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Regional evaluation of rock glacier activity in the semi-arid Andes using optical and radar satellite imagery

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Abstract

As evidenced by existing inventories, the semi-arid Andes (Chile and Argentina) has a high density of active rock glaciers and host some of the largest ones in the world. The movement of rock glaciers, which is crucial for understanding the effects of climate on mountain cryosphere, remains largely based on subjective interpretation of geomorphological signs visible on ortho-imagery. In order to get a regional assessment of rock glacier's activity levels, we combined two type of satellite imagery, Synthetic Aperture Radar and optical. Both SAR-derived interferograms and maps of displacement derived from optical image correlation were used to evaluate to mean activity level of more than 200 active rock glaciers. Base on this, a geospatial analysis was performed to assess the main controlling factor on the rock glaciers kinematic.

Keywords: rock glaciers; surface movements; remote sensing; SAR; image correlation; Andes.

Introduction

In the present context of Climate change, rock glaciers dynamics have potential consequences for the stability of mountain slopes (Huggel *et al.*, 2012). In the Andes, similarly to the Alps, cases of rock glacier destabilization have been observed (Bodin *et al.*, 2012). Between 29 and 34°S, more than 8000 fresh rock glaciers have been mapped by official Chilean and Argentinian authorities (IANIGLA, 2010; UGP-UC, 2011). In those inventories, the activity status of rock glaciers has been assessed based on ortho-imagery, implying subjectivity-related biases.

To overcome this limitation, we combined optical and radar satellite imagery (acquired between 2012 and 2017), from which we derived maps of SAR phase difference (TerraSAR-X) and of horizontal surface displacement (Landsat).

Study area and datasets

Our study area covers almost 3000 km², around 29-30°S, and has a median elevation of 4120 m asl. With a mean elevation of 4500 m asl, 321 rock glaciers are present, covering a total of 34 km².

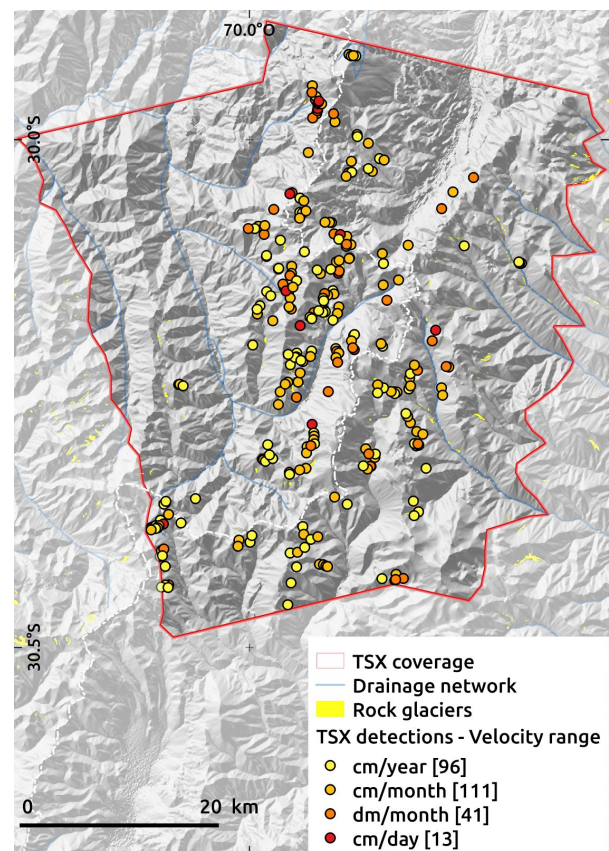


Figure 1: Velocity levels detected on rock glaciers with the interpretation of TSX-derived interferograms.

Following Barboux *et al.* (2014) procedure, we first interpreted the TSX interferograms overlaid with ortho-imagery in a GIS. Over 261 rock glaciers with SAR-derived interpretation, 54 show relatively fast surface velocity, higher than 2 m/yr (Figure 1).

Landsat images from between 2013 and 2017 were processed with image correlation technique (Zerathe *et al.*, 2016) to derive horizontal displacements over the area (Figure 2).

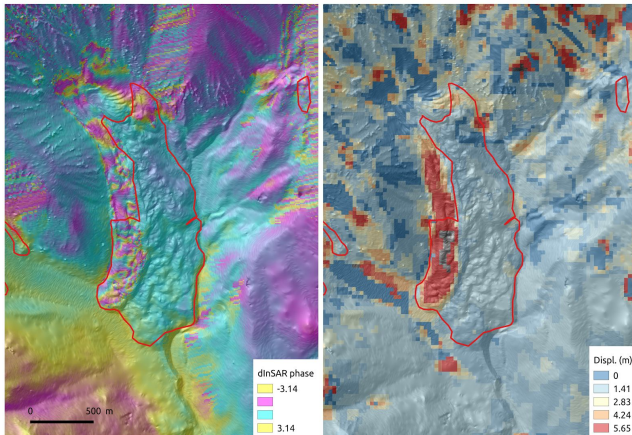


Figure 2: Comparison between SAR phase signal from a 11-day interferogram (left panel) and horizontal displacements derived from Landsat images of 2013 and 2017 (right panel) on an active rock glacier.

Results

Deriving topographic attributes from TanDEM-X 12-m DEM, no clear dependency between velocity and elevation nor slope was found. The clearest control on the rock glaciers velocity range seems to be the solar radiation, with lower values on slow rock glaciers and higher ones on the fastest (Figure 3).

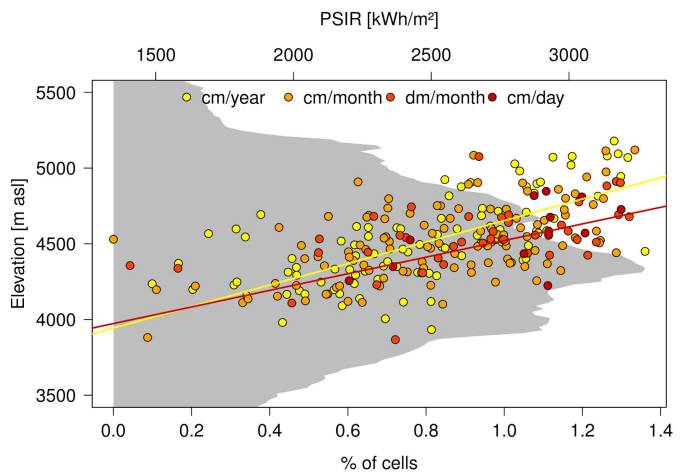


Figure 3: Hypsography of the study area and XY plot of elevation VS potential solar incoming radiation (PSIR).

Outlook

At the moment of writing this abstract, the processing of the optical imagery have not yet be fully completed. The resolution of the Landsat images (15m) is a clear limitation, though the large time span should allow producing horizontal displacement maps for the fastest rock glaciers of the study area, and to compare these maps with the TSX interpretations.

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