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The 2016 gigantic twin glacier collapses in Tibet: towards an improved understanding of large glacier instabilities and their potential links to climate change

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In northwestern Tibet (34.0°N, 82.2°E) near lake Aru Co, the entire ablation area of an unnamed glacier (Aru-1) suddenly collapsed on 17 July 2016 and transformed into a mass flow that ran out over a distance of over 8 km, killing nine people and hundreds of cattle. Remarkably, a second glacier detachment with similar characteristics (Aru-2) took place 2.6 km south of the July event on 21 September 2016. These two events are unique in several aspects: their massive volumes (66 and 83 Mm3 respectively), the low slope angles (<13°) of the failed glacier sections, the maximum avalanche speeds (> 200 km h-1) and their close timing within two months. The only similar event currently documented is the 2002 Kolka Glacier mass flow (Caucasus Mountains). The uncommon occurrence of such large glacier failures suggest that such events require very specific conditions that could be linked to glacier thermal regime, bedrock lithology and morphology, geothermal activity or a particular climate setting. Using field and remote sensing observations, retrospective climate analysis, mass balance and thermo-mechanical modeling of the two glaciers in Tibet, we investigate the processes involved in the twin collapses. It appears that both, mostly cold-based glaciers, started to surge about 7-8 years ago, possibly in response to a long period of positive mass balance (1995-2005) followed by a sustained increase of melt water delivery to the glacier bed in the polythermal lower accumulation zone (1995-2016). Inversion of friction conditions at the base of the glacier constrained by surface elevation change rate for both glaciers shows a zone of very low basal friction progressively migrating downward until the final collapse. We interpret this to be the signature of the presence of high-pressure water dammed at the bed by the glacier's frozen periphery and toe. Large areas of low friction at the bed led to high shear stresses along the frozen side walls as evident in surface ice cracking patterns observed on satellite imagery. This process progressively weakened the ice, until the final rupture releasing both water and ice into a high-speed long-runout glacier avalanche. We suggest that the combination of increasing temperature and precipitation in this area of the Tibetan Plateau is the probable driver of the twin collapses. However, such an event occurs only for a very specific configuration of thermal regime, glacier morphology and probably other characteristics that may include the fine-grained sedimentary lithology of the bed and/or hydrothermal activity beneath the glaciers.