Monitoring the Stability of a Moraine Dam by Differential Interferometry (DInSAR) to Prevent GLOFs Disasters from Arhuaycocha Lake

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ABSTRACT

The Cordillera Blanca in Peru is the most heavily glaciated tropical mountain range in the world (Emmer et al., 2020), where 800–850 km^2 total glacial area in 1930 decreased to 600 km^2 at the end of the 20th century (Kaser, 1999). The decline has resulted in the formation of moraine-dammed lakes from flow stagnation and recession of glacier tongues (Harrison et al., 2018) affecting 230 glacial lakes in the region, of which 119 were moraine-dammed (Emmer & Vilímek, 2013). The fast growth and formation of lakes caused a dramatic increase in glacial lake outburst flood (GLOF) occurrence from 1930 to 1970. A previous decline (Emmer, 2017) is associated with the Little Ice Age, while GLOF incidence throughout the 21st century as lakes and glaciation respond more dynamically is associated with anthropogenic climate warming (Anacona et al., 2015). Although the GLOF frequency has not fluctuated directly in response to global climate, it will increase as the global climate continues to warm, with hazardous impacts for downstream regions (Harrison et al., 2018). Most of the recorded GLOFs from moraine-dammed lakes in the Cordillera Blanca were caused by slope movements into lakes in which the displaced material was dominated by icefalls, snow avalanches, and rockfall (Emmer & Cochachin, 2013) producing displacement waves, which may overtop, deforming or displacing a lake's moraine dam (Jawaid, 2017). It is also clear that intense rainfall, the extreme variability of air temperature, or snowmelt will lead to a rise in the water level of the lake (Yamada & Sharma, 1993). This causes a deformation that can be identified through interstitial pressure measurements (Corsetti et al., 2018).

DInSAR techniques have been developed to measure the temporal behavior of the displacements or deformation (Toural Dapoza et al., 2019). With ascending and descending DInSAR measurements it is possible to calculate 3D deformation of glaciers at one instance of time (Samsonov, 2019). It is necessary to have two independent acquisition modes from the ascending and descending line of sight (LOS) motions and solve the geometry relationship (incidence angle and satellite tracking heading angle) which are inverted to retrieve the horizontal and vertical components of the displacement. This developed methodology is detailed in Fig. 1 and we call it multi-geometry data LOS fusion.

The multi-geometry data fusion LOS methodology shows that the moraine dam of Arhuaycocha lake suffered subsidence of 17 cm (Fig. 2). The average subsidence zone was concentrated around the drainage channel (Fig. 2), and the zone of greatest subsidence was recorded at the lateral base. The dam shows higher displacement in the greatest rainfall seasons (Fig. 3). We concluded that subsidence in the moraine dam tracked with continued precipitation in wet months, and the loss of storage in dry summer months triggered rebound.

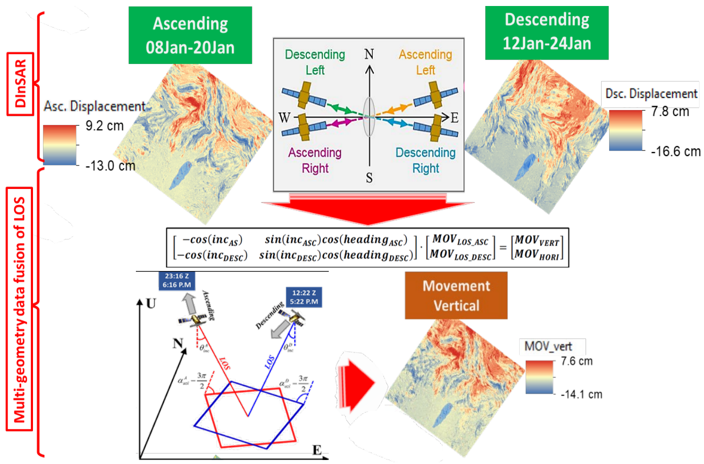

Figure 1. Methodology for multi-geometry fusion of LOS

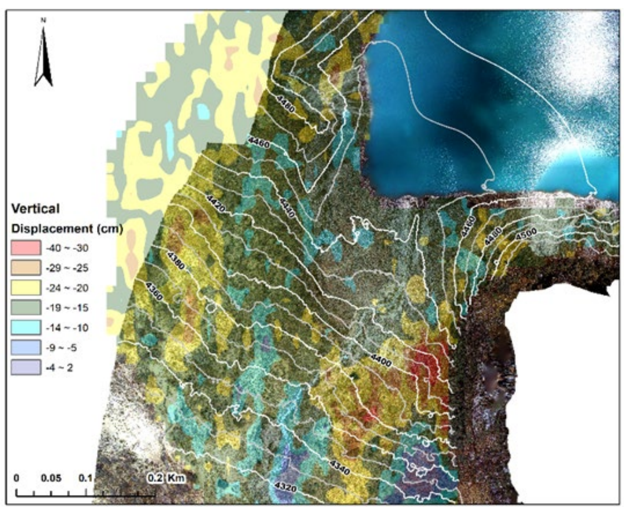

Figure 2. Accumulated vertical displacement for moraine dam Arhuaycocha

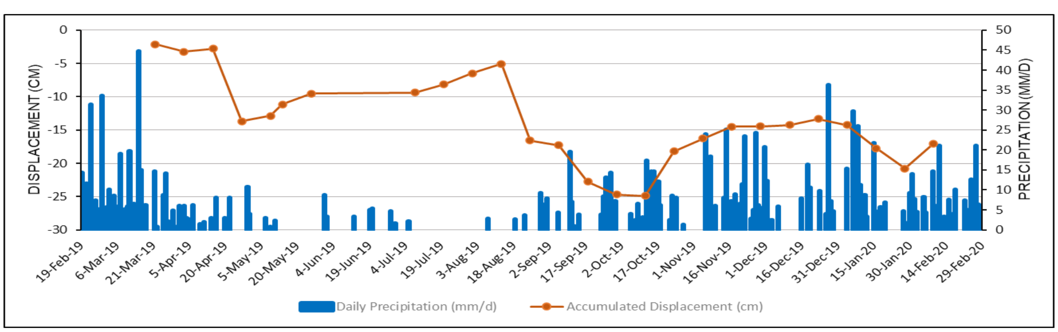

Figure 3. Daily precipitation and accumulated displacement of the moraine dam Arhuaycocha

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