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The 2010 eruption of Merapi Volcano, Indonesia: Use of satellite remote sensing to support crisis response activities

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The U.S. Geological Survey through the Volcano Disaster Assistance Program (VDAP) provided satellite remote sensing and other technical support to the Indonesian Center for Volcanic and Geologic Hazard Mitigation (CVGHM) during the October to November 2010 eruption of Merapi Volcano. A variety of satellite data were utilized including Synthetic Aperture Radar (SAR) primarily from the Radarsat-2 and TerraSAR-X sensors, thermal infrared from the ASTER sensor, and high resolution visible and near-infrared data from the GeoEye 1 and WorldView-2 sensors. Increased satellite tasking frequency and expedited product generation were supported by several pre-existing national and international hazard response protocols including the International Charter for Space and Major Disasters (Radarsat-2 and TerraSAR-X), the NASA Urgent Request Protocol (ASTER), and the USGS Hazards Data Distribution System (GeoEye 1 and WorldView-2). Images were available for analysis by volcanologists at the USGS Alaska and Cascades Volcano Observatories typically within 2-6 hours of acquisition and critical data and analyses were provided to CVGHM within the same time periods. CVGHM colleagues integrated the remote sensing data with real-time seismic data as their primary tools for monitoring the eruption, issued warnings and called for evacuations which saved many thousands of lives.

Data from SAR sensors were especially useful in observing changing conditions in the summit crater as they were able to penetrate the frequent weather clouds, steam, volcanic gas, and ash emissions which obscured visible and thermal infrared observations of the summit for most of the main eruptive period. Data were collected in HH polarization with beam resolutions that varied from 1 to 8 meters, depending upon the acquisition mode, allowing for detailed views of the summit crater, rapidly growing lava domes, vent features, and pyroclastic flow deposits. Data from these multiple satellite sources documented key morphological changes during eruptive events. Explosive eruptions on 26 and 30 October (local time) removed the 2006 lava dome, enlarged the summit crater, and deeply incised the headwall of the Kali Gendol drainage. Remote sensing data confirmed that the 2010 eruptive period began not with extrusion of lava (as characterized all other recent eruptions of Merapi) but instead with an explosive event. This fact, along with subsequent documentation of very rapid rates of dome growth, reinforced and validated CVGHM concerns that the 2010 eruption would be much larger and more hazardous than those of the past century. Reconfiguration of the summit crater over the course of the eruption channeled the majority of pyroclastic activity down the Gendol drainage. Rapid lava dome growth, (at times in excess of 25 m3/s) was indicated by repeat SAR observations prior to the largest explosive event on 5-6 November. This event produced pyroclastic flows and surges that traveled up to 15 km from the summit shortly after the evacuation zone was extended to 20 km. Rapid dome growth then resumed for a period of less than a day on 6 November, and was followed first by dome subsidence and then by ash emissions from several vents adjacent to or penetrating the just-erupted lava dome. These small ash and gas emissions continued through mid-November as dome growth slowed and eventually ceased. Although lava, pyroclastic flow and surge, and tephra-fall deposits were readily observed and their extent measured using SAR, infrared and visible wavelength satellite data, lahar deposits were not easily identifiable.

Overall, the CVGHM-VDAP crisis response utilized satellite data to a much greater extent than during previous VDAP eruption responses and the information played a major role in monitoring the eruptive activity and in supporting decisions by CVGHM regarding the extent of hazards and evacuations.