SAR INTERFEROMETRY AND SPECKLE TRACKING APPROACH FOR GANGOTRI GLACIER VELOCITY ESTIMATION USING ERS-1/2 AND TERRASAR-X SPOTLIGHT HIGH RESOLUTION DATA

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ABSTRACT: Himalayan glaciers viz. Gangotri, Siachen, Bara Shigri and Patsio are major glaciers in the north western (NW) Himalayan region, which are in general recession since last 150 years [1]. Precise measurement of glacier movement and retreat is prime requirement for assessing global warming effects in Himalayan region. For quantifying the glacier movement in the Himalayan region InSAR technique is used and it is observed that ERS-1/2 tandem data give high correlation over Gangotri glacier and Siachen glacier. It is observed that Gangotri glacier is advancing at the rate of 10 cm per day in LOS direction. However, with the use of SAR Speckle tracking method two dimensional (Azimuth and range directions) velocities of glaciers can be obtained [2]. In this study an attempt is made to measure 2-D velocity components of Gangotri glacier. New generation TerraSAR-X (TS-X) high resolution spotlight mode (HS), single look slant range complex (SSCs) data of 28th August, 2008, 08th September, 2008, 19th September, 2008 and 30th September, 2008 are exploited for this study. Interferogram, coherence image and intensity image are generated. It is observed that Interferometric SSC data of 28th August, 2008 and 08th September, 2008 give some fringes outside glacier area and complete decorrelation is shown on the Gangotri glacier due to high movement of glacier. InSAR fringes of 8th and 19th September, 2008 is marred by snow fall over lower middle part of the glacier. A comparison will be made between SAR speckle tracking method and InSAR method for glacier movement estimation in LOS direction.

1. INTRODUCTION

During the past decade, Spaceborne Differential Interferometric Synthetic Aperture Radar (DInSAR) has been successfully used to measure millimeter- to meter-level deformation on the surface due to earthquake, landslide, glacier movement and physical process at depth including magma accumulation and migration, pressurization, and crystallization [3-5]. However application of SAR interferometry is limited in faster-moving areas [6]. With a 1day repeat period, ERS-1/-2 tandem SAR data are much better matched to fast motion estimations. Goldstein [7] clearly demonstrated the value of InSAR for mapping glacial ice motion, but also indicated that use of differential phase could be limited by temporal decorrelation. However, the relatively large temporal separation of the repeat coverage for current satellites (RADARSAT; 24 days, ERS-2; 35 days, ENVISAT; 35 days, ALOS; 46 days, TerraSAR-X; 11 days), coupled with the large speeds that can occur in land locked and outlet glaciers and ice streams, complicate the analysis of differential phase for radial ice motion for coastal or high speed regions.

In the case of decorrelation due to rapid and incoherent flow, SAR speckle tracking procedure is a welcome alternative to SAR interferometry for the estimation of glacier motion [8]–[12]. Fortunately, several authors have demonstrated the ability to measure velocity in fast-moving areas by tracking SAR speckle algorithms. Speckle tracking can be used to estimate glacial ice motion in coherent pairs of SAR images. The technique is particularly appropriate when either the ice motion or temporal separation of the data acquisitions is large [13]. In these circumstances, a speckle tracking technique can yield 2 dimensional ice motions, albeit with reduced accuracy in the range direction [9]. In this paper SAR speckle tracking technique is discussed for Gangotri glacier 2-D velocity estimation. A correlation-matching is commonly used to obtain both azimuth and range-direction offsets based on the coherent speckle pattern of small chips of two repeat-pass SAR image acquisitions [14], [15], [2] [16]. Through oversampling of the correlation surface, the matching peak can be determined to a small fraction of a pixel. The range offset δr and azimuth offset δa detected from cross-correlation matching include a nonmotion component contributed by the imaging geometry (baseline effect and orbital crossing) and topography effect. The topography-induced offsets only occur in the range direction and can be removed by using a digital elevation model. The geometry-induced terms in the range and azimuth offset can be modeled and removed using two linear equations [16]

$$d_r = \delta_r - (a_0 + a_1 x + a_2 y) \qquad (1)$$

$$d_a = \delta_a - (b_0 + b_1 x + b_2 y) \qquad (2)$$

where d_r and d_a are, respectively, the surface displacements in the range and azimuth directions measured in pixels, x and y are the range and azimuth coordinates of the slant range image, a_0, a_1, and a_2 are coefficients for accounting for the geometry term in range direction, and b_0, b_1, and b_2 are coefficients for accounting for the geometry term in the azimuth direction. The velocity components in range (V_r) and azimuth (V_a) directions can be calculated from [16]

$$Vr = \{dr - B \cos(\chi - \theta)\}/T \sin(\beta + \alpha r) \cdot Sr \quad (3)$$

$$Va = \{da/T \cos(\alpha a)\} \cdot Sa \quad (4)$$

where B is the length of the baseline (converted to unit in range pixel), χ is the baseline angle, θ is the radar look angle, α_a is the terrain slope in the azimuth directions, and S_r and S_a are pixel sizes in meters in range and azimuth directions. The Speckle tracking technique will be used on TerraSAR-X data for Gaogotri glacier movement studies.

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