

Catastrophic non-linear glacier change on Juneau Icefield, Alaska

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Plateau icefields may be especially sensitive to climate change due to the non-linear controls their topography imparts on their response to climate change. We used geomorphological mapping (field surveys and remotely sensed mapping) and structure-from-motion to reconstruct the extent, volume and velocity of Juneau Icefield (Alaska / British Columbia) and its surrounding glaciers during the LGIT, the Holocene, and then in the “Little Ice Age” (1770), 1948 and 1979, and approximately decadal from 1979 to 2020 AD.

Our LIA reconstruction indicated that the study area included 1158 glaciers in 1770 AD, covering $5853.55 \pm 229.75 \text{ km}^2$, which is 2037.27 km^2 greater than in 2019 AD. 108 glaciers disappeared from 1770-2019. Total icefield volume loss (LIA to 2020 AD) was $176.14 \pm 27.22 \text{ km}^3$. Total rates of recession 1770-1948 AD were $-6.27 \text{ km}^2 \text{ a}^{-1}$, icefield volume loss was $-0.12 \pm 0.05 \text{ km}^3 \text{ a}^{-1}$, and 97.14% of glaciers receded. From 1948-1979, glaciers receded at $-5.53 \text{ km}^2 \text{ a}^{-1}$, icefield-wide volume loss was $-0.88 \pm 0.20 \text{ km}^3 \text{ a}^{-1}$ and 31.84% of glaciers advanced. Several glaciers thickened slightly, with an advance of 1,486 m for Taku Glacier.

From 1979-1990, recession accelerated, reaching $-7.95 \text{ km}^2 \text{ a}^{-1}$, and 8.53% of glacier advanced. Glacier recession was $-17.19 \text{ km}^2 \text{ a}^{-1}$ (1990-2005) and accelerates sharply after 2005, reaching $-23.69 \text{ km}^2 \text{ a}^{-1}$ (2005-2015) and then $-45.69 \text{ km}^2 \text{ a}^{-1}$ (2015-2019). This indicates an eight-fold increase in recession from 2015-2019 relative to 1948-1979, and a fivefold increase relative to 1979-1990. All glaciers receded from 2005-2019.

Icefield-wide volume loss from 1979-2000 reached $-3.00 \pm 0.18 \text{ km}^3 \text{ a}^{-1}$, $-3.08 \pm 0.14 \text{ km}^3 \text{ a}^{-1}$ (2000-2010), and $-5.91 \pm 0.16 \text{ km}^3 \text{ a}^{-1}$ (2010-2020). Thinning is now apparent at elevations of 1725 m asl on Gilkey Glacier and 1670 m asl on Meade Glacier, where thinning almost reaches the ice divide. Thinning has now reached the plateau accumulation areas of Norris Glacier and Mendenhall Glacier. This has resulted in increasing glacier fragmentation, with

disconnections between accumulation and ablation areas occurring with rapidly increasing frequency after 2005 AD.

This study shows a glaciological threshold response to a warming climate and a rising ELA. Thinning on the plateau area is inducing rapid and accelerating recession of glacier tongues and fragmentation of the icefield. The non-linear behavior observed is highly concerning for the future viability of the icefield.



Collecting cosmogenic nuclide samples from Taku D Nunatak, Juneau Icefield