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Towards the Automatic Detection of Volcanic Unrest using Sentinel-1 InSAR data and Machine Learning

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Recent improvements in the frequency, type and availability of satellite images mean it is now feasible to routinely monitor volcanoes in both urban and remote areas. In particular, Interferometric Synthetic Aperture Radar (InSAR) data can detect volcanic surface deformation, which has a strong statistical link to eruption. LïCSAR, our automated processing chain for Sentinel-1 SAR data (http://comet.nerc.ac.uk/COMET-LiCS-portal/), has produced at the time of the writing more than 30,000 interferograms on 1300 active land-volcanoes. The amount of data is too large to be manually analysed on a global basis. Therefore, machine learning algorithms become necessary to automatically detect the volcanic ground deformation signals. The proposed method works on wrapped interferograms with no atmospheric corrections. The ground deformations displayed as fringes provide strong low-level visual features for image classification. We extract the spatial characteristics of the interferograms using deep Convolutional Neural Networks (CNN). We provide a probability that a given interferogram contains ground deformation. The positive results (probability >0.5) are checked manually by an expert and fed back for model re-training. Following the retraining process with Sentinel-1 data, the classifier reduced the number of interferograms flagged to approximately 100, which required further inspection, of which at least 39 are considered 'true positives'. For example, the ground deformation unrest at Cerro Azul (Galapagos) in March 2017 was detected with a probability of 1.0. In this case, the positive predictive value (PPV) is only about 40%, which is mainly due to the lack of positive samples. To solve this issue, in a second step, we increase the number of positive samples by using synthetic data (atmospheric effects + deformation), which increases the PPV to 80% after retraining. Our study shows that machine learning can efficiently detect large, rapid deformation signals in wrapped interferograms. Further development will be required to detect slow or small deformation patterns, which can be done using other inputs such as unwrapped stacked interferograms. Our work is the first to use machine learning approaches for detecting volcanic deformation in large datasets and demonstrates the potential of such techniques for developing volcanic unrest alert system to support risk assessment on volcano observatories.