Estimation of glacier surface velocity of Drang-drung glacier by DInSAR technique using Sentinel-1 SLC SAR data

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Abstract*: *Glaciers are sensitive to climate change, especially the mountain glaciers due to their relatively small size they show rapid and fast changes to the ongoing trend of warming in climate. In the Himalayan region, the glaciers serve as important source of water for agriculture, power supply and tourism related activities. Glacier velocity gives information about the glacier health and helps in understanding the climate change, mass balance, and glacier dynamics. Differential SAR Interferometry (DInSAR) is the radar interferometry technique for measuring surface changes with a higher accuracy up to millimeter range. Velocity estimates are important to understand the glacier related hazards and can help in alleviating the possible future damage downslope. In this study, the velocity of one of the biggest and benchmark glaciers in Zanskar region has been estimated using DInSAR technique on Sentinel 1 SLC data. The results show that glacier has moved approximately 1m over a period of 12 days.

***Keywords*: DInSAR, interferogram, drang-drung glacier, glacier velocity.**

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I. INTRODUCTION

Alpine glaciers are very sensitive to changes in temperature regime over short time periods [1]. Mountain glaciers, which are generally smaller in size than large ice bodies available in polar regions, show higher deformation rates (1). Due to the displacement gradient (i.e., strain) threshold of Synthetic Aperture Radar Interferometry (InSAR), only a limited number of studies [2], [3], [4] have successfully measured the ice-flow velocity field with InSAR.

Glaciers move due to their own weight and under the influence of gravity. To understand the glacier dynamics including mass balance and climatic changes it is essential to know the glacier velocity. The instruments that can be used for recording and measuring the movement of glaciers include stakes and theodolite, laser ranging, and global positioning systems (GPS). These instruments allow for point measurements only and thus impose a constraint in terms of time and cost especially over large inaccessible and inhospitable areas. Remote sensing has proved to be effective and practical both in terms of time and cost for estimation and mapping of the glacier velocity. InSAR is a powerful technique for measuring the glacier velocity and strain rate (velocity gradient) with centimeter accuracy [5]. In this technique, the phase difference of two or more SAR images acquired from slightly different orbit positions or view angles and at different times is exploited to obtain topography and surface change due to earthquake, volcano, land subsidence, and glacier velocity mapping.

Himalayan region, known as Third Pole, houses thousands of glaciers and amasses huge seasonal snows. The meltwater from snow and glaciers supports a sizable portion of agriculture activities and power supply in the densely populated Himalayan regions. To forecast the response of glaciers and required mitigation of possible hazards to future climatic trends the understanding of glacier dynamics becomes inevitable. Differential Interferometric Synthetic Aperture Radar (DInSAR) technique has potential to accurately estimate and monitor the glacier dynamics owing to its all-weather usability and penetration capability into the upper layers of snow and ice. The penetration depth is dependent on wavelength of the incoming signal and the higher penetration enhances the correlation between scenes which ultimately yields better interferometric results [6].

The use of Differential Interferometric Synthetic Aperture Radar (DInSAR) for surface displacement studies is still in its infancy in India [7]. In the Indian Himalayan region, very few glacier dynamic studies have been conducted [8], [9], [10], [11]. The surface displacement studies are always important and a major issue in Himalayan region. To investigate and mitigate the hazards related to glacier retreat/ advance, better estimate of the surface dynamic behaviour is necessary.

In this study, Drang-drung glacier located in Zanskar Valley has been selected to estimate its velocity using

DInSAR technique. The glacier shows a movement of above 1m over a period of 12 days.

II. Study Area and Dataset

A. Study Area

The study is carried over Drang-drung glacier (Fig.1) located in Zanskar Valley of Northwestern Himalayan region near the Pensi La mountain pass in the Kargil district of Ladakh in India. The climate of Zanskar region is cold-arid type and mean annual precipitation is 250 mm [12], [13]. The elevation of glacier is between 4100-6250m amsl [12], [13] and lies between 33.65^0-33.85^0 E latitudes and 76.24^0-76.37^0 N longitudes. Drang-drung glacier is the second largest glacier in Ladakh region. This glacier is mostly debris free and has good accessibility having an area of 70.47 sq. km. The meltwater from Drang-drung glacier considerably contributes to Zanskar river [12], [13].

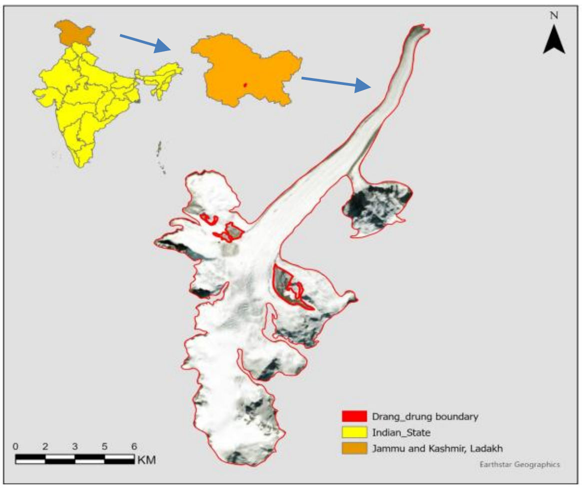

Fig. 1. Drang-drung glacier

B. Dataset

The glacier velocity was obtained from two Sentinel-1 SAR TOPS IW Single Look Complex (SLC) images taken on 13 August 2020 (master) and 25 August 2020 (slave) using VV polarization. A 30m digital elevation model (DEM) from Shuttle Radar Topographic Mission (SRTM) was used to produce the differential interferogram and for geocoding and coregistering the SAR images.

III. Methodology

The data was processed in Sentinel Application Platform (SNAP). Two SLC images containing phase and amplitude bands were processed to get the precise orbital information, containing information about the position of the satellite during the acquisition of SAR data. Coregistration of the master and slave images based on the orbit information and SRTM DEM (30m) was done.

The interferogram is generated by cross-multiplying the master image with the complex conjugate of the "slave." The amplitude of both images is multiplied while their respective phases are differenced to form the interferogram. The bursts are joined together into a single image using TOPS deburst tool in SNAP. The flat-earth phase present due to the curvature of the reference surface is estimated using the orbital and metadata information and subtracted from the complex interferogram using SRTM DEM (30m). The interferogram is filtered using Goldstein phase filtering that reduces the residues in the interferogram to be used in phase unwrapping afterwards [14]. Interferometric fringes (Fig. 3) represent a full 2π cycle of phase change. The interferometric phase is ambiguous and only known within 2π. Phase unwrapping (Fig. 4) carried out with SNAPHU, solves this ambiguity by integrating phase difference between neighboring pixels and gives actual LOS displacement. The unwrapped phase product is geocoded, and terrain corrected after importing into SNAP and glacier displacement is obtained.

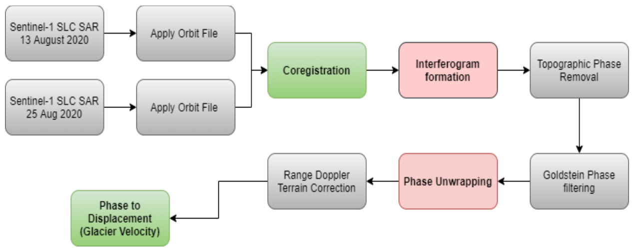

Fig. 2. Flowchart showing methodology

IV. Results

Fig.3 shows the interferogram of Drang-drung glacier depicting glacier movement. One cycle of fringe variation (cycle of colours) marked in the figure 3, corresponds to 2.8 cm of movement. As evident in the figure the movement is in the snout and at the beginning of the zone of ablation. The quality and reliability of unwrapped results strongly depends on the input coherence (Fig.5). Reliable results can only be expected in areas with high coherence. The glacier velocity (Fig.6) ranges from 0.675 to 1.05 m over the 12-days [15] with highest velocity in the zone of ablation and towards the centre (Fig. 3) of the glacier [16], [17]. The highest velocity in the centre part just at the beginning of the zone of ablation can be attributed to the steep slope and gravity. Further research using DInSAR technique supplied with sufficient field data will help in validating the results obtained.

V. Conclusion

This study provides the characterization of the dynamics of the Drang-drung glacier in terms of surface velocity estimates from 13 August 2020 to 25 August 2020. Results from the DInSAR of Senitnel-1 images revealed significant motion along the length of the glacier especially in the zone of ablation with a minimum velocity of 0.675m and a maximum velocity of 1.05m. Such observations are useful in assessing the glacier's response to climate change and provide an avenue to understand glacier dynamics.

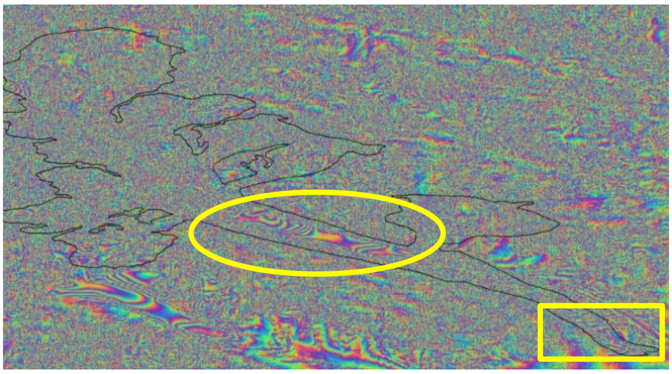

Fig. 3. Interferogram of Drang-drung glacier.

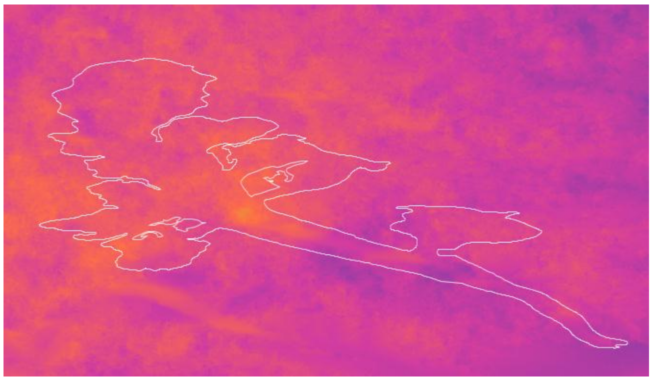

Fig. 5. Phase unwrapped interferogram of Drang-drung glacier

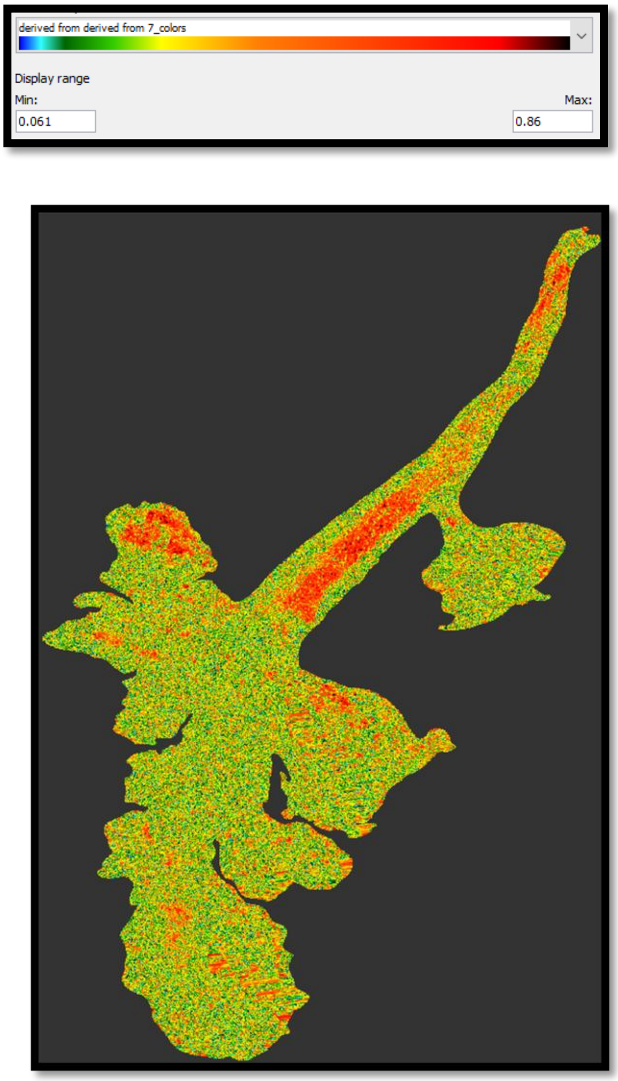

Fig. 4. Coherence over the study area

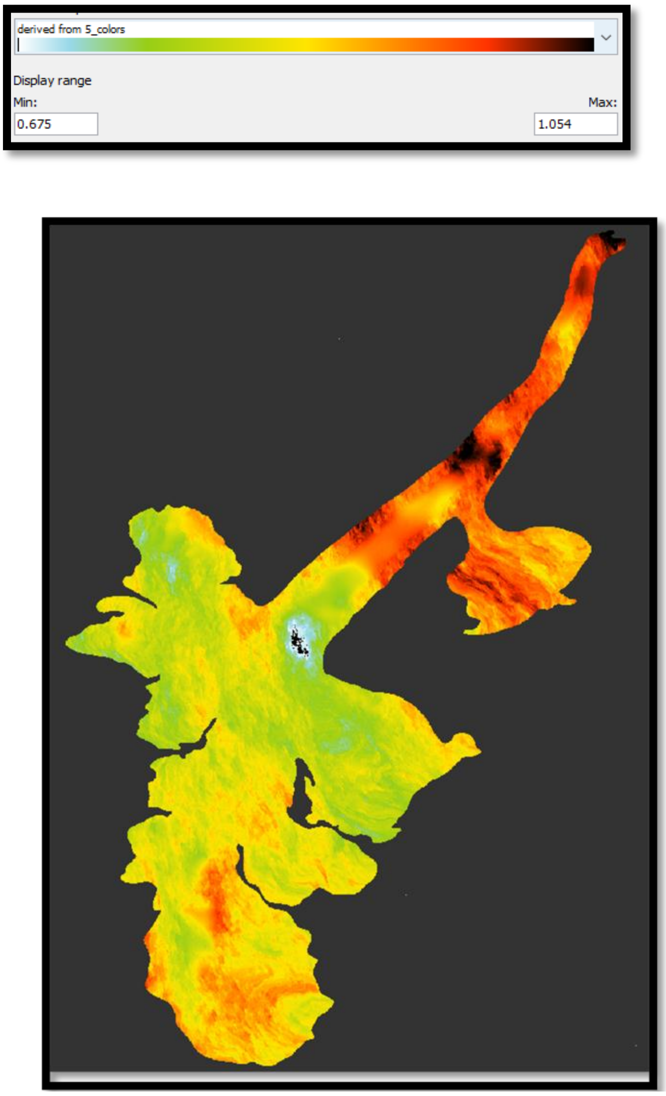

Fig. 6. LOS displacement of Drang-drung glacier

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