Helmholtz Centre Potsdam
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GNSS on Glaciers - Continuous Monitoring of a Glacier Lake Outburst Flood

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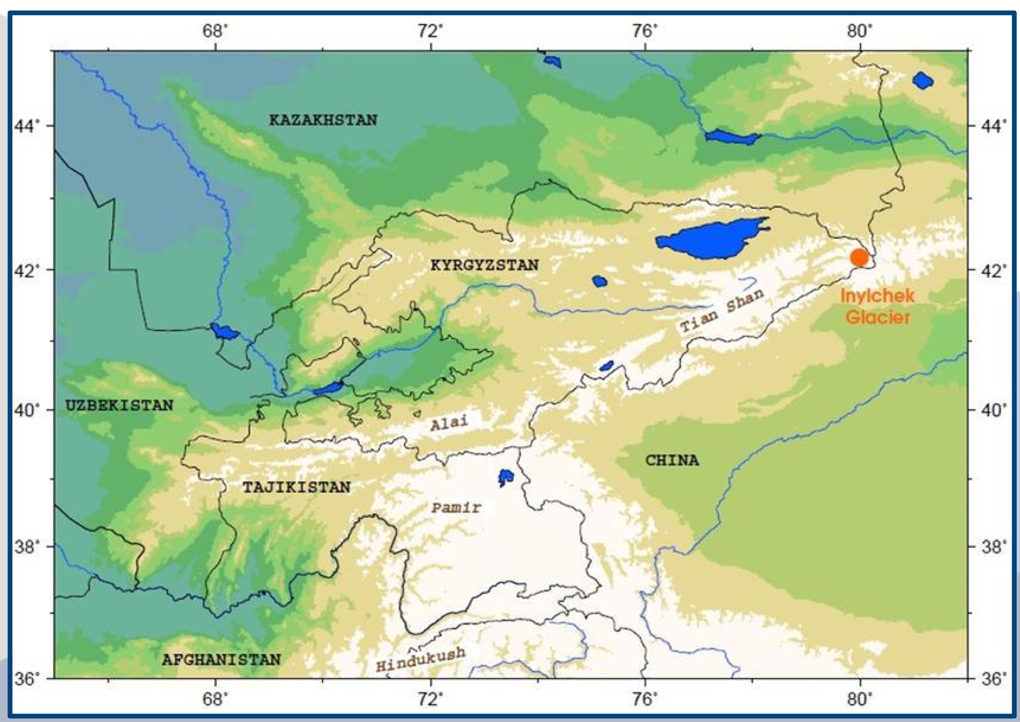
Natural glacier events such as ice avalanches, debris flows or glacier lake outburst floods (GLOF) may have hazardous impacts on the downstream area of the glacier and can cause severe destructions. The Inylchek Glaciers in Kyrgyzstan are among the largest non-polar glacier systems in the world. In spring, an ice-dammed lake is formed (Lake Merzbacher) by melt-water from the northern tributary. The lake drains predominantly every year suddenly within a few days causing a destructive flood. To understand the mechanism of the GLOF and to evaluate the potential to develop an early warning system, a network of continuously operating GNSS stations at the Inylchek Glaciers provide horizontal and vertical positions of the ice-dam in front of the Merzbacher Lake. GFZ and CAIAG jointly operate this Global Change Observatory consisting of a network of GNSS stations.

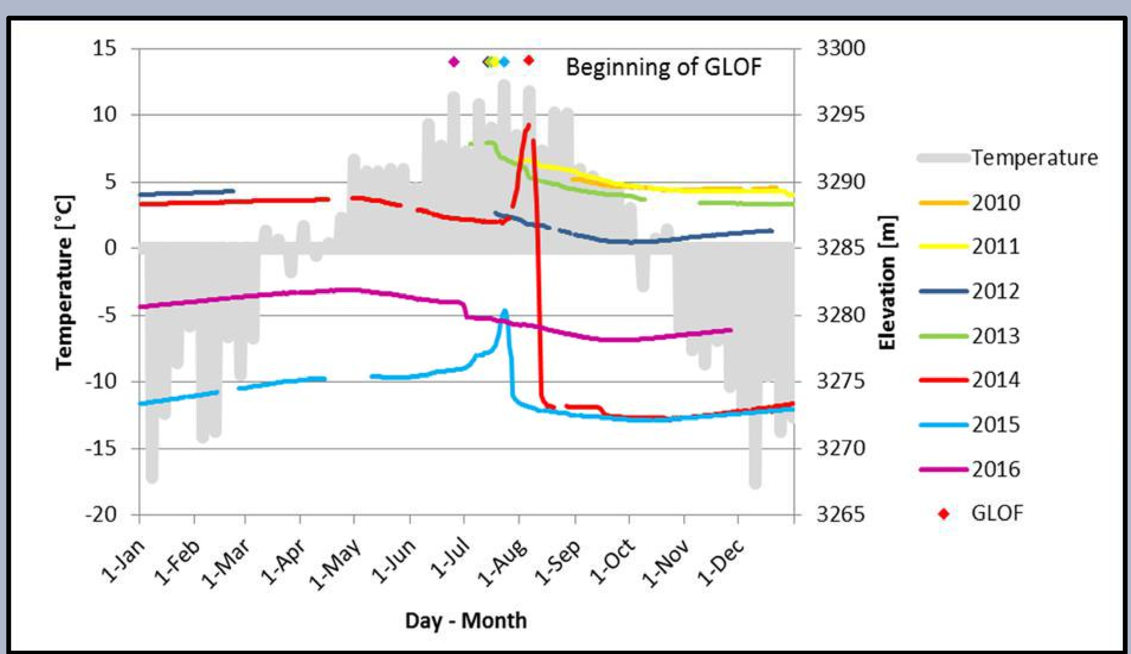


Map of Central Asia with the Tian Shan Mountains in eastern Kyrgyzstan showing the location of the Inylchek Glaciers at the border to China and Kazakhstan.

Northern and southern tributary of the Inylchek Glaciers showing the locations of the GNSS monitoring stations marked with green triangles.

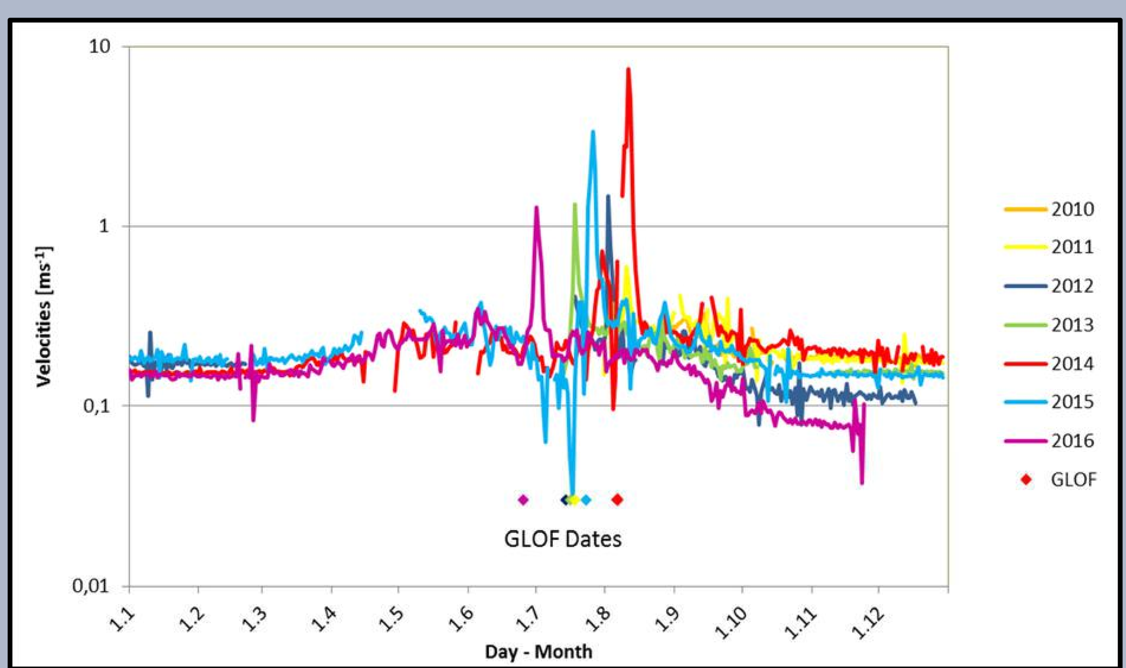
Kinematic ice dam station (ICED) with a Topcon GNSS receiver, a Vaisala WXT520 weather sensor, power supply and HF radio antennas.

The stations provide short-latency 1Hz GNSS data which is processed daily using MIT's kinematic software TRACK in combination with IGU orbits downloaded from CDDIS. The resulting time series is analyzed for rapid changes due to ice cracking and averaged to daily positions. For the usage of other applications, additional instruments are integrated such as meteorological, hydrological and seismic sensors. Furthermore, optical cameras support the monitoring of the GLOF.



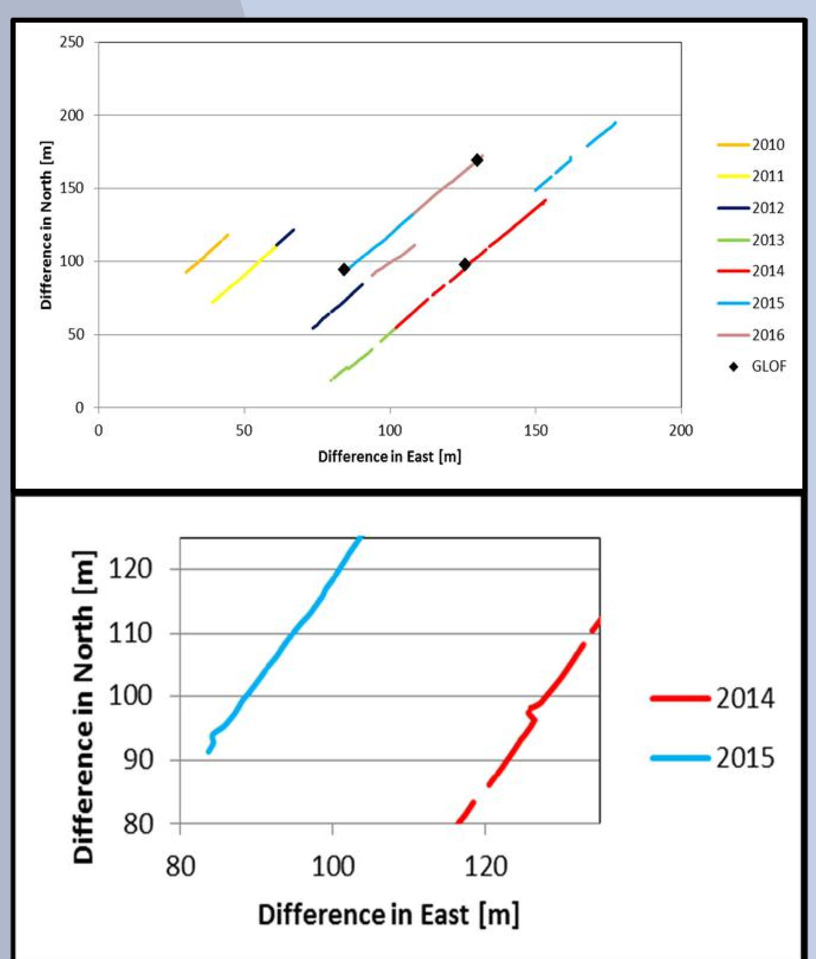
Elevation changes of the station ICED for the years 2010 to 2016 compared to air temperature values. Temperature values for 2014 are shown but are representative also for the other years. The different elevation is the result of varying initial positions. GLOF dates are marked with diamonds.

Irrespective of the general motion of the glacier during the year, the ice-dam is strongly influenced by the formation and outburst of the Lake Merzbacher. Shortly prior and after the GLOF, the GPS time series show a substantial change in the ice-dam's behavior. Especially the vertical position and surface velocities increase shortly before the GLOF supporting the assumption that the ice-dam adjacent to the lake becomes afloat. Water penetrated underneath the ice-dam and bend the ice upwards. After the GLOF, e.g. in 2014, the elevation decreases rapidly by 20 m within eight days. In 2015, the GLOF changes in timing, magnitude and available lake water volume but the motion pattern of the ice-dam is similar compared to the years before.

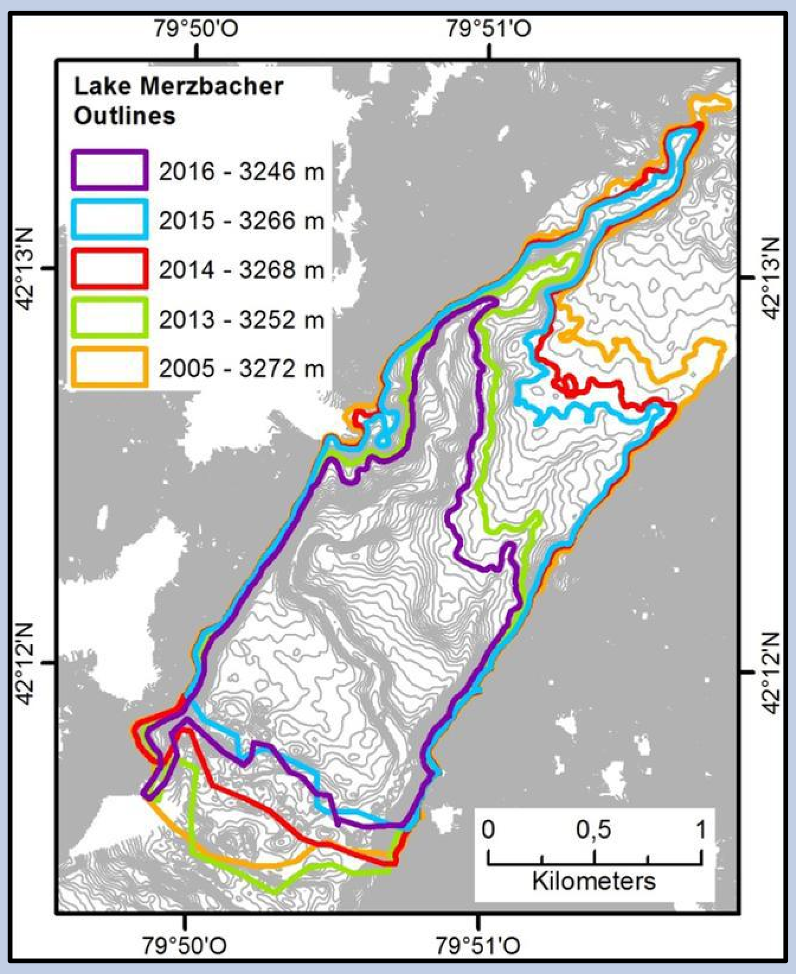


Surface velocities of the station ICED for the years 2010 to 2016 and GLOF dates marked with diamonds.

Before the GLOF the ice-dam changes its direction of movement due to the counter-pressure of the lake's water. After the discharge, the ice masses can stretch unhampered.



(a) Tracks of the moving ICED station for the years 2010 to 2016 with different initial positions for each year. (b) Horizontal movement of ICED showing the change of direction around the GLOF for 2014 (red) and 2015 (light blue).



Bathymetry of Lake Merzbacher shown with 2m contour intervals. The maximal lake extends for the years 2005, 2013, 2014, 2015 and 2016 are highlighted in different colors.

Around the GLOF dates, the surface velocities show a significant change and are 3-5 times higher shortly before and up to 16 times higher during the GLOF. These results show the potential to develop an early warning system for the glacier-dammed lake outburst flood using continuous GNSS monitoring.

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