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Repeat glacier collapses and surges in the Amnye Machen mountain range, Tibet, triggered by a developing rock-slope instability

Frank Paul
University of Zurich, Department of Geography, Zurich, Switzerland (frank.paul@geo.uzh.ch)

Collapsing valley glaciers leaving their bed to rush down a flat hill slope or valley bottom at the speed of a racing car are so far rare events. They have only been reported for the Kolkaglacier (Caucasus) in 2002 and the two glaciers in the Aru mountain range (Tibet) that failed in 2016. Both events have been studied in detail using satellite data and model-ing to learn more about the reasons for and processes related to such events. In direct comparison the two events share some similarities but had also differences. For example, both collapses occurred very sudden and the ice masses reached very far (several km) with high velocities (>200 km/h) and large volumes (>50 million m3) involved. On the other hand, the climatic regimes in both regions and the trigger mechanisms are very different. Whereas Kolkaglacier is a well-known surge-type glacier, surge-type behaviour was not known for the two Aru glaciers before the event.

This study reports about a series of so far undocumented glacier collapses that occurred in the Amnye Machen mountain range (eastern Tibet) in 2004, 2007 and 2016. The region is well known for its several surge-type glaciers, but collapses had so far not been reported. The timing and potential triggers for the collapses were identified from the analysis of dense time series of satellite data (Landsat and Sentinel 2) in combination with very high resolution images as available in Google Earth and maps from bing.com. Additionally, DEMs from SRTM, AWD3D30 and the HMA DEM from NSIDC are used to follow the strong volume changes of the ice over the 2000-2015 period. Despite local artifacts and DEM uncertainties, glacier elevation changes can be well followed and are fully compliant with the events derived from optical satellite data. The various extents of the glacier (before and after the surges and collapses) and avalanche deposits were digitized manually from the satellite images.

The analysis revealed that all three glacier collapses were associated with a glacier surge, but from 1987-1995 the glacier surged to a much larger extent without collapsing. The more recent surges and collapses were likely triggered by a progressing slope instability that released large amounts of ice and rock to the upper flat part of the glacier, distorting its dynamic stability. The progressive enlargement of the rock outcrops can be exactly followed in the satellite image time series and the very high resolution images acquired after the second and third collapse reveal numerous details about the (incompetent) lithology of the rock wall, the failure zone at the glacier and the avalanche deposit. The first collapse from 2004 shortly damned a lake and covered an area of about 2.2 km2. The volume of the deposit was estimated at 36 million m3 by Chinese authorities. They speculated that the development is a direct response to regional temperature increase that destabilized the surrounding hanging glaciers. The surges and collapses of this glacier might continue in the future as more ice and rock is available to fall on it.