YNU-GCISC Project Final Report

Joint Project

Collaborated by

Yunnan University

&

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CONTENTS

1. Introduction

The High Mountain Asia (HMA) are facing rapid changes in snow and ice due to climate change, which has significant impacts on the environment, water resources and may cause natural hazards. The economy of the major river basins in Asia is mostly reliant on agriculture and energy. Assessment of glaciers and its future impact on downstream stream flow play an important role for regional economy. Changes in these resources will seriously impact food security, energy demands and environment of Pakistan. Recent climate change has seriously declined Glaciers worldwide. It is crucial to understand these changes, particularly in the field. Significant number of glaciers are debris covered which complicates the melt characteristics in the Karakoram and their melt characteristics are necessary to understand. These glaciers are rarely observed in the field to understand their changing behaviour with orientation and slope. This study investigates glacier melting with debris cover thickness about glacier slope, aspects, latitude and altitudes. The debris-cover thickness measurement positions will also be measured with high-resolution dGPS to get precise glacier altitudes. These measurements will be compared with the available elevation data from remote sensing satellites will help to estimate glacier surface elevation changes in the last seventeen years (2000-2017). The derived results (from debris cover thickness) will also help to generalise the debris cover glaciers response to climate change in the UIB. Moreover, our ground measurements will also incorporate temperature measurements at various altitudes and aspects to assist in estimating temperature lapse rate and degree-day factor for glacier melting mainly in (September-October). The rationale behind temperature measurements is the previous observations, where temperature rise of only a few days in the summer seasons significantly affected glaciers in the Karakoram region (however, no such observations are available mainly in the glacier environment mostly above 3000 m a.s.l.). The study will also help to understand the influence of summer temperature variations on the Karakoram Anomaly where most of the studies assume precipitation as the primary factor behind the anomaly.

The complex mountain's terrain of the Karakoram makes it challenging to understand glacier behaviour (Hewitt 2005). Observations of glaciers are necessary to quantify current and future hydrological changes particularly in the field (Mayer et al., 2006, 2010; Hewitt 2005, 2011; Muhammad and Tian 2016). Debris covers most of the medium and large glaciers in the Karakoram (Bolch et al., 2012) having a substantial difference in melting compared to debris-free glaciers (Gardelle et al., 2012; Scherler et al., 2011). Existing of debris-cover complicates the response of glaciers to climate change (Bolch et al., 2012; Scherler et al., 2011; Hewitt 2005, 2014; Rankl et al., 2015). Remote sensing estimates of debris cover and debris-free glacier melting comparison strongly contradict (Kääb et al., 2012; Gardelle et al., 2012). The glacier melt-rate vary with debris-cover thickness and altitude (Mayer et al., 2006, 2010; Muhammad et al., 2016). In addition, the melt-rates also vary significantly with the orientation of the glacier (Lambrecht et al., 2011). However, quantitative estimates of the influences of slope and direction on the ablation rates are not available for the Karakoram where the glaciers mass balance is anomalous.

The thickness of debris varies with altitude, which substantially influences the rate of ablation (Pratap et al., 2015). The ablation is typically highest at around 1 cm and lowest above 40 cm of the debris thickness (e.g., Rakhiot and Barpu glaciers (Mattson 1993), Baltoro glacier (Mihalcea et al., 2006), Hinarche glacier (Mayer et al., 2010), Dokriani Glacier (Pratap et al., 2015)). An increase in the ablation rate for up to 1 cm of debris thickness is due to conduction of absorbed radiative heating, while its decreased melting for increased debris thickness is due to the insulation effects. In addition, recent observations show a significant increase in the debris-cover area of the observed glaciers in the Himalaya and the Karakoram (Muhammad and Tian 2016) which may affect glacier melting in the future. Therefore, it is necessary to observe field-based debris cover glaciers response to climate change for consistent modelling of glaciers in the region (Brown et al., 2003). We expect the results of this study will be of broad scientific community and stakeholders' interest for future water resources availability, management and understanding/ management of associated hazards.

1.1 GPS

GPS is a radio Navigation Satellite System comprises of space, control and user segments that measures position i.e. location and elevation, velocity and time (PVT) on earth (Kaplan and Hegarty 2005). The space segment includes the 24 operational satellites that orbit the earth every 12 hours at an altitude of approximately 20,200 kilometers (Getting 1993). Control segment consist of one Master Control Station, five Monitor Stations, and Ground Antennas around the globe to monitor satellite health, clock and position. The user segment acquires signals sent from satellites with GPS receivers used to determine where the satellites are located.

DGPS is based on carrier phase positioning requires that a GPS receiver be set up on a precisely known location (Kouba and Héroux 2001). This GPS receiver is the base or reference station. The base station receiver calculates its position based on satellite signals and compares this location to the known location. The difference is applied to the GPS data recorded by the second GPS receiver, which is known as the roving receiver. Real-time dGPS occurs when the base station calculates and broadcasts corrections for each satellite as it receives the data (Olsen et al. 1989). The correction is received by the roving receiver are applied to the position it is calculating, and results in a differentially corrected position.

1.2 Stakes installation and measurements

To understand the melt characteristics of the glaciers at various debris cover, stakes were installed using steam driller from clean ice glacier to at variable debris covered ice up to 40 cm of debris layer thickness. All the stakes were installed within about 30 m area along the central axis of all the three glaciers namely Ghulkin, Hinarchi, and Hoper in the Karakoram. All these three accessible glaciers were selected to understand the melt characteristics with varying orientation (East, west, and south facing). The stakes were re-measured daily to quantify the melt with debris cover distribution. The location of all these glaciers were also measured with dGPS to locate the stakes at the glaciers. Some information about these glaciers are giver in the following table

Sr. No.	Glacier Name	Glacier Area (Sq. Km)	Glacier Length (Sq. Km)
1	Ghulkin	31232	1186
2	Hinarchi	13530	2754
3	Hoper	13729	938

Table 1: Selected basins of UIB showing total glaciarized area and length.

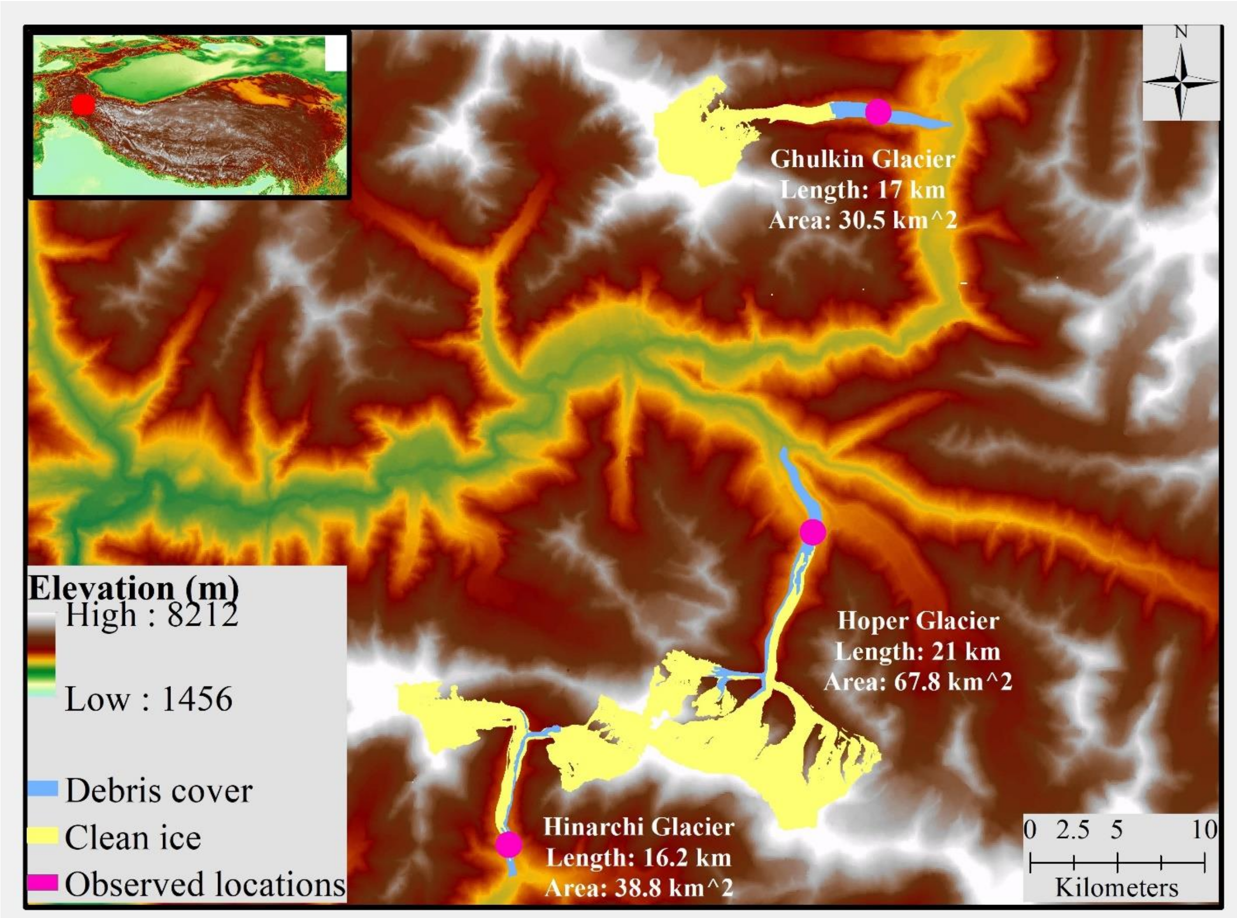


Figure 1: Study area showing glaciers visited during Expedition 2018

2.0 Objectives

- To precisely measure glaciers surface melt with various debris cover from 0 to 40 cm and measure the debris cover distribution with differential GPS having 10 centimeter vertical accuracy
- To measure temperature at various debris cover to understand the impact of temperature variation on glacier melt.

3.0 Pakistan Field Expedition 2018

A joint field expedition to Bagrot Valley, Gilgit and Hunza valleys of Pakistan have been carried out between Global Climate Change Impact Study Center (GCISC), Institute of International Rivers and Eco-Security, Yunnan University (IIRES, YNU) and International Center for Integrated Mountains development (ICIMOD) officials from the mid-September to the end of September.

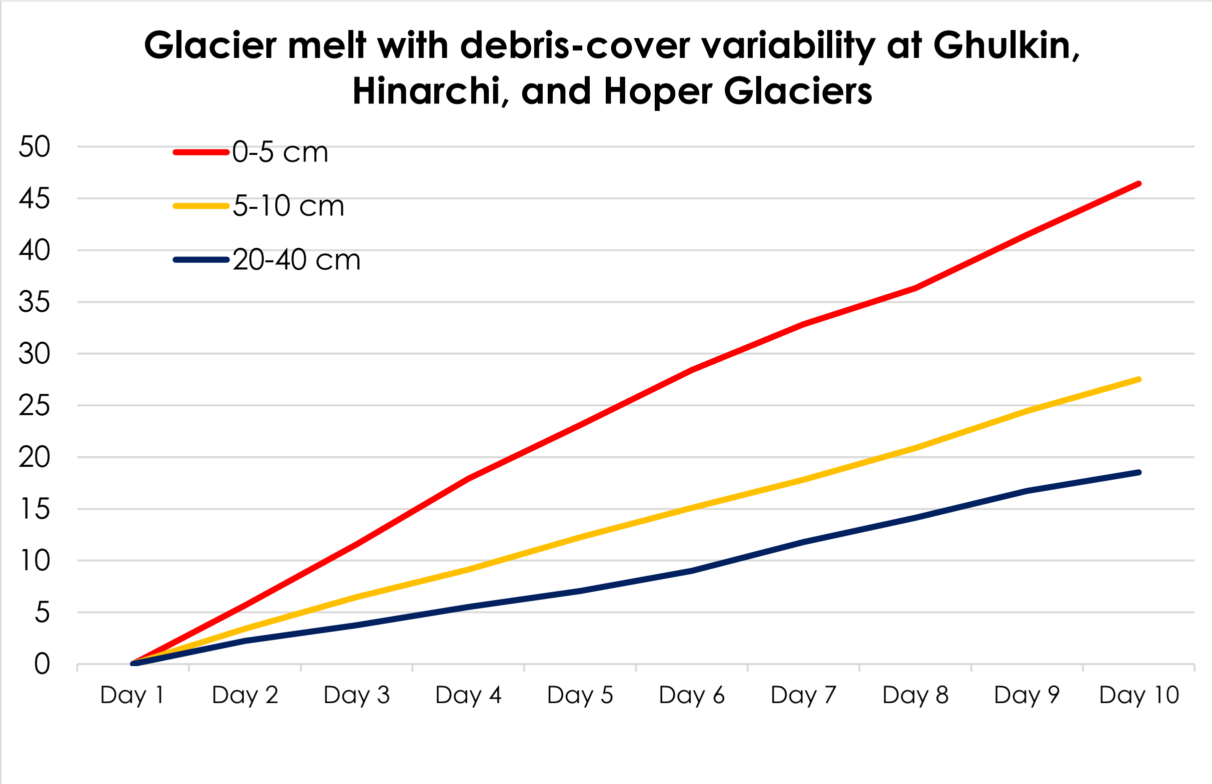
In the first phase an expedition of Hinarchi glacier was performed. Glacier surface altitude was measured to the position where it was accessible for debris cover distribution. The main task was to measure the daily melt at glacier surface with variable debris cover. We also installed temperature data loggers at debris cover surface and at 1 cm to 40 cm debris cover thickness. Similar measurements were carried out at Hoper and Ghulkin glaciers in the Hunza valley. The surface melt were measured for a couple of days at every glacier and then we hired local porters to continue the measurements for almost one month. Daily melt values were collected from the porters and also the temperature data loggers were removed after one month to get the data. We have now measured glacier surface melt from 25 to 27 days at all the three glaciers and the temperature data is also recorded by the automatic temperature data logger. The data will be analyzed for the final report and for a research paper to be published in an international journal.

4.0 Remaining task

The data of glaciers surface melt have been collected for almost a month and temperature data is also collected for the same. Temperature and glacier surface melt (at debris cover varying from 0 to 40 cm) data analysis is remaining for all the three glaciers. After the data analysis, our results will be compared to other studies, particularly in the High Mountain Asia. We will also compare the melt rates variability with aspect (as we have measurements over glaciers facing south, east, and west.

5.0 Preliminary Results

Glacier melt (average for all the three glaciers) varying with debris cover for the first ten days has been analyzed and shown in the figure below. The rest of the data will be analyzed for the final report and research paper.



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