Monitoring recent activity of the Koytash Landslide (Kyrgyzstan) using radar and optical remote sensing techniques

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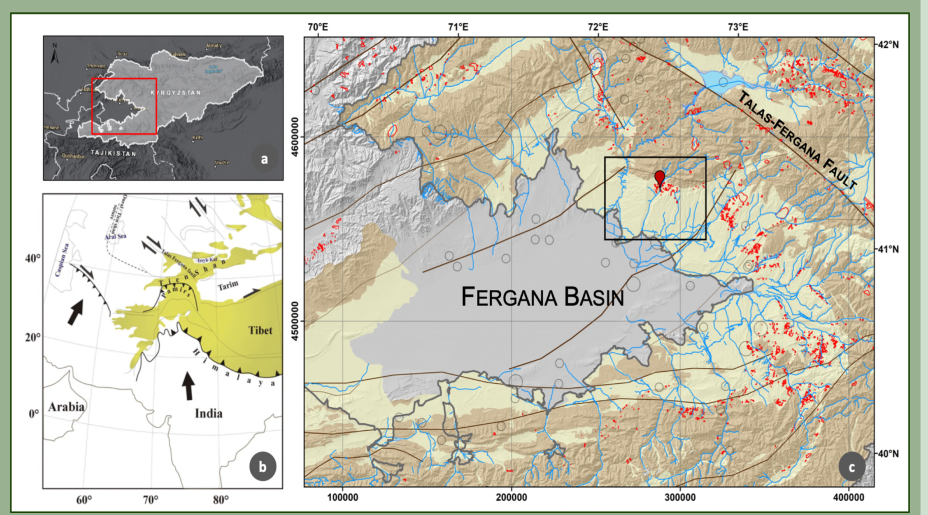
Introduction

Landslides are omnipresent in most mountainous areas of the world where they represent a major problem for society. Around the Fergana Basin and in the Mailuu-Suu Valley, in Kyrgyzstan, landslides are often reactivated due to intense rainfalls, especially in spring season, and as a consequence of the high seismicity.

Based on remote sensing data, this research explores the meteorological, geological and geomorphological factors influencing the reactivation of mass movements.

In spring 2017, Kyrgyzstan suffered a massive activation event which caused 160 emergency situations, including the reactivation of Koytash and Tektonik. These landslides represent a major threat to the local population of the small town of Maily-Say, as well as the villages downstream.

In this region, risks are accentuated by the presence of uranium tailings, remnants of the former nuclear mining activity.



Koytash is a former deep-seated landslide with a rotational movement. It was reactivated the 22nd of April 2017 during the massive activation event.

Tektonik has a specific morphology with a well-marked scarp and its lower part divided into two lobes. Unlike Koytash, Tektonik was reactivated only in its upper part.

Methods

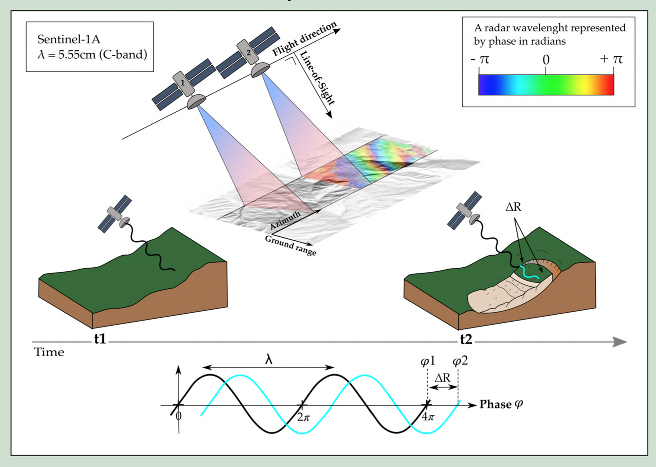
I. Meteorological analysis – Landslide trigger assessment by comparative analysis of rainfall, snow depth, and temperature. Data was collected from TRIMM, GLDAS, and CHIRPS images as well as *in-situ* data from the Ak-terek station.

II. DEM comparison – Characterization of the evolution in landslide geomorphology through the use of Digital Elevation Models (DEMs):

- Georeferentiation
- Creation of a Unmanned Aerial Vehicle (UAV) DEM based on images from August 2017
- Subtraction between TanDEM-X 2011 and UAV 2017 DEMs
- Identification of depletion and accumulation zones
- Determination of the sliding direction

III. D-InSAR & times series – Differential SAR Interferometry (D-InSAR) analysis to highlight displacements along the Line of Sight (LOS) through the calculation of the phase difference between two SAR images taken at different time periods.

- Comparison of interferograms computed using SAR images before (August 2016), during (March 2017), and after (August 2017) the landslides reactivation.
- Collection of Earth Observation time series to map active deformation areas and monitor their average velocities between January 2016 and May 2017 using the FASTVEL algorithm.



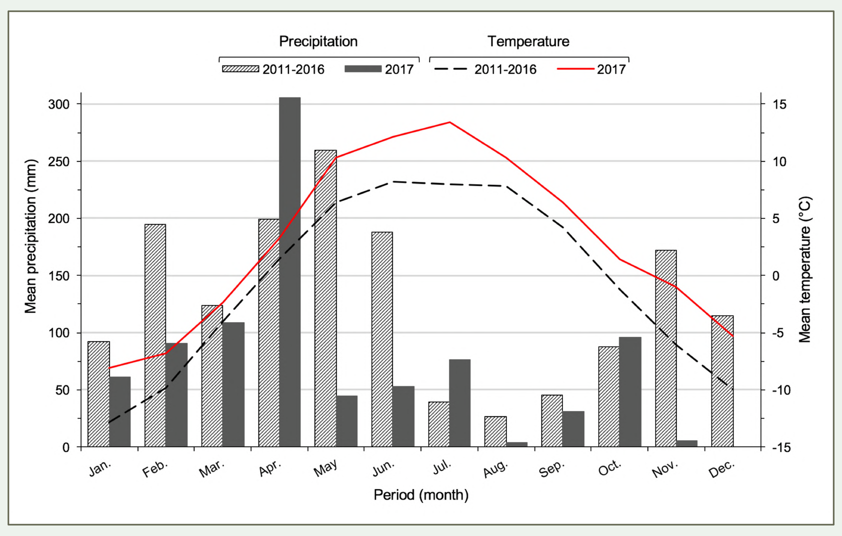
IV. Optical remote sensing – Mapping of geomorphological elements using high resolution satellite images (SPOT, Pléiade) and computation of the Normalized Difference Vegetation Index (NDVI) before and after the reactivation. Multi-temporal optical analysis of the landslides since 2007.

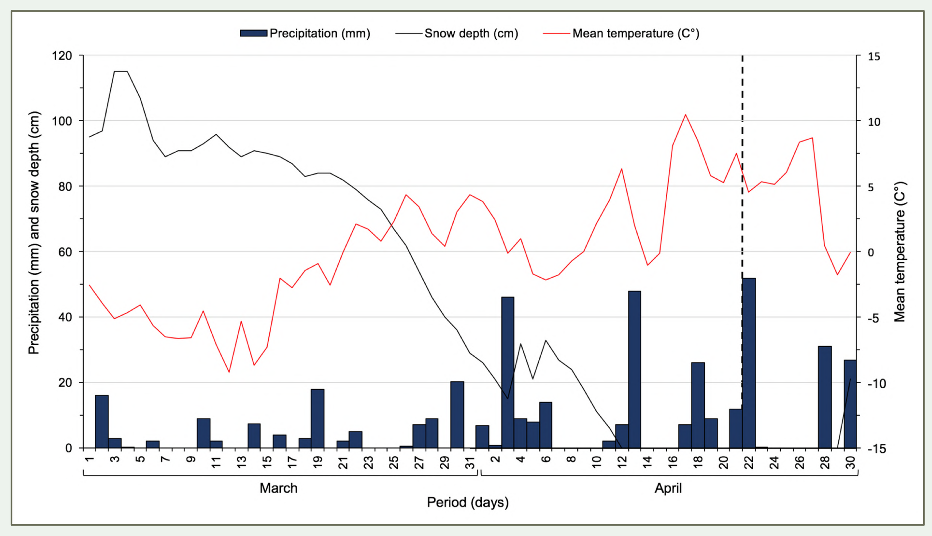
Results

I. Meteorological analysis

In-situ data from the Ak-terek meteorological station highlighted different elements which could explain the massive reactivation episode in the Mailuu-Suu valley in spring 2017.

- Mean annual rainfall: 1460.5 mm/y between 2011-2017 **VS** 877.4 mm in 2017
- 30% of the annual rainfall of 2017 precipitated in April
- Mean annual T° increased in 2017, with freeze-thaw cycles throughout March and April.
- Loss of 68.5 cm of snow cap between March and April
- Highest rainfall peak (52 mm) on the 22nd of Avril 2017 → the day of Koytash's collapse

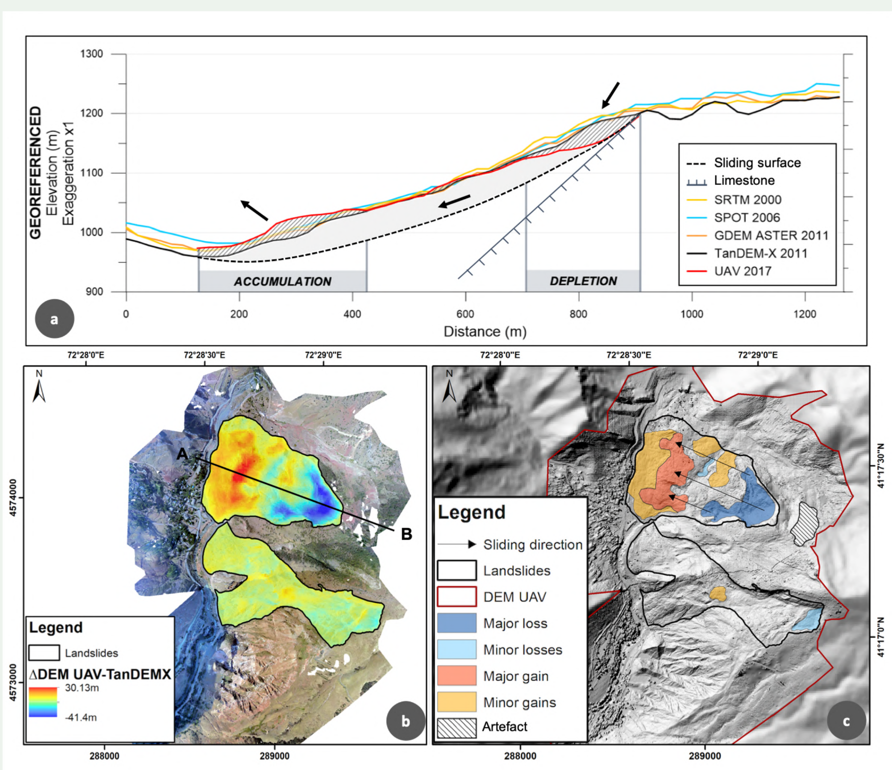




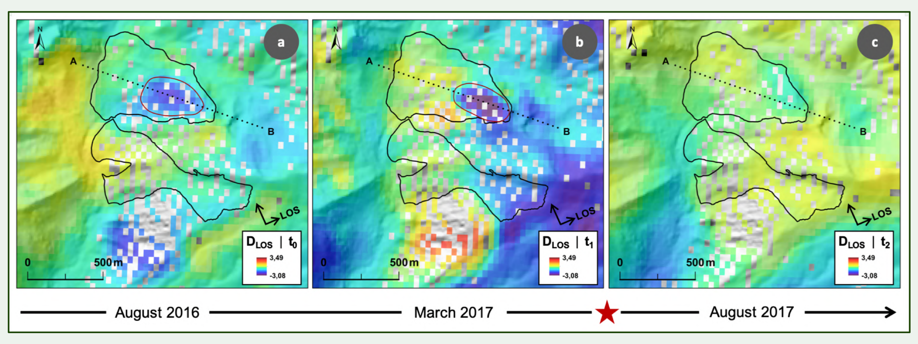
II. DEMs comparison

- Maximal accumulation = **30,13m** (bottom)
- Maximal depletion = **41,4m** (top)
- Sliding direction from **SE to NW**

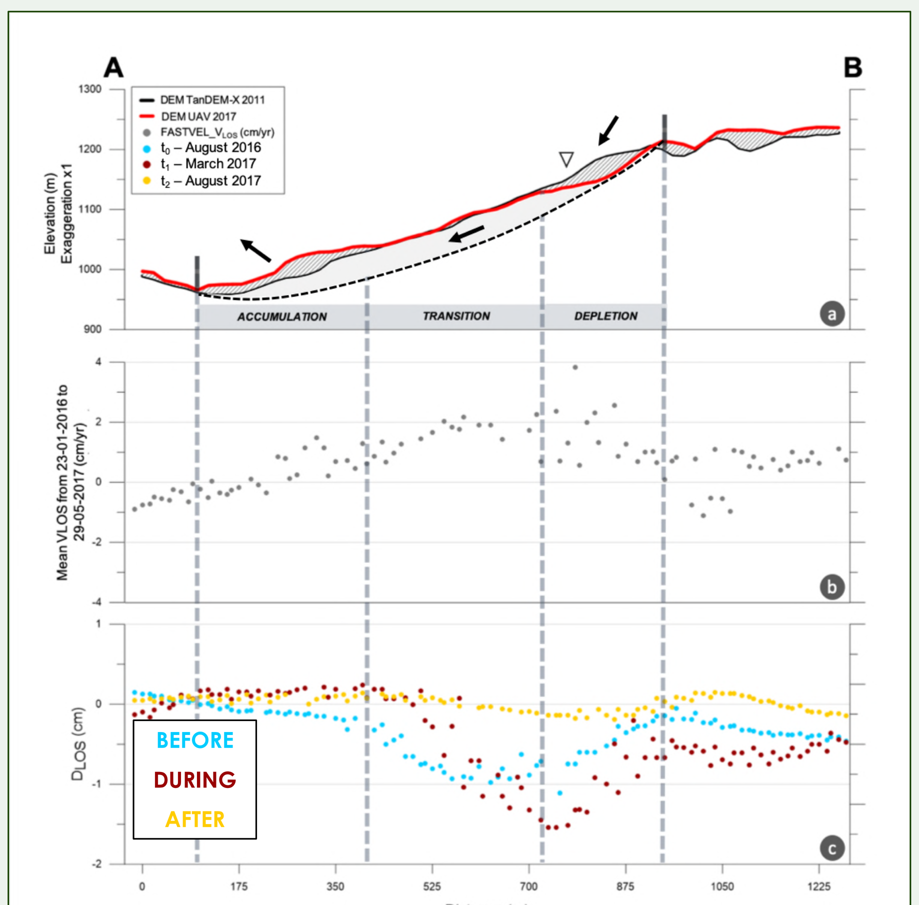
- The upper part of the landslide collapsed and apply a strain on the lower part
  → DEPLETION
- The lower part was uplifted due to the pressure
  → ACCUMULATION



III. D-InSAR & time-series

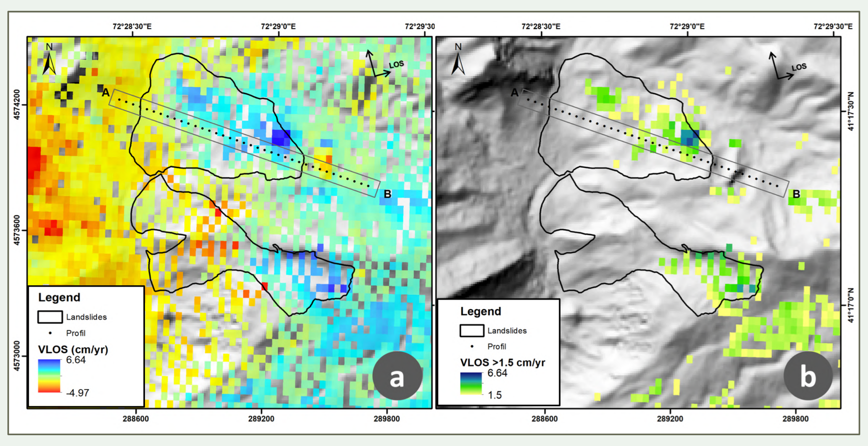


— Before — During — After →



- *BEFORE* : Negative values on top of Koytash represent a displacement away from the sensor, indicating that there is already an effective subsidence in the scarp area where geological material is moving down the slope.
- *DURING* : The deformation magnitude has increased. In the lower part, there is an uplift with positive values.
- *AFTER* : Stabilization phase with practically no deformation recorded.

The time series results show two positive anomalies in the upper parts of both landslides. The graph below (b) represents the velocities higher than 1.5, highlighting the most active parts before the rupture.



IV. Optical remote sensing

Geomorphic Mapping

- Reactivated zones VS new landslides
- Almost 30% of the landslides in the Mailuu-Suu valley were reactivated in spring 2017
- Tektonik was reactivated in its upper part while Koytash collapsed completely and dammed the river below

Multi-temporal analysis

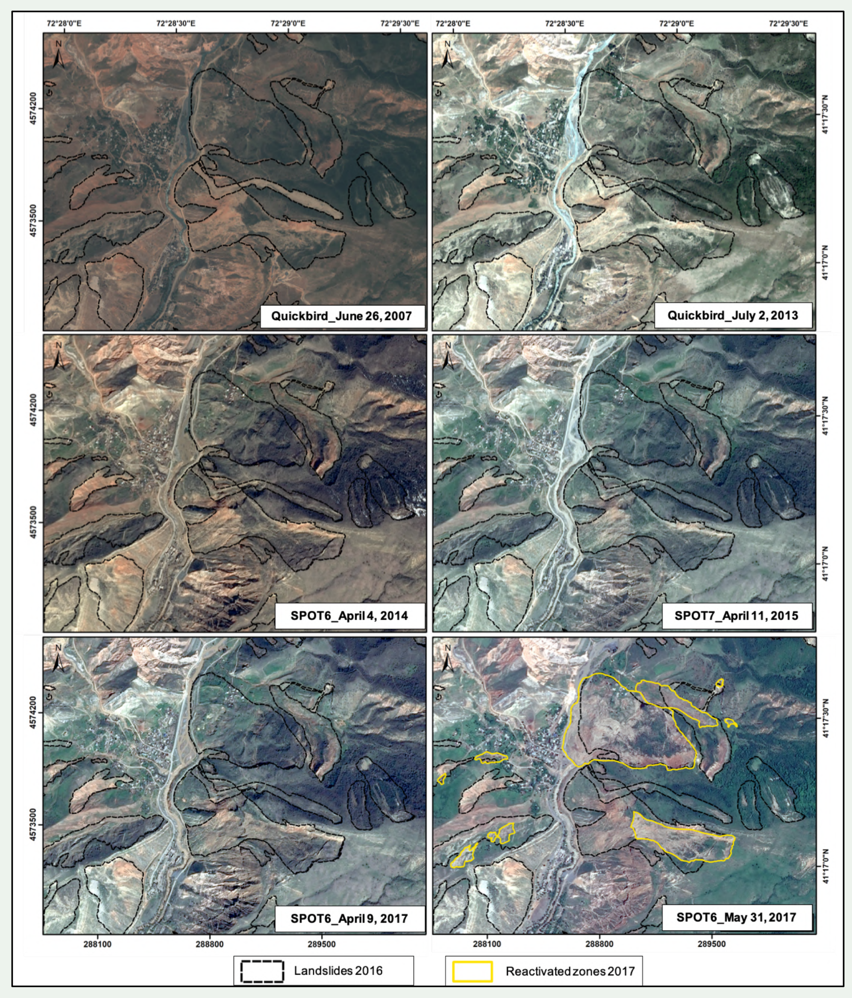
- Evolution of the deformation zones since 2007

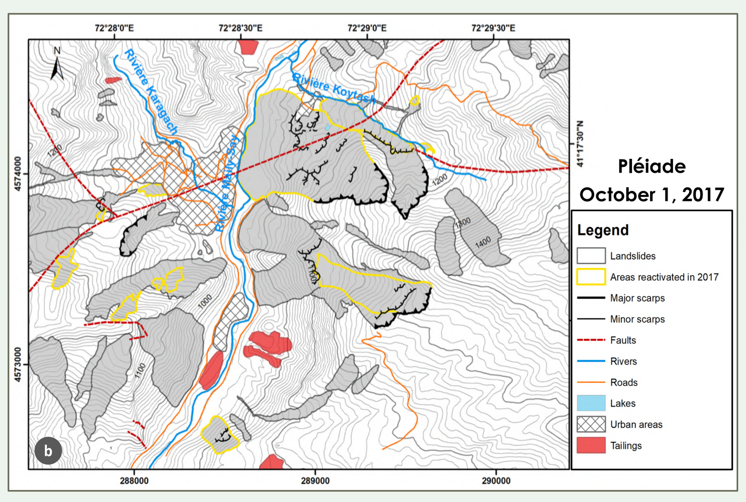
NDVI calculation

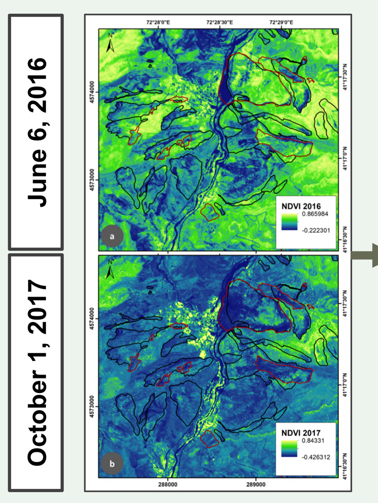
- Identifies areas of land cover change due to:

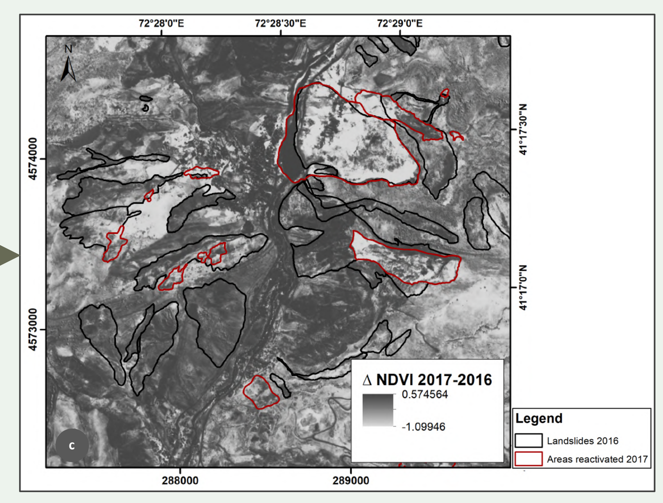
→ the mass movements

→ the period of image acquisition









Conclusion & Outlook

The multidirectional approach used in this study, justified by the complementary nature of the techniques, enabled the gathering of complete and coherent results :

- Combination of radar and optical data to demonstrate the recent landslide activity
- Identification of the triggering factors responsible for the collapse of numerous landslides in Central Asia in Spring 2017
- Exploitation of multiple techniques to overcome their respective limitations.

Testing other SAR algorithms, automating the daily calculation of the meteorological statistics, studying the regional seismicity will help further understand the mechanisms underlying landslide activations.

Piroton V., Schlögel R., Barbier C., Havenith H-B. (2020). *Monitoring the recent activity of landslides in the Mailuu-Suu Valley (Kyrgyzstan) using radar and optical remote sensing techniques.* Geosciences 10(164), 27p. doi:10.3390/geosciences10050164.