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ORIGINAL PAPER

The applications of Monte Carlo algorithm and energy cone model to produce the probability of block-and-ash flows of the 2010 eruption of Merapi volcano in Central Java, Indonesia

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Abstract Volcanic eruption hazard mapping is very important to fulfill information needs to prepare for emergency situations. Rapid mapping is one of the steps necessary for emergency response in disaster mitigation effort. Limitations of time, data, and knowledge mapping techniques can be a problem when performing the operational work. In this research, the combinations of the Monte Carlo algorithm and energy cone model have been applied to reproduce the probability of block-and-ash type of pyroclastic flows of the 2010 eruption of Merapi volcano. These approaches are applied as an alternative method of rapid, objective, and reproducible for hazard mapping of pyroclastic flows. In addition, the method of Interferometry Synthetic Aperture Radar (InSAR) has been used in this research to update the digital elevation model (DEM) data. The availability of DEM data updates was required as input of topography, which determines the pyroclastic flows. This research has produced DEM PALSAR 2010 pre-eruption of Merapi volcano, with a spatial resolution of 30 m. The result of the vertical accuracy calculations was performed using the root mean square error (RMSE) approach, which show the value of RMSE at 9.08 m. There are four eruptive phases, which have been used for the simulation scenarios, namely: phase 1 (period 26–29 October 2010), phase 2 (period 30 October–3 November 2010), phase 3 (period 4–5 November 2010), and phase 4 (period 6–23 November 2010). The results of the Monte Carlo algorithm to reproduce the effects of the 2010 eruption of Merapi volcano, has show that the height correction (hc) on the DEM data gives effect to the probability distribution of pyroclastic flows. At the hc=1, 2, 3, 4, and 5 m, the value of overall accuracy based on cross-correlation matrix of the reference map are 76.38, 77.38, 77.00, 77.75, and 77.25 %, respectively. In these scenarios, the hc=4 m can give the best accuracy. Meanwhile, the results of the comparison of the results of the difference of the average run out on the energy cone model obtained from the reference map is 843 m.

Keywords Monte Carlo algorithm · Energy cone · InSAR method · Pyroclastic flows · Merapi volcano · Central Java · Indonesia

Introduction

Merapi volcano is a stratovolcano located in Central Java, Indonesia (Fig. 1). This volcano can be categorized as one of the active volcanoes in the world, producing explosive eruptions. The volcano has been formed as a result of the activities of the Indo-Australia plate zone, which has caused the volcanic activity along the central part of Java Island (Lavigne et al. 2000; Yulianto et al. 2013). Lava dome formed as a result of increased volcanic activity in the magma chamber. The process has been occurring continuously, causing the movement of magma toward the surface of the earth. Lava dome has the potential to collapse due to gravity (BPPTK 2010). The collapse of the lava dome could trigger the flow, which is referred to as "nuées ardentes d'avalanche" or "pyroclastic flow" or "wedhus gembel" (McGuire 1996; Voight

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