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# Surge of Hispar Glacier, Pakistan, between 2013 and 2017 detected from remote sensing observations

Irfan Rashid [a,*], Tariq Abdullah [a], Neil F. Glasser [b], Heena Naz [a], Shakil Ahmad Romshoo [a]

[a] Department of Earth Sciences, University of Kashmir, Hazratbal Srinagar, Jammu and Kashmir 190006, India
[b] Centre for Glaciology, Department of Geography and Earth Sciences, Aberystwyth University, Aberystwyth, Wales SY23 3DB, UK

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ABSTRACT

This study analyses the behaviour of an actively surging glacier, Hispar, in Pakistan using remote sensing methods. We used 15 m panchromatic band of Landsat 8 OLI from 2013 to 2017 to assess the changes in glacier velocity, glacier geomorphology and supraglacial water bodies. For the velocity estimation, correlation image analysis (CIAS) was used, which is based on normalized cross-correlation (NCC) of satellite data. On-screen digitization was employed to quantify changes in the glacier geomorphology and dynamics of supraglacial water bodies on the glacier. Our velocity estimates indicate that the upper part of the glacier is presently undergoing an active surge which not only affects the debris distribution but also impacts the development of supraglacial water bodies. Velocities in the actively surging part of the main glacier trunk and its three tributaries reach up to ~900 m $yr^{-1}$. The surge of Hispar also impacts the distribution of supraglacial debris causing folding of the medial moraines features present on the glacier surface. Changes in the number and size of supraglacial lakes and ponds were also observed during the observation period from 2013 to 2017.



## 1. Introduction

Glacier surges have been reported from many areas of the world including the Canadian and Russian High Arctic, Svalbard, Iceland, Greenland, Alaska and parts of the Himalaya (Sevestre and Benn, 2015). These surge-type glaciers go through an active phase and a quiescent phase. While the active phase is characterized by recurring non-steady flow that can last for a few months to years, the quiescent phase lasts longer, typically tens to few hundreds of years (Meier and Post, 1969). Karakoram glacier surges are poorly understood (Hewitt, 2005). The glacier velocities of surge-type glaciers in Karakoram during active phase increase by up to 200% than during the quiescent phase (Hewitt, 1969). Peak velocities of around 2 km $yr^{-1}$ during summer months have been observed (Quincey et al., 2015). Majority of the surge type glacier have been reported to vary between 12 and 25 km in length (Hewitt, 1969) and are often fed by tributary glaciers (Hewitt, 2007). There is a positive correlation between surge-type glaciers and glacier length, area, perimeter, average width, debris cover and orientation (Barrand and Murray, 2006). Insignificant changes in debris cover, indicative of stable mass budget of glaciers in Hunza river basin, has been recently reported (Herreid et al., 2015; Bolch et al., 2017). The season of Karakoram glacier surge initiation varies. Some surges develop extremely quickly (Kick, 1958; Gardner and Hewitt, 1990) while others develop gradually over several years (Quincey et al., 2011). These surges can result in huge advance of the glacier snout (km-scale), over a short time span (weeks to months). It has been suggested that Karakoram glacier surges may be triggered by change in thermal conditions (Hewitt, 2007) that coincide with warming driven by long-duration precipitation patterns (Quincey et al., 2011), although other studies advocated changes in hydrological conditions as a possible trigger mechanism for glacier surges in the region (Copland et al., 2011; Mayer et al., 2011). However, it is pertinent to mention that the glacial hydrological regimes are controlled by the thermal regimes.

Drawing on data from eight glaciers, Quincey et al. (2015) suggested that no single classical mechanism is able to comprehensively describe the flow-instability of surge-type glaciers in Karakoram. Their analysis did not find any evidence of seasonal control on the initiation of glacier surges in the region. They suggested that these surge events are triggered by a blend of hydrological and thermal processes.

Here we present new data concerning glacier velocity and changes in the surface character of a surge-type glacier in Pakistan, the Hispar Glacier. Hispar is a ~50 km long surge-type glacier (Copland et al., 2011; Hewitt, 2005), located in the Karakoram Mountains (Lat: 36.02–36.32 N; Lon: 75.02–75.55 E) in Gilgit Baltistan province of Pakistan (Fig. 1). The mountains enclosing Hispar and its tributaries are characterized by very steep snow-covered cliffs rising to slope angles of 77° which result in numerous snow avalanches feeding the glacier. The altitudinal extent of Hispar Glacier is 3088 to 7113 m amsl. Taking snow-line as an approximation of equilibrium line altitude (ELA), the

* Corresponding author.
*E-mail address:* irfangis@kashmiruniversity.ac.in (I. Rashid).

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