The Potential of InSAR Technology in Early Warning for Volcanic Hazards: Monitoring Deformation Time Series at Seasonally Snow-Covered Volcanoes

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Ground deformation of a volcanic area is a key indicator of volcanic unrest because it reflects subsurface pressure variations. Satellite-based Interferometric Synthetic Aperture Radar (InSAR) shifted volcanic deformation monitoring from local to long-term and global, complementing ground-based instruments. Many automated systems, such as LiCSAR and LiCSBAS, have been designed to process the vast volume of raw satellite data into interferograms and compute deformation time series. However, seasonal snow cover often causes technical issues, such as coherence loss and unwrapping errors, leading to errors in deformation calculations, especially for automated systems. Here, we use snow products of MODIS, a NASA satellite mission, to identify volcanoes experiencing seasonal snow cover and find that nearly half of global Holocene volcanoes are experiencing seasonal snow. This indicates that at these volcanoes, the automated processing system under default settings may not optimally utilise satellite data.

In this research, we focused on Laguna del Maule, Chile, which has been steadily uplifting since 2007 and is characterised by seasonal snow cover and steep-sided lava flows. Automated LiCSBAS with default settings underestimated InSAR line-of-site deformation by 26% at GNSS site MAU2. Also, we can predict the coherence of Sentinel-1 interferograms using MODIS snow products, achieving 78% average accuracy, peaking at 99% in early winter, confirming that seasonal snow is the main cause of coherence loss at seasonally snow-covered volcanoes. This study shows that InSAR can provide reliable ground deformation monitoring in volcanic areas, and MODIS snow products help to improve InSAR auto-processing efficiency and further enhance the capability of InSAR to detect volcano unrest.