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Physical Geography

The Khurdopin glacier surge revisited – extreme flow velocities and formation of a dammed lake in 2017

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Glacier surges are a common phenomenon globally with an especially high density in the Pamir and Karakoram mountain ranges. During a surge ice mass is relocated within weeks to years from from the upper reaches to the lower tongue at a velocity up to several orders of magnitude than during quiescence. We use new high resolution satellite imagery (Planet, ASTER) to document a rapid surge in Pakistan during 2017 and an associated lake formation. We show the potential of these images for research as well as for hazard assessment and early warning.

Motivation & Background

1) *Research:* Reasons for and processes of glacier surges are poorly understood

2) *Hazard Management:* Recurring glacial lake outburst floods in Northern Pakistan threatening livelihoods and infrastructure

3) *Satellite Data:* Show applications of rapidly improving satellite imagery

Study Site

Khurdopin Glacier is located in the Shimshal valley in the Pakistani Karakoram (Figure 1). The catchment includes a number of surging glaciers. 2000 inhabitatnts mainly live of local agriculture. Khurdopin Glacier surges every 20 years resulting in the local river being blocked causing a lake to form. The sudden emptying of the lake results in increased discharge which has caused heavy damage to downstream infrsatructure in recent decades. An ancient warning system was in place at the beginning of the 20th century (Figure 1).

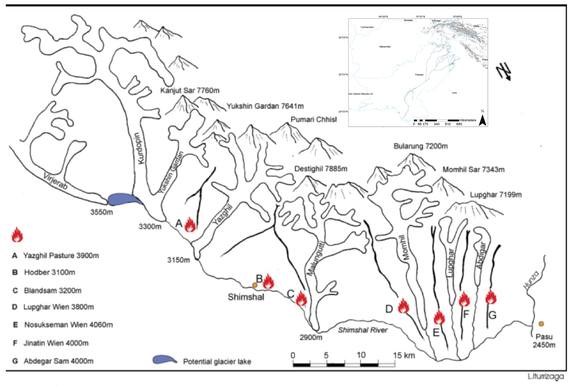


Figure 1: The Shimshal catchment drawn with the original warning system utilized when the lake at Khurdopin Glacier filled (Itturizaga, 2005)

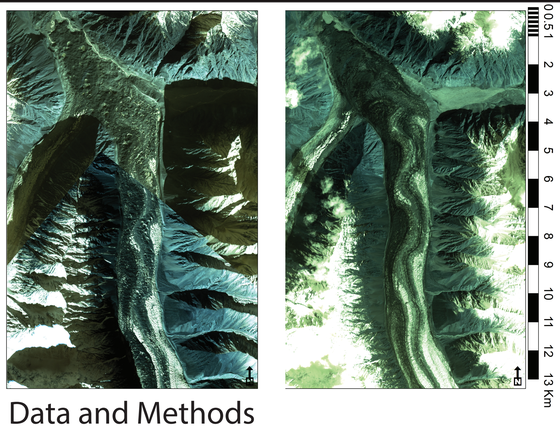
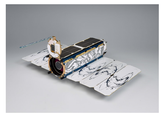


Figure 2: Images of Khurdopin Glacier taken by the Planet Satellites (Planet, 2017) on 12/30/2016 and 09/12/2017 at 3 m resolution from left to right. Below, the Planet Dove satellite with extended solar panels.



Data and Methods

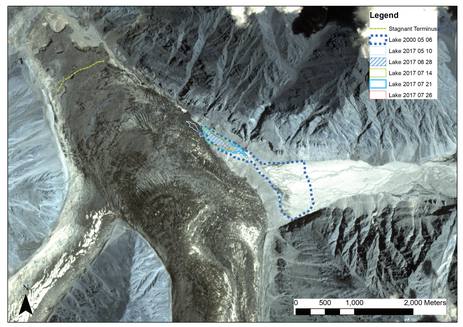
(1) Velocities via feature tracking (COSI-Corr):
Previous: 30 m Landsat img. with maximal 2 week overpass
Today: 3 m img. from *Planet Doves* (Planet, 2017) at subweekly overpass (Fig. 2)

(2) Ice Volume Changes
Previous: commercial tasking, SRTM, ASTER
Today: ASTER Ames Pipeline (30 m), TanDEM-X (10 m)

Hazard Mapping

Caused by the surge a lake formed in June 2017 that drained in July (Figure 3) and destroyed bridges and agricultural land below. This lake is likely to form again in subsequent years as soon as the melt period starts, like after previous surges.

Using Planet imagery and a DEM we were able to produce a map and volume projections in near real-time to share with local stakeholders. The high resolution imagery also provides the possibility to track indicators of potentially dangerous surface changes (i.e. collapsing tunnels, ice floes blocking the outflow).



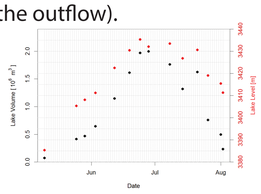


Figure 43 Map of the terminus at the surge peak with mapped lake outlines (left). Lake area and volume (top right). Surge front in May 2017, with darkened ice due to increased basal erosion (bottom right).

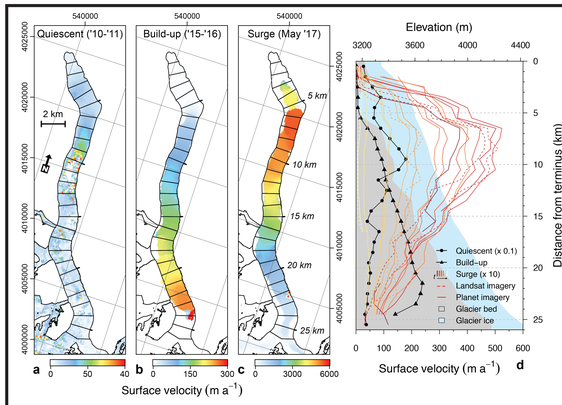
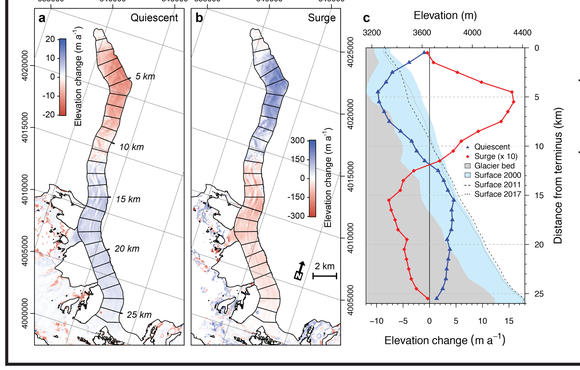


Figure 34 Velocities for different periods on the lower tongue (above). Volume changes based on 3 DEMs (below).



Scientific Results

- velocity increase over 4 yrs.
- rapid surge during 9 mth.
- peak velocities of 15 - 20 m d^{-1} (4000 - 5000 m a^{-1})
- switch from cold to temperate bed
- disappearing supraglacial ponds indicate disturbed hydrological network
- tipping point at steep bedrock section
- relocation of >10^9 m^3 of ice within two years

Conclusions and Outlook

- Highest glacier flow velocities measured in the Karakoram
- Potential of high resolution and high frequency images to better investigate glacier surges
- Potential of Planet imagery for use in hazard warning in remote areas

- Collect field data to improve understanding of triggers for a surge
- Investigate other surging glaciers for similar surge patterns
- Capacity building of local stakeholders to employ satellite imagery (including Sentinel for water mapping) as a tool for hazard warning and risk assessment
- Evaluate use of Planet data for other fields of hazard assessment (landslide mapping, flooding, etc.)

References

Itturizaga, L. (2005), New observations on present and prehistorical glacier-dammed lakes in the Shimshal valley (Karakoram Mountains), Journal of Asian ES
Steiner J., et al. (2017), The Khurdopin glacier surge revisited – extreme flow velocities and formation of a dammed lake in 2017, The Cryosphere
Planet (2017), Planet Team: Planet Application Program Interface: In Space for Life on Earth., [online] Available from: https://api.planet.com, 2017