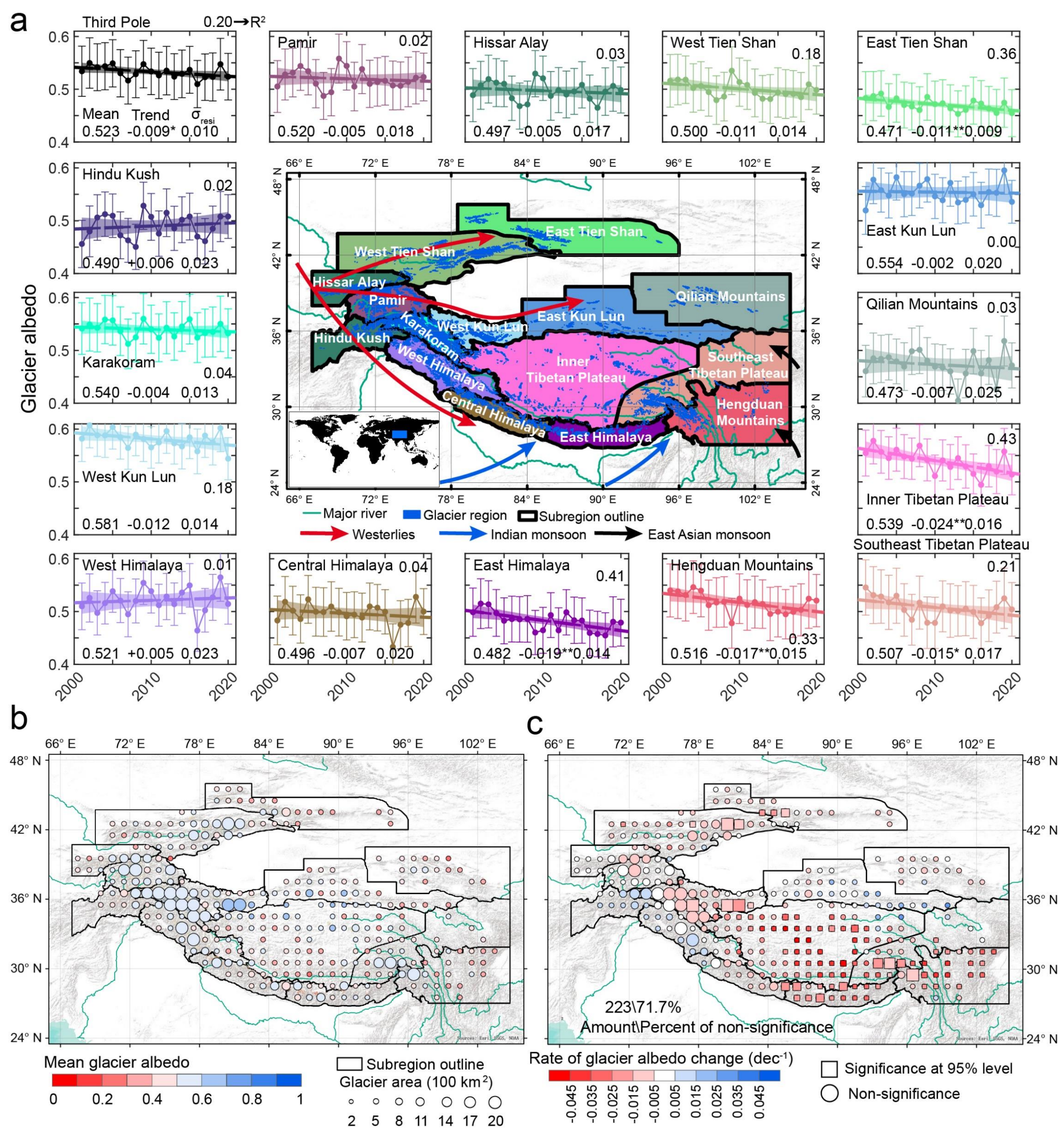

Figure.1 Glacier albedo and its decadal trend across the Third Pole for the period 2001–2020 derived from MODIS surface reflectance data. a: Time series of annual albedo; b-c: Mean and trend of annual albedo at 1° × 1° grids.

2. Seasonal variability

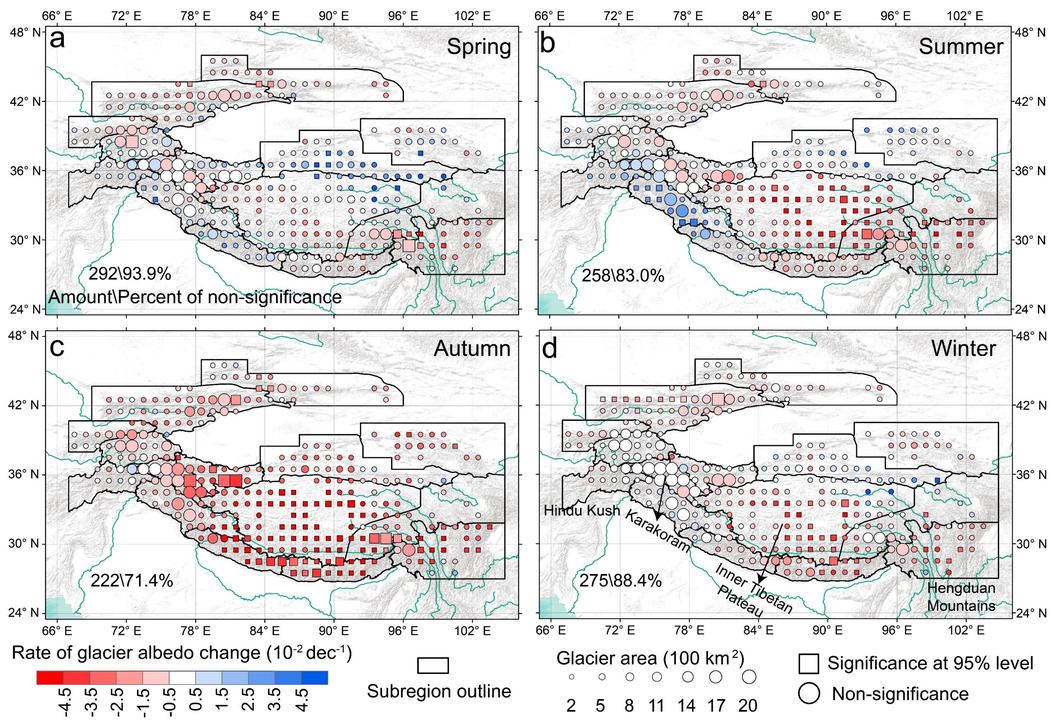

Figure.2 Trends of seasonal glacier albedo (same with Fig. 1c but for four seasonal glacier albedos)

The pattern of seasonal albedo varies considerably across the Third Pole (Fig. 2-3) and highlights the main mechanisms of glacier albedo change. Glacier albedo shows a stable or increasing trend in spring and early summer (Figs. 2a and 3), especially in the westerly-dominated and winter-accumulating subregions. This decrease in autumn is more pronounced in the transitional and monsoonal subregions such as the Inner Tibetan Plateau, the Southeast Tibetan Plateau and the Hengduan Mountains (Fig. 3)

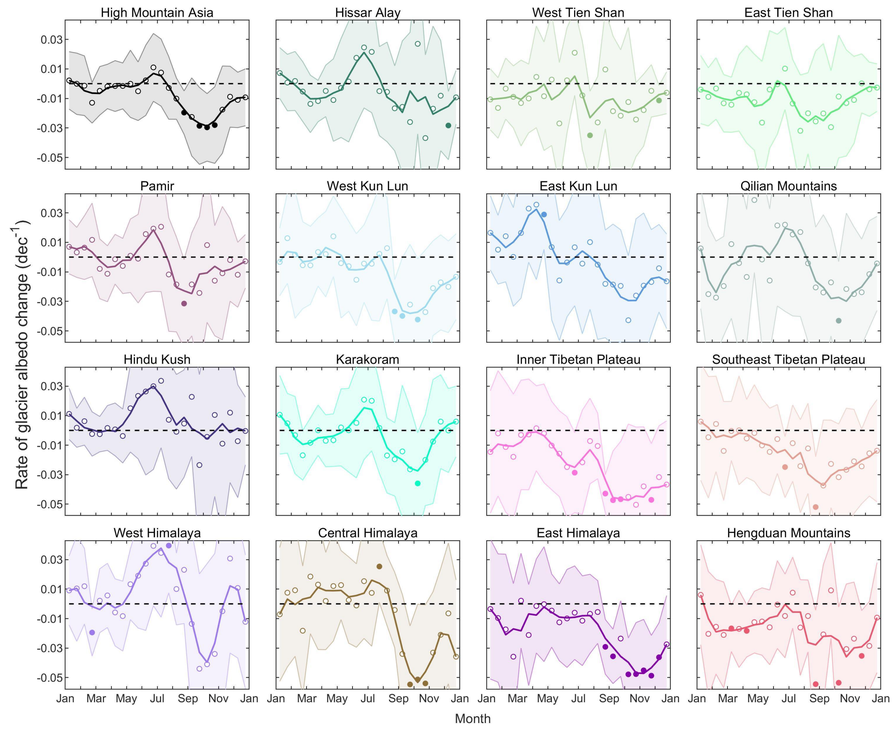

Figure 3. Rate of seasonal albedo change over the HMA and its subregions. The lines are moving averages with a three half-month window, black dotted lines show zero rate. Solid circle indicates that albedo trend is significant at 95% confidence level, hollow circle indicates not significant. The shaded area is the uncertainty of the trend.

3. Elevational variability

Notably, the glacier albedo trends generally show a maximum decrease at higher elevations in westerly-dominated regions (Fig. 4). While the maximum decrease is observed in the mid-elevation of the monsoon-dominated and transitional regions, likely due to the expansion of bare-ice ablation areas into high-elevation. However, similar to annual albedo, we also find strong signals of interannual variability in most elevation, which should be the main response of glacier albedo to climate.

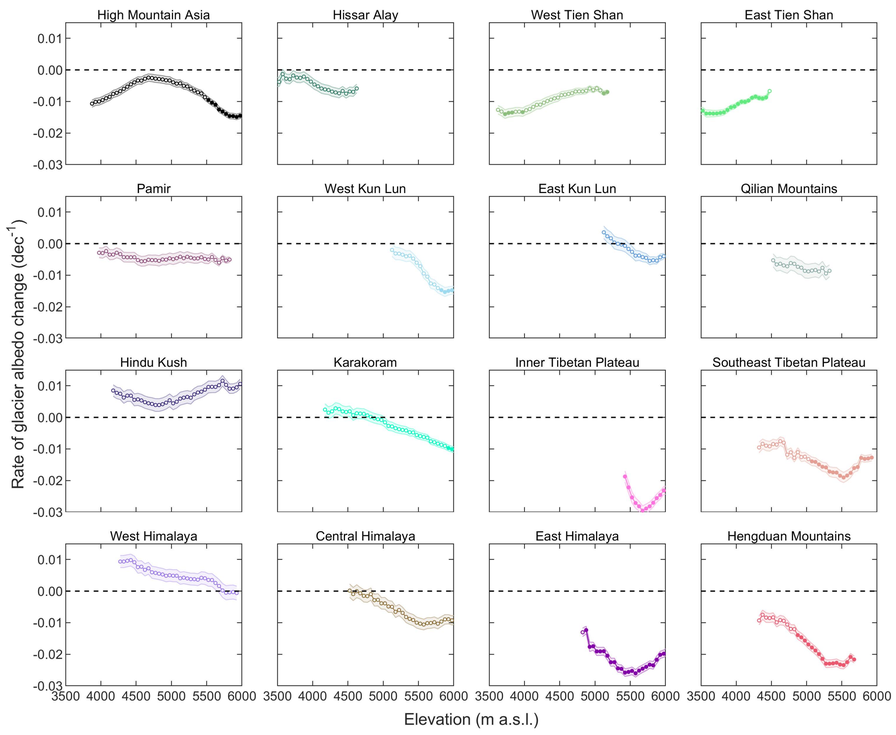

Figure 4. Same with Fig. 3 but for elevation bins.

CONCLUSIONS

- Glacier albedo over the Third Pole varies across distinct climate regimes in terms of its annual mean, trend, altitudinal pattern.
- Glacier albedo is declining in the most regions, but high interannual variability is the dominant signal for the past 20 years

ACKNOWLEGMENT

This research was supported by the by the Second Tibetan Plateau Scientific Expedition and Research (STEP) programme (2019QZKK0201, 2019QZKK0103); the National Natural Science Foundation of China (42201144, 91737205), the Chinese Academy of Sciences President's International Fellowship Initiative (Grant No. 2020VTA0001) and the MOST High Level Foreign Expert program (Grant No. GL20200161002) and the Dragon 5 project (grant no. 32439).

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