Merapi 2010 eruption: An interdisciplinary approach to constraining pyroclastic density current dynamics

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The large explosive eruption of Merapi volcano, Indonesia, in 2010 presented a key, and rare, opportunity to study the impacts of a major explosive eruption in a densely populated area. Pyroclastic density currents (PDCs) produced throughout the 2010 eruption were unusually destructive, causing near complete devastation across a 22 km2 swath of the densely populated and forested southern flanks and casualties to the end of their runout, 15.5 km from the volcano. Decline to eruption end within a further 18 days enabled us to collect perishable geological, damage and casualty data safely and within a pristine impact environment, before rains or human activity could destroy valuable data. By integrating the results of our interdisciplinary studies, we could reconstruct the spatial and temporal dynamics of the PDCs and their main hazard characteristics. In the areas damaged by PDCs, we used empirical damage data and calculations of material and structural resistance to lateral force to estimate approximate dynamic pressures. Estimates of dynamic pressures associated with the 5 November paroxysm exceed 15 kPa more than 6 km from source and rapidly attenuate over a distance of less than 1 km at the end of the PDC runouts. Findings clarify how the temporal and spatial distribution of devastation was influenced by summit and flank morphology and by the preceding sequence of activity. Analysis of thermal indicators, such as deformed plastic, and correlation with information on burns injuries and fires provided estimates of ambient temperatures associated with the PDCs. Even at the relatively low temperatures estimated for the PDCs (200-300 deg C) they were lethal to people inside as well as outside buildings, in part because of the building design that enabled the PDCs to rapidly infiltrate inside. Such detailed quantitative data can be used to support numerical PDC and impact modelling as well as risk assessment and mitigation at dome-forming volcanoes, providing an improved understanding of the complexity of PDCs and their associated impacts on exposed populations.