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Four-dimensional visualization of volcanic landforms based on optical photogrammetric and radar tomographic data

Volcanoes are dynamic landforms whose morphology can change rapidly due to eruptions or mass-wasting events. Photogrammetry, using UAVs, aerial platforms, and satellites, enables detailed three-dimensional (3D) reconstructions of volcanic topographies. By generating a time series of these 3D models over several decades, we create four-dimensional (4D) visualizations (considering that the fourth dimension is time) that document the temporal evolution of volcanic structures. Such comparative analyses are crucial for understanding eruption-induced changes and long-term edifice evolution. This contribution presents examples of 4D visualizations based on datasets for Shiveluch and Bezymianny stratovolcanoes (Kamchatka, 1967–2020) and the Askja caldera (Iceland, 2014–2022). The 3D reconstructions were generated from satellite and historical aerial imagery using the photogrammetric workflow of Agisoft Metashape software. Post-processing of the 3D models for the 4D visualizations was performed using QGIS, Blender, and Adobe After Effects. For the Askja caldera, we also developed an immersive virtual reality (VR) models using Unreal Engine 5 and Adobe Audition, allowing users to explore the reconstructed topographies before and after the 2014 massive landslide. Additionally, we introduce novel 3D models of the internal conduit structure of the recently formed Svartsengi volcanic cone (Iceland), derived from tomographic processing of UAV-borne three-band Synthetic Aperture Radar (SAR) data collected in 2024. The use of P-band radar, capable of penetrating up to 50 meters below the surface, opens new perspectives in subsurface volcanic imaging. Finally, we discuss challenges related to representing erosional and mass-wasting processes within 4D topographic models and address limitations in validating SAR tomography results due to restricted ground access in active volcanic environments. The author(s) declare no conflicts of interest.

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