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Monitoring of Merapi volcano, Indonesia based on Sentinel-1 data

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Despite the well-established interest of Synthetic Aperture Radar data for volcanoes study and monitoring, their integration to operational monitoring activities in volcanoes observatories remains limited so far. We here describe the effort in progress to integrate in near real time the information derived from Sentinel-1 satellites into the monitoring devices at BBPTKG in charge of Merapi volcano survey as well as the use of Sentinel-1 data during the recent period of unrest. Merapi (7°32.5' S and 110°26.5' E) located in the densely populated Province of Yogyakarta in Central Java is one of the most active volcanoes in Indonesia. The eruptive history of Merapi is characterized by two eruptive styles: 1) recurrent effusive growth of viscous lava domes, with gravitational collapses producing pyroclastic flows known as « Merapi-type nuées ardentes » (VEI 2); 2) more exceptional explosive eruptions of relatively large size (VEI 3-4), associated with column collapse pyroclastic flows reaching distances larger than 15 km from the summit. The eruptive periodicity is 4 to 5 years for the effusive events and 50 to 100 years for the explosive ones. The last explosive events (VEI 3-4) occurred in November 2010 and was followed by a period of limited activity. In August 2018, a new dome was observed inside the summit crater, thus marking the start of a new phase of effusive activity. A new period of unrest then started in mid-October 2020, characterized by an increase in seismic activity as well as large and localized displacements in the summit area. Magma finally reached the surface on 4 January 2021. Deformation is currently recorded by EDM and tiltmeters together with a network of 10 permanent GNSS stations. GNSS data are automatically processed and inverted for a pressure source at depth. Both displacement time series as well as spatial probability distribution are directly available through WebObs (Beauducel et al., Frontiers, 2020), an integrated web-based system for monitoring. Sentinel-1 data are acquired over the volcano every 12 days on descending track 76 and every 6 days on ascending track 127. Since mid 2017, Sentinel-1 data are automatically downloaded on a local server at BPPTKG. Interferograms and coherence images are then produced using the NSBAS processing chain (Doin et al, 2012) and automatically integrated to WebObs to enable detection of potential rapid and significant changes in signal. Mean velocity maps are also produced as well as time series of surface displacement at given location enabling direct comparison with GNSS measurements. The descending InSAR time series shows a strong displacement away from the satellite in a 1.5 km wide area located on the north-eastern part of the crater. This signal became

significant in September 2020. It is consistent with field measurements recorded and allows to map the affected area. In mid-November 2020, Sentinel-1 data thus provided the first information on the spatial extent of the ongoing surface displacements, which was useful for crisis management.