Date of Submission	05/08/2024

IPL Project (IPL-Number) Annual Report Form

Period of activity under report
from 1 January 2021 to 31 December 2023

1. Project Number and Title:

Monitoring and comparison rock glaciers kinematic process using SAR interferometry and offset-tracking in Western Himalaya, Inner Qinghai-Tibet and Alps.

2. Main Project Fields

Select the suitable topics. If no suitable one, you may add new field.

(1) Technology Development

☑***A. Monitoring and Early Warning,*** B. Hazard Mapping, Vulnerability and Risk Assessment

(2) Targeted Landslides: Mechanisms and Impacts

A. Catastrophic Landslides

(3) Capacity Building

B. Collating and Disseminating Information/ Knowledge

(4) Mitigation, Preparedness and Recovery

A. Preparedness

3. Name of Project Leader

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Core members of the Project:

Nicola Casagli, Full Professor, DST-UNIFI

Veronica Tofani, Full Professor, DST-UNIFI

Xiaoqing Chen, Professors, IMHE-CAS

4. Objectives (5 lines maximum)

The main objective of this project is to retrieve surface velocities from typical rock glaciers in Western Himalaya, Inner Qinghai-Tibet and Alps using both Interferometrical and offset-tracking techniques. Spatial and temporal time-series analysis reveals rock glacier kinematic process in different places, indicating hazards response to climate change.

5. Study Area

The study areas will be the Karakoram (Western Himalaya), Sanjiangyuan (Qinghai-Tibet) and Valle d’Aosta

(Italian Alps), specifically selected due to their high sensitivity to climate warming and susceptibility to ground instability phenomena.

6. Project Duration

The duration of the project is three years.

7. Report

1) Progress in the project (30 lines maximum)

Rock glaciers are tongue-like or lobate shaped landforms consisting of unconsolidated rock debris and ice in an alpine environment, creeping downslope due to the deformation of internal ice and frozen sediment. Understanding how these geohazards occur, their deformation process and their kinematic is significant to improve forecasting methods and risk mitigation precautions. In our project, we have selected three cases considering the physical geography units, climate setting and economic development level.

First case is located in the border of Himalaya and Karakoram, Passu, Pakistan, where the average elevation is around 4000 m. Around 60% of the catchment area is covered by the clean-ice glacier and debris-covered-ice glaciers. Because of the heatwaves, and other extreme precipitation events fueled by our rapidly changing climate, rock glacier dams, and out-break flooding have been reported in this basin during the last decades. We have utilized the Sentinel-1 A satellite images from Oct. 2017 to Aug. 2021 to retrieve the ground deformation (Fig.1). Only few points, derived from InSAR, existed in the tongue and flanks of rock glaciers with the average velocity of 22.5 mm/yr (Fig.1a). From time-series analysis result (Fig.1b), the maximum deformation ranges up to 117 mm, which indicates the largest show deformation behavior occurred at the frontal parts in the form of rockslides or rock falls. Moreover, this type of rock glacier is a debris-covered glacier where a continuous ice body that has been buried and preserved (Fig.1c).

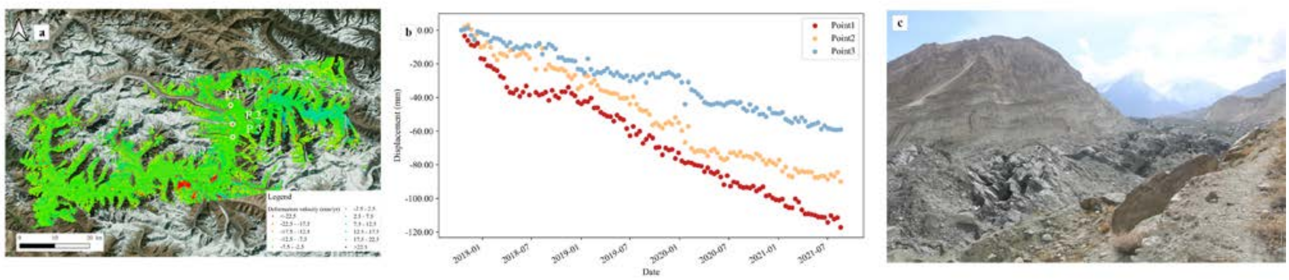

Figure 1 The deformation monitoring using inSAR technology in western Himalaya and Karakoram a) the average ground deformation velocity; b) The accumulative deformation of typical points; c) field investigation of rock glacier where the surface is covered by thinner debris and thick ice.

The second case is located in Tianshan, China. For this area 176 ascending and 78 descending Sentinel-1A images from Feb. 2017 to Dec. 2021 were combined to retrieve historical deformation of typical rock glacier (Fig.2). By contrast to Pakistan cases, the average elevation is around 3200 meters, and annual average temperature is -2° C. Strong deformation areas are mainly concentrated in the frontal tongue, and deformation decreases concentrically with increasing distance from the ablation area. Average deformation velocity and maximum cumulative deformation is estimated by 45 mm/yr and 328mm (Fig.2c, d), respectively. Interestingly, annual and seasonal deformation fluctuations were also detected, with the amplitude between 10-25 mm, indicating the inner part of this type has permafrost and is sensitive to freeze-thaw cycles. This type of rock glacier is formed of superficial moraine, which has re-advanced and superimposed subsequently on the permafrost body under the gravity, producing and mounds and ridges (Fig.2e, f).

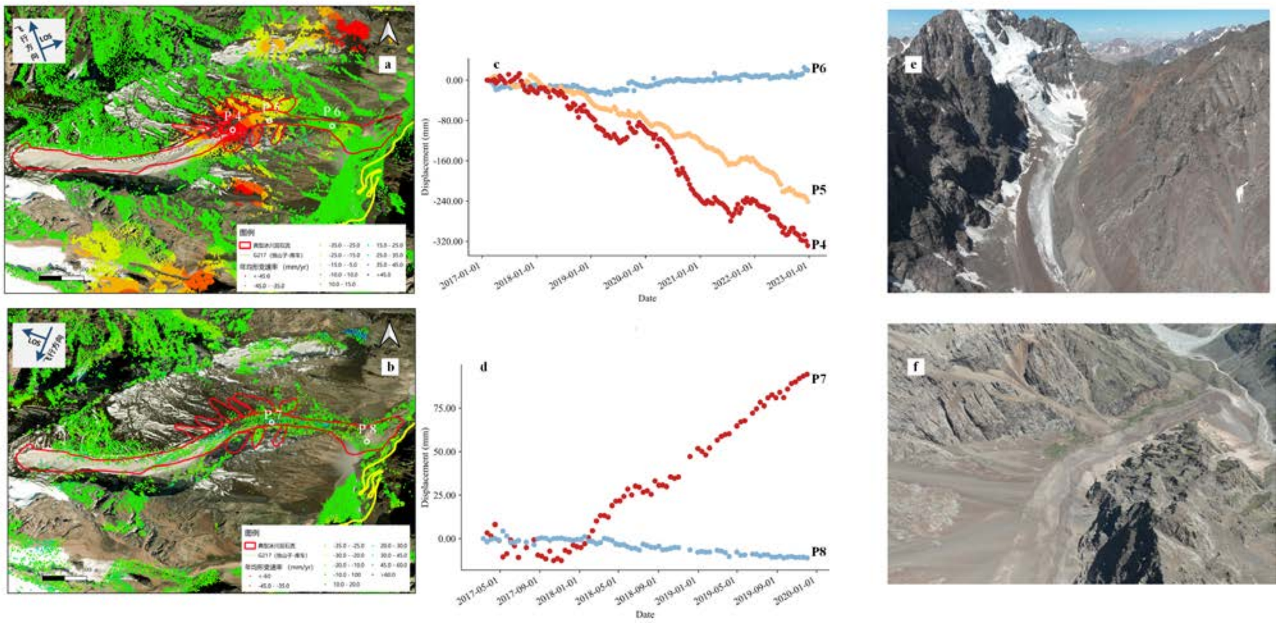

Figure 2 The deformation monitoring using InSAR technology in Tianshan, China. a, b) the average ground deformation velocity; c, d) the accumulative deformation of typical points; e, f) field investigation of rock glacier where the surface is covered by thick debris and permafrost.

The third case is located in the Valle d'Aosta (VdA), a mountain region located in North-western Italy, at the border with France. The region is characterized by a wide variety of slope instabilities, encompassing deep-seated landslide and complex or rotational landslides as well as rockfalls and debris flows. Glacial action is another main factor that controls the past and current orography of VdA. Considering its geomorphological and climatic context, VdA is characterized by mass movements related to periglacial landforms, such as rock glaciers, that are quite common in alpine environments. In VdA 937 rock glaciers are mapped, covering 2% of its territory; 57% of them are classified as relict. Active rock glaciers are usually found above 2200 m a.s.l. along north-exposed slopes, whereas relict landforms are found at lower altitudes, but never below 1600 m a.s.l.

One of these rock glaciers is locate in the Ayas valley, above the village of Champoluc, in the northeastern part of the VdA Region (Figure 3), an active rock glacier registering a steady-state creep with deformation rates varying from few mm/yr to few cm/yr.

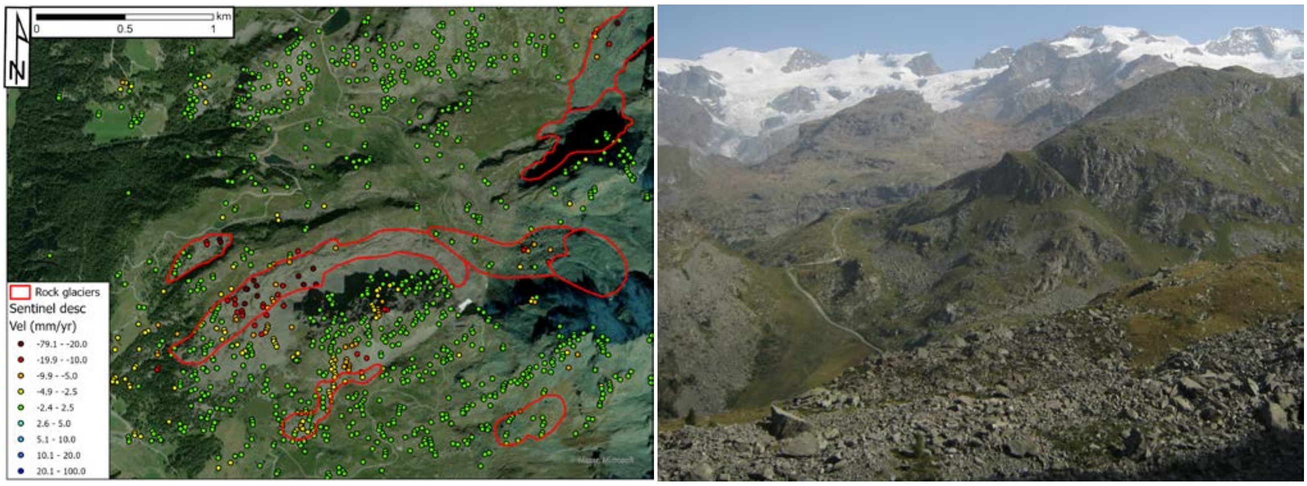

Figure 3 The deformation monitoring using InSAR technology in Valle d'Aosta, Italy. a) the average ground deformation velocity; b) field investigation of rock glacier where the surface is covered by thick debris.

In conclusion, surface movement rate of rock glacier are controlled by internal glacier type and external climate variations. Improved understanding of rock glacier interactions in different regions, therefore, is of critical importance to understand the response of high mountain glacial systems to climate change.

2) Planned future activities or statement of completion of the Project (15 lines maximum)

Our next step is to exploit the offset-tracking methods accommodate a full spectrum of rock glacier deformation processes from slow creeping to fast flowing. Active rock glacier with long-term deformation trend will be identified and mapped. Considering remote sensing data is huge volume and cost a lot of time, we will complete this job in May 2025. Finally, detailed climate analysis, deformation comparison and mechanism difference will be discussed.

3) Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)

The final rock glacier inventory map (location, spatial distribution, time-series deformation pattern, type) will be transferred to local civil protection agencies and international landslides research councils (*e.g.*, ICL, ICIMOD, LEWS). Our monitoring result will be written in a report, and some interesting conclusions are intended to be submitted to the journal LANDSLIDES. PhD students or researchers on both sides will visit and exchange under the support of this project. The detailed fee will be covered by other research projects or fundings.

4) Results (15 line maximum, e.g. publications)

Our final result is the regional active rock glacier inventory maps in different area across Asia, Central Asia and Europe. The detailed processing and related comparison result will publish the academic paper. In addition, our research work will be present in international conference, willing to provide valuable suggestion for stakeholders.

Note:

1) If you will change items 2-7 from the proposal, please write the revised content in Red.
2) Please fill and submit this form to ICL Network <icl-network@landslides.org>
3) Reporting year must be one or two years (Maximum).