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Meltwater discharge and flooding of the outlet stream of Qaanaaq Glacier, northwestern Greenland

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Glacial meltwater discharge is increasing in Greenland under recent warming climate. As a consequence, floods and damages on infrastructures are reported at outlet streams of land terminating glaciers. For example, discharge from Qaanaaq Glacier in northwestern Greenland rapidly increased on 21 July 2015, leading to a flood of a proglacial stream and destruction of a road between a settlement and Qaanaaq Airport. Another flood on 2 August 2016 caused even more serious damage. These events occurred after an intensive melt period and a heavy rain storm, suggesting a risk of similar disaster increases in the future under warming and wetter conditions in the Arctic. To better understand the mechanisms causing the flood events at Qaanaaq Glacier, we investigated meteorological conditions during the 2015 and 2016 events, and performed field measurements in the summer 2017 and 2018.

Before the flood on 21 July 2015, high temperature was continuously observed for 5 days. Daily mean temperature rose above 5 [U+2103] in the accumulation area (944 m a.s.l.), causing intensive melting over the entire glacier. The most likely interpretation of the flood was that meltwater accumulated in snowpack and suddenly drained from the glacier when it reached saturation. The flood on 2 August 2016 was due to extraordinary heavy rainfall with daily precipitation of 90 mm. In addition to a clear influence of the precipitation on the stream discharge, we assume that a snow-free glacier surface condition enhanced rapid increase in glacier runoff. From 7 July to the date of the flood, daily mean air temperature at 944 m a.s.l. remained above freezing for the entire period, resulting in disappearance of snow on the glacier below 950 m a.s.l.. Snowline elevation on the day of the rain storm was significantly higher than usually observed in late summer. Largely exposed ice surface has no capacity to store water, thus helped immediate runoff of a large amount of rainwater. These analyses suggested that retention and saturation of meltwater within a snow layer play a key role in the flood events in 2015 and 2016.

Discharge from Qaanaaq Glacier was measured from 21 July to 3 August 2017. Melt and runoff from the glacier was estimated by repeating surveys of snow depth, density, stratifications, ice melt and meteorological conditions along a route spanning the terminus to the accumulation area (243–968 m a.s.l.). Stream discharge rapidly increased in late July, leading to a peak value of 8.11 m^3 s^{-1} on 28 July 2017. Estimated total glacier melt accounted for only 60 % of the runoff measured before the peak discharge, indicating the rest of meltwater remained on the glacier. From 21 to 28 July, snowline elevation rose from 500 to 650 m a.s.l. after intensive melting. Our data suggested that meltwater stored in snowpack reached saturation, and rapidly released during the period of rapid melting and upglacier snowline migration. Together with data in 2018, we conclude that saturation and disappearance of snowpack are the key to predict rapid increase in stream discharge and following flood.