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Research paper

Regional representation of glaciers in Chandra Basin region, western Himalaya, India

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ABSTRACT

Hamtah and Chhota Shigri are two nearby, well monitored glaciers of western Himalaya, lying in the same climatic zone and driven by the same climatic conditions. In this study, topographical characteristics of both the glacier have been explored to understand the role of topography in controlling the glacier response. Further, their topographical characteristics and possible response towards climatic variations have been compared with each other and also with that of the other glaciers in the basin to find out the suitability of these two glaciers to be considered as representative of the region. Multi sensor and multi temporal remote sensing data have been used to carry out to fulfill the objectives. It is found that being in the same climatic zone, the mean accumulation area ratio of Chhota Shigri is 54% and Hamtah is 11% between 1980 and 2014. In comparison to Hamtah, Chhota Shigri glacier has a small upslope area, low compactness ratio indicating the ability of the glacier to receive direct precipitation and solar radiation. The analysis revealed that the Chhota Shigri glacier has a closer resemblance with the other glaciers in the region than Hamtah glacier. Also, the topographical settings of Chhota Shigri glacier are suitable for recording and reflecting year-to-year climatic variations.

1. Introduction

Glaciers respond directly to climate and therefore serve as the best early indicator of climate change. The study of glaciers can provide reconstructions of the past climate, the understanding of present climate and an assumption of future climate. Himalaya, the youngest and highest mountain chain in the world is home to a large number of glaciers, some of which are largest in the world outside the polar regions. There are around 10,000 glaciers in the Indian Himalaya (Sangewar and Shukla, 2009), located at high and inaccessible regions. Monitoring and measurement of these glaciers are important in climatological, hydrological and societal aspects. However, pertaining to the complexities of terrain, harsh environment and logistic difficulties, it is not humanly possible to visit and directly monitor all the glaciers of Himalaya. In spite of the constraints there are a few glaciers in Indian Himalaya which have been taken up for direct field measurements by various Indian research institutes, universities and government organizations (DST, 2012). The field measurement of Chhota Shigri (By Jawaharlal Nehru University, India), Hamtah (by Geological Survey of India), Dokriani and Chorabari (both by Wadia Institute of Himalayan Geology, India) are continuously being carried out since past few years. The Chhota Shigri and Hamtah are two nearby glaciers (within ~15 km of each other) which fall under the same climatic zone. The melt water of both glaciers feed to the Chandra River, Chandra Basin, western Himalaya. The study of mass balance of Chhota Shigri glacier has reported that the glacier has been experiencing mass loss with a rate of -0.30 ± 0.36 mwe y^{-1} over a period of 1969–2012 (Azam et al., 2014b), with a slight gain in the mass during 1988 and 1999 (Vincent et al., 2013). Whereas, Hamtah glacier has a strong negative mass balance and is losing mass since 2001 with a rate of -1.45 mwe y^{-1} (Geological Survey of India, 2011; GSI henceforth). These results indicate variance in the

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response of Chhota Shigri and Hamtah glaciers towards the same climatic fluctuations. Further, there are about 201 glaciers in the Chandra Basin (Sangewar and Shukla, 2009) and it is beyond the capacity of any institute or organization to monitor each glacier individually in the field. The objective of the present study is to find out which glacier between Hamtah and Chhota Shigri is more likely to record climatic signals and can effectively reflect year-to-year climatic variations and can better represent the region. Therefore, the long term records available from the representative glaciers can be utilized as input to various climatological and hydrological models to predict the future response of glaciers. However, with the disparity in the responses of the two glaciers, the question arises as to which glacier reflects the climate fluctuations and can be taken as the representative of the whole region for modeling studies. In view of this, the present study aims at addressing two fundamental aspects:

(1) What are the key factors responsible for the variations in the responses of Chhota Shigri and Hamtah glaciers and which glacier between the two can be taken as representative for the region; and
(2) Which glacier between these two is able to record climatic signals and can reflect year-to-year climatic fluctuations for inferring climatic variability.

If climate is the driving force behind the glacier change, the glacier topographical parameters are the controlling factors which modulate the changes. Glacial topography has a strong influence on glacier dynamics and also explains the variability in the recessional rates of glaciers of the same basin (Davies et al., 2011). In addition, the hypsometry of a glacier that determines the ratio of solid and liquid precipitation within a basin is an important factor (Lutz et al., 2014). Hypsometry (area-altitude relationship) of a glacier plays a critical role in the response of the terminus to change in equilibrium line altitude (ELA; Furbish and Andrews, 1984). Moreover, it has been demonstrated that the termini of glaciers with different hypsometry behave differently under similar climatic forcing, highlighting the fundamental importance of geometry as a control on the behavior of glaciers (Jiskoot et al., 2009), an aspect that deserves consideration in assessment of glacier variation in the context of current climate change (De Angelis, 2014). A similar study on the concept of benchmark glaciers and their representativeness is reported by Fountain et al. (2009). This study attempts to find out the climatic response of the two glaciers by studying their accumulation area ratio (AAR) and to understand the variability in the response by analyzing their topographic, morphometric and hypsometric settings. Glacier mass balance is the un-delayed and unfiltered response of the glacier to climate change and AAR can be taken as the proxy for mass balance (Paterson, 1994). Therefore, by estimating the variation in the value of AAR we can infer the variability in the climatic parameters such as temperature and precipitation. The topographical parameters, indices and AAR in this study have been derived from multi-spectral, multi-temporal remote sensing data.

2. Study area

Chhota Shigri and Hamtah glaciers are the two “nearby” Indian Himalayan glaciers which have been continuously monitored for mass balance, glacier melt runoff, glacier meteorological and debris cover studies and are acknowledged by World Glacier Monitoring Service (2012) (WGMS, 2012) for contribution of data. These glaciers are located in the Chandra Basin on the northern slopes of Pir-Panjal range of Himalaya, in the Lahaul-Spiti valley of Himachal Pradesh (GSI, 2007; Ramanathan, 2011) and drain into the Chandra River. The Chhota Shigri glacier is ~15 km east of Hamtah glacier and both are roughly oriented from south to north (Fig. 1).

Chhota Shigri glacier (32.2°N, 77.5°E) is a compound valley type glacier covering an area of ~15 km^2 and has a length of ~9 km extending between 4050 to 6363 masl (Vincent et al., 2013). The mean width of the glacier is ~1.1 km (Sangewar and Shukla, 2009) and the maximum width is ~1.8 km near equilibrium line altitude (Kumar and Dobhal, 1997). The snout of the glacier is steep, at an angle of 35° (Kumar and Dobhal, 1997) and heavily covered with debris. The thickness of the debris cover decreases from snout upstream to the glacier (Vincent et al., 2013). Towards the east of the glacier, a well defined lateral moraine with an average height of ~35 m is present. This lateral moraine descends from an elevation of 4460 masl and extends downstream to the Chandra River. The peri-glacier features in the west side of the glacier are deformed and show no clear morphological features; however, the moraines on the right flank of the glacier valley (east side) are well preserved and are laterally continuous till the Chandra River. The Chhota Shigri glacier is a well-documented glacier and more information can be obtained from Dobhal et al. (1995), Kumar and Dobhal (1997), Wagnon et al. (2007), Ramanathan (2011), Vincent et al. (2013), Azam et al. (2014a).

Hamtah glacier (32.24°N, 77.37°E) is a relatively simple valley type glacier having a single lobe, extending from south to north between 5000 and 4020 masl covering an area of about ~3 km^2 and is ~6 km long (GSI, 2007). According to the inventory report by Sangewar and Shukla (2009) the mean width of the glacier is

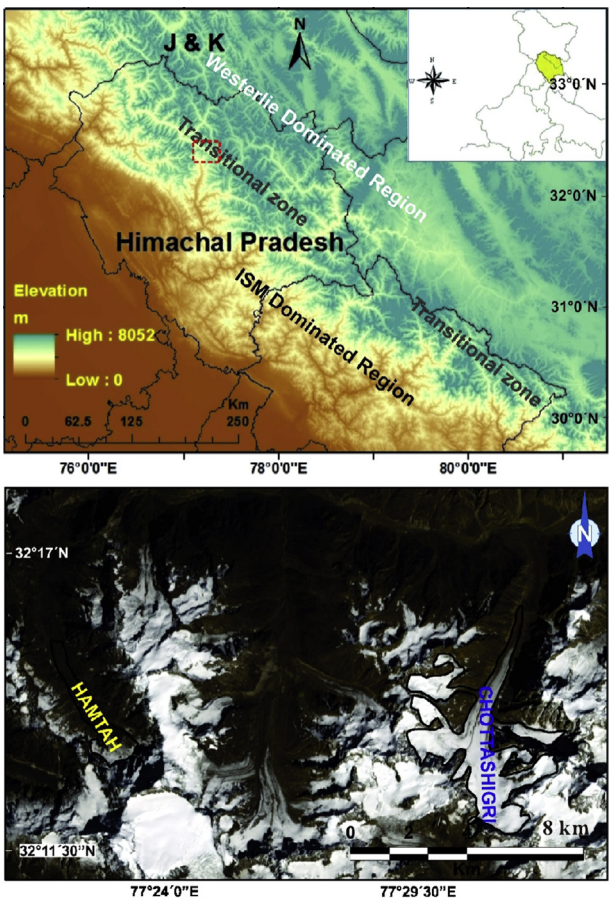

Figure 1. Location map of Chhota Shigri and Hamtah glaciers. The upper image illustrates the dominated climatological zones of Western Himalaya, shown on SRTM DEM. The lower image shows Chhota Shigri and Hamtah glaciers on Landsat 8 image of October 2014.

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