
Evolution of the Merapi summit area related to the 2021-2023 effusive eruption, as revealed by radar and optical satellite imagery

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Résumé

Tracking the summit activity of steep-sloped stratovolcanoes is challenging because changes, including unrest, lava dome growth or eruptive deposits, can vary in extent, amplitude and duration. As ground-based instruments have limited spatial resolution, satellite imagery is a promising tool to map both localized and widespread deformation. In this study, we leverage the complementary strengths of radar (TanDEM-X, Sentinel-1) and optical (Pléiades) satellite data to track Merapi's summit activity during the 2021 eruption, which involved the growth of two lava domes - one within the crater and one on the southwest flank. High-resolution DEMs derived from TanDEM-X and Pléiades data show that both domes grew rapidly before stabilizing around July 2021, each reaching a volume of $3.4 \pm 0.7 \text{ Mm}^3$. The total lava volume is about 6 times higher than in 2018. Alternatively, additional Sentinel-1 and Pléiades displacement time-series allowed the detection of significant pre-eruptive changes on Merapi's upper flanks. Between June-August 2020, a 50 m pit formed on the southwest flank due to the collapse of an old lava flow, coinciding with the later location of the 2021 flank dome. On the same flank, more than 20 m displacement downslope is detected at three nearby other lava flows between 2019-2021, with the strongest acceleration occurring between November 2020-June 2021. Sentinel-1 time-series detected a sliding of the entire west flank of 10 cm/yr at least between June 2020-December 2023. In parallel, a potential short-lived inflation of the east flank of 3 cm/yr was observed between June-December 2020. This study demonstrates that the joint use of radar and optical satellite imagery is essential for capturing the full range (centimeters to meters) and spatial extent (meters to kilometers) of summit and flank deformation. Such integrated remote sensing approaches are critical for understanding Merapi's complex, multi-hazard behavior, where effusive eruptions and flank instabilities can occur jointly. Challenges still remain in the understanding of their interplay: satellite imagery combined with modelling will hopefully address this issue in the near future.

Mots-Clés: geodesy, Merapi, lava dome, volcanology, optical, SAR

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