

## **Integration of multi-source remote sensing data for landslide precursor detection**

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**Landslides** are one of the most common and dangerous geological hazards. They are often triggered by intense rainfall or occur after prolonged droughts, earthquakes, or volcanic eruptions. With climate change and rising temperatures, **their frequency and intensity are expected to continue increasing**. These phenomena **pose a serious threat to both the environment and the economy**, causing damage to infrastructure, loss of land, and threats to human life each year. Due to their sudden nature and the complexity of factors affecting slope stability, such as geological structure, hydrological conditions, climate, and human activity, **effective prediction and monitoring of landslides remains a major challenge** and a key component of landslide mitigation strategies.

Advancements in **remote sensing** techniques have significantly enhanced their role in monitoring the Earth's surface and analyzing natural hazards such as landslides. Unlike traditional methods, these techniques enable observation of the Earth from satellite, airborne, and ground-based platforms, allowing analyses in areas with limited accessibility and across various temporal intervals and spatial scales. **Radar imagery (SAR)** plays a key role, as it can detect land surface displacements with millimeter-level accuracy regardless of weather and lighting conditions. High-resolution **optical images** are also used to identify surface displacements through methods such as image correlation or pixel tracking, which analyze shifts between successive images. **Multispectral images** provide valuable information about surface changes and **conditions conducive to** landslide activity. Analyzing these data allows for monitoring of changes in vegetation cover and condition, as well as soil moisture, which can serve as indicators of slope instability. Due to their wide spatial coverage, these techniques have significant potential for analyzing changes occurring on the land surface, especially in the context of regional-scale observations.

The primary objective of the project is **the integration of remote sensing data from various sources to identify landslide precursors**. Due to the complexity of processes leading to landslide formation, as well as the significant morphological and environmental diversity of landslide-prone areas, developing a universal monitoring system for continuous changes in these regions presents a substantial challenge. This system should **enable the detection of early warning signals preceding catastrophic events**, allowing for more effective preventive measures. With this in mind, the key outcomes of the project are to:

- assess the usefulness of remote sensing data for detecting surface changes in landslide-prone areas,
- analyze the effectiveness of integrating radar, optical, elevation, and precipitation data,
- evaluate the potential of machine learning (ML) methods for identifying landslide precursors and classifying at-risk areas based on integrated remote sensing data.

Developing an effective methodology requires not only selecting the most appropriate data but also integrating them and automatically detecting significant signals within complex datasets. In this context, ML methods play a crucial role by enabling the development of a consistent methodology for identifying landslide precursors. The main result of the project will be **the automatic detection of warning signals, allowing the classification of areas based on the presence of landslide precursors and the estimation of the probability of their activation**, both in studied areas and new locations. This approach will enable the assessment of the generalizability and adaptability of the developed algorithm to varying geomorphological and climatic conditions. In addition, spatial and temporal analyses of the detected precursors will allow the delineation of zones with a higher risk of landslide activation, as well as the evaluation of their reliability and usefulness for implementing early warning systems. Particular emphasis will be placed on analyzing the timing and frequency of precursors, their correlation with past events, and the potential for integration with operational risk mitigation strategies.