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Realistic volcanic deformations synthesis based on simulation data via generative model

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Volcanic eruptions are large-scale rare events causing extensive economic damage and loss of life each year. About 1500 volcanoes are considered active, and 800 million people live less than 100km away from them. Therefore, forecasting volcanic activity and eruptions are of great significance.

The most precise way to monitor volcanoes and volcanic deformation is onsite monitoring; however, many active volcanoes are inaccessible. In the past years, Interferometric Synthetic Aperture Radar (InSAR) technology has been utilized with the help of deep learning (DL) to detect fast, intense volcanic deformations automatically. Previously, we employed the InSAR data with state-of-the-art processing to achieve high deformation accuracy over longer periods and apply DL to detect subtle long-term volcanic deformations automatically. Like the mentioned approaches, we face the challenges of small training sets and the gap between the train and test set.

The DL model is trained on synthetic data and makes many false positive detections on the real test set. Grad-CAM analysis uncovered that the false detections are activated by the region-specific patterns of salt lake deformations, slope processes, and residual tropospheric noise. To increase the diversity of synthetic samples and reduce the false positives, we apply generative adversarial networks (GANs), to transfer the style of realistic terrain to synthetic data.

This approach allows the generation of an infinite amount of synthetic data containing the regional deformation patterns and can be replicated for other regions. Since we are using real and synthetic data, it is significant that model can be trained with unpaired images. We employ a multi-domain and bidirectional state-of-the-art image-to-image translation model, StarGAN v2. We test the model on different tasks. The first task is to learn the transformation from synthetic background data to real background data. For volcanic deformations, we rely on established models for volcanic deformation simulations, like Mogi, Okada, or volumetric models. The second task demands the model to translate between synthetic and real and volcanic and non-volcanic domains. This model is capable of directly generating realistic-looking samples with volcanic deformations but with less control than the previous approach.